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Hydrogeologic Investigations Based on Drill-Stem Test Data Palo Duro Basin Area Texas and New Mexico

Technical Report

May 1984

E. Scott Bair
Timothy P. O'Donnell
Larry W. Picking

Stone & Webster Engineering Corporation

Prepared for

Office of Nuclear Waste Isolation
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ABSTRACT

Drill-stem test (DST) data were compiled from wildcat wells and DOE-sponsored wells in the Palo Duro Basin area of Texas and New Mexico. The data were used to construct pressure-depth diagrams and to map regional potentiometric surfaces, based on equivalent freshwater heads calculated from initial shut-in pressures of the Wolfcamp and Pennsylvanian brine aquifers, the two regionally important deep-basin aquifers downgradient of the proposed repository host rock. Eighty percent of the 5,502 DSTs were screened from the data base containing DST data from various deep-basin geologic units because they did not comply with shut-in time and shut-in pressure agreement criteria. After screening, three sets of pressure-depth diagrams and potentiometric surfaces were constructed, corresponding to three levels of data refinement.

The initial Wolfcamp and Pennsylvanian regional potentiometric surfaces, representing their present configuration, contained several local prominent mounds and depressions with unrealistic variations in flow directions and hydraulic gradients. Evaluation of pressure-depth data and oil and gas production data showed that many of the DSTs were performed in depressured oil and/or gas production zones, where formation pressures were reduced due to extraction of formation fluids. The low shut-in pressures recorded in these tests caused abnormally low heads to be calculated and contoured. Formation pressures recorded in these depressured zones represent local temporal pressures in a regional flow system that is probably steady state. Deletion of depressured DSTs produced potentiometric surfaces of the Wolfcamp and Pennsylvanian aquifers prior to oil and gas production, but still contained a few local prominent mounds and depressions caused by local aberrant DST data. Elimination of local grossly overpressured and grossly underpressured DST data, based on comparison of initial shut-in pressures and heads at a similar depth in the same geologic unit in the same well and/or adjacent wells, further refined the potentiometric surfaces. These surfaces probably closely approximate the regional configuration of the Wolfcamp and Pennsylvanian potentiometric surfaces prior to oil and gas production. Statistical analysis of the culling procedures showed that most of the refinement in the Wolfcamp and Pennsylvanian data sets was due to culling depressured DSTs. Some

additional refinement was due to culling local grossly underpressured and grossly overpressured DSTs.

Although almost all the DST data in the study area are underpressured relative to the range of probable hydrostatic pressure gradients, formation pressures measured in wells located on the High Plains are far more underpressured than formation pressures measured in wells located on the Rolling Plains. This probably is due to differences in the depth from the ground surface, across the High Plains/Rolling Plains escarpment, to potentiometric levels in the deep-basin strata. When the Wolfcamp and Pennsylvanian pressure-depth data are normalized to common hypothetical planes that eliminate the effect of measuring depth from varying topographic elevations, the underpressuring of High Plains and Rolling Plains data is similar. Normalizing the data to common planes also makes identification of abnormally pressured data more obvious because differences in topographic elevation are eliminated.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

LIST OF TABLES

1 EXECUTIVE SUMMARY

This report presents the methods, results, and interpretations of hydrogeologic investigations based on drill-stem tests (DSTs) performed in the Palo Duro Basin area of Texas and New Mexico. The primary objective is to produce regional potentiometric surfaces of the Wolfcamp Series and the Pennsylvanian System, the two regionally important downgradient aquifers that underlie the proposed repository host rock. The potentiometric surfaces will be used to evaluate flow patterns, to determine flow velocities, to aid in the development of a conceptual hydrodynamic model of the deep-basin flow system, and to serve as a basis for calibration of numerical flow models.

The report covers an area extending westward from the Palo Duro Basin in northern Texas, across the Tucumcari Basin in eastern New Mexico, and into the recharge area of the deep-basin flow system in east-central New Mexico along the eastern flank of the Pedernal Uplift and the Sierra Grande Uplift. In another report, the study area will be extended eastward across north-central Texas into the reported discharge area of the deep-basin flow system in south-central Oklahoma (Levorsen, 1967).

A screening process and classification system were devised and used to evaluate the quality of DST data obtained from wildcat wells and DOE-sponsored wells. The purpose of this system was to eliminate dubious data from improperly run tests, incomplete shut-in pressure and shut-in time records, poorly calibrated or malfunctioning equipment, and misreported results. Shut-in time and shut-in pressure agreement criteria were devised and used to delete tests that were run for such a short time that pressure equilibrium probably could not be approached and to delete tests that obviously did not approach pressure equilibrium. Approximately 20 percent of the 5,502 DSTs performed in 1,971 wells were considered usable for the purposes of this hydrogeologic investigation.

The various geologic units were grouped into three major hydrostratigraphic units which maintain their hydrologic importance throughout the region. The shallowest of these units is a freshwater aquifer system primarily developed in the Tertiary Ogallala Formation and the Triassic Dockum Group. The intermediate hydrostatigraphic unit is an Upper Permian shale and evaporite aquitard and separates the shallow freshwater flow system from the deep-basin hydrostratigraphic unit which consists primarily of the Lower Permian Wolfcamp Series and the Pennsylvanian System, which contain brine aquifers.

Regional potentiometric surfaces of the Wolfcamp and Pennsylvanian aquifers were constructed using equivalent freshwater heads calculated from initial shut-in pressures (ISIPs) from DSTs. Initial potentiometric surfaces were constructed using all the screened Wolfcamp and Pennsylvanian data. These maps represent the present configuration of the Wolfcamp and Pennsylvanian potentiometric surfaces and contain several local prominent mounds and depressions with several thousand feet of relief. On a regional scale, the configuration of these potentiometric surfaces was not considered reasonable due to the dramatic local variations in flow directions and hydraulic gradients.

Consequently, pressure-depth data from DSTs performed in the deep-basin strata were analyzed. This analysis showed that almost all the DSTs are underpressured relative to the range of probable hydrostatic pressure gradients and that many DSTs are grossly underpressured. Heads calculated from the grossly underpressured data produced the depressions on the initial potentiometric surfaces. Further evaluation showed that almost all the grossly underpressured data were obtained from DSTs performed in strata that were depressured due to oil and gas extraction.

Formation pressures recorded in depressured zones are valid pressures but represent local temporal pressures in a regional flow system that is probably steady state. (The term "temporal pressure" is used instead of "transient pressure" because the formation pressure may or may not be transient with respect to the pumping stress.) A method was developed using oil and gas production and field location data to identify DSTs performed in depressured strata. As a result, 23 depressured DSTs were culled from the Wolfcamp data set and 120 depressured DSTs were culled from the Pennsylvanian data set. Deletion of depressured DSTs produced potentiometric surfaces of the Wolfcamp and Pennsylvanian aquifers that represent flow conditions prior to oil and gas extraction. These surfaces contained a few local prominent mounds and depressions caused by local aberrant DST data, which on a regional scale were not considered reasonable.

Further refinement of the potentiometric surfaces to eliminate the local aberrant data was achieved by culling 11 grossly underpressured and 9 grossly overpressured DSTs from the Wolfcamp data set and 10 grossly underpressured and 24 grossly overpressured DSTs from the Pennsylvanian data set. Culling was based on comparison of ISIPs and heads in the same geologic unit at a similar depth in the same well and/or in adjacent wells. Commonly these grossly underpressured and grossly overpressured data produced heads 1,000 to 10,000 feet higher or lower than heads in the same geologic unit in the same well or in adjacent wells at a slightly different depth. The resulting regional potentiometric surfaces lack the local prominent mounds and depressions but still preserve some local variations in flow directions and hydraulic gradients. These maps are regarded as the most reasonable representations of the regional Wolfcamp and Pennsylvanian potentiometric surfaces and represent their regional configurations prior to oil and gas production.

Statistical analysis of the culling procedures, based on linear regression of pressure-depth data and statistical comparisons of original head values versus gridded head values, showed that most of the refinement in the Wolfcamp and Pennsylvanian data sets was due to culling depressured DSTs. Some additional refinement was due to culling a relatively small number of local grossly underpressured and grossly overpressured DSTs.

Pressure-depth data showed that although almost all the deep-basin DST data in the study area are underpressured with respect to the range of probable hydrostatic pressure gradients, data from wells located on the High Plains are far more underpressured than data from wells located on the Rolling Plains. This probably is due to the greater depth from the ground surface to potentiometric levels in the the deep-basin strata beneath the High Plains compared to the Rolling Plains. This interpretation is based on the marked difference between Y-intercepts of linear regression analyses of pressure-depth data from the High Plains versus the Rolling Plains.

Using planar regression, hypothetical best-fit planes were derived for the Wolfcamp and Pennsylvanian pressure-depth data which, when used as the datum for measuring depth, maximized linear correlation between pressure and depth. These planes minimize the scatter in the pressure-depth data caused by variation in ground-surface elevation. The hypothetical plane for Wolfcamp data slopes to the northeast. The hypothetical plane for

Pennsylvanian data south of the Amarillo Uplift also slopes to the northeast but at a slightly steeper gradient. In contrast to the Y-intercepts of linear regression lines from the nonnormalized High Plains versus Rolling Plains data which showed a marked difference, the Y-intercepts of linear regression lines from normalized High Plains versus Rolling Plains data showed a marked similarity.

2 INTRODUCTION

2.1 PURPOSE AND SCOPE

This report presents the methods, results, and interpretations of hydrogeologic investigations based on drill-stem tests (DSTs) performed in the Palo Duro Basin area of Texas and New Mexico. The hydrogeologic investigations are based on analysis of formation pressure data obtained from DSTs performed in wildcat wells and DOE-sponsored wells. The methods and techniques used in the hydrogeologic investigations are presented in detail.

The basic results are in the form of potentiometric surfaces of the Wolfcamp Series and the Pennsylvanian System, pressure-depth diagrams showing formation pressures in various geologic units, and a master file of geologic, hydrologic, and formation pressure data. The primary objective of the study is to produce regional potentiometric surfaces of the Wolfcamp and Pennsylvanian aquifers, the two regionally important downgradient aquifers that underlie the proposed repository host rock. The potentiometric surfaces will be used to evaluate flow patterns, to determine flow velocities, to aid in the development of a conceptual hydrodynamic model of the deep-basin flow system, and to serve as a basis for calibration of numerical flow models. Although some preliminary interpretations are presented, the majority of the interpretation of the regional hydrodynamics of the deep-basin flow system will be contained in later reports.

The portion of the study area described in this report extends westward from the Palo Duro Basin area of northern Texas, across the Tucumcari Basin in eastern New Mexico, and into the recharge area of the deep-basin flow system in east-central New Mexico where the deep-basin strata crop out. In another report, the study area will be extended eastward across north-central Texas and into the discharge area reported in south-central Oklahoma, where the deep-basin strata also crop out but at a lower elevation (Levorsen, 1967).

2.2 METHODS, ASSUMPTIONS, AND LIMITATIONS

Almost all the formation pressures used to construct pressure-depth diagrams and potentiometric-surface maps are initial shut-in pressures (ISIPs) obtained from DST records, which may not be equivalent to extrapolated formation pressures obtained from Horner plots. Very few extrapolated formation pressures were available.

In order to construct potentiometric surfaces of the Wolfcamp Series and Pennsylvanian System, it was necessary to assume that formation fluids in the various flow systems have a constant, uniform density equal to that of fresh water. Consequently, equipotential data shown on the potentiometric surfaces represent the elevation to which an equivalent freshwater head would rise in a well penetrating to the midpoint depth of the DST. Formation fluid samples from the Palo Duro Basin area show that the density of most formation fluids below the surficial freshwater aquifer on the High Plains have a density greater than that of fresh water. These samples also show that fluid densities vary vertically and laterally across the basin.

Although use of equivalent freshwater heads may produce inexact results, it is a method commonly used for representing heads in aquifers containing fluid of varying density. On a regional scale, construction of potentiometric surfaces based on equivalent freshwater heads should present reasonable results for the evaluation of flow directions and hydraulic gradients.

DST data included in this report were obtained from tests performed in wildcat wells prior to mid-1981 and from tests performed in DOE-sponsored wells in 1981, 1982, and 1983. Another report will include more recent DST data from wildcat wells drilled between mid-1981 and early 1983, plus all DST data from Dallam and Sherman Counties, Texas, and from 29 additional counties in north-central Texas and south-central Oklahoma

2.3 SOURCES OF DATA

Almost all the DST data were purchased from Petroleum Information Corporation (PI), Denver, Colorado, and consist of incomplete records of DSTs performed in wildcat wells. The data base was obtained in 1981 and includes DST data from 43 counties in the Palo Duro Basin area of Texas and New Mexico and date from the 1940s through mid-1981.

Complete DST records generally consist of a continuous record of pressure changes during shut-in and flow periods, the amount of recovery during shut-in periods, and the temperature, density, and chemical characteristics of the formation fluid. Many of these data frequently are not determined or are not recorded. Incomplete DST records, as listed in the PI data base, usually consist of ISIP, initial shut-in time (ISIT), final shut-in pressure (FSIP), and final shut-in time (FSIT), as inscribed on the DST chart and recorded at the well head. Occasionally, recovery data are listed in the PI data base.

The following list summarizes the pertinent types of information usually listed in the PI data base:

- Location - latitude, longitude, state, county; block (Texas); township, range, and section (New Mexico)
- API well number
- Operator and lessee
- Completion date
- Elevation - ground, Kelly Bushing, derrick floor
- Depths to top and bottom of tested interval
- Geologic unit of tested interval
- Test data - ISIP, ISIT, FSIP, and FSIT

Most of this information was included for each well and each DST in the data base. Elevation data occasionally were missing. In these instances, 7 1/2-minute quadrangle maps were used to determine a ground elevation at the well site.

Instead of relying on the well drillers' identification, geophysical logs were used to identify the geologic unit tested. This provided consistent and uniform picks of formation tops and bottoms across the study area. In wells where geophysical logs were not available, the tested geologic unit was determined from interpolation and/or extrapolation of data from nearby wells. In addition, property ownership maps were used to verify the location of the wells listed in the PI data base. The latitude and longitude of a few wells were found to be incorrectly listed in the PI data base.

DSTs were performed in eight wells sponsored by DOE during 1981, 1982, and 1983. Data from these tests were included in the master DST data base and compare favorably with data subsequently obtained from long-term pumping tests performed in the wells. Results from the long-term pumping tests, while used to confirm the results from the DSTs, were not incorporated into the master data base per se. This was done to prevent bias which might result from mixing data obtained from two different testing techniques

Some records from complete DSTs were provided by the Texas Bureau of Economic Geology and were incorporated into the master DST data base.

2.4 HYDROGEOLOGIC SETTING

2.4.1 Regional Geologic Setting

The Palo Duro Basin, along with several other small structural basins, is located within a larger area known in this program as the Permian Basin (Figure 2-1). The Permian Basin comprises that portion of western Texas, eastern New Mexico, western Oklahoma, southwestern Kansas, and southeastern Colorado that is underlain by bedded salt deposits of Permian age (Johnson and Gonzales, 1978). The Palo Duro Basin is a shallow, asymmetric, structural basin lacking surface expression, which measures 90 miles north to south and 165 miles from northwest to southeast. The deepest part of the basin is an elongate trough adjacent and parallel to the Matador Uplift. The trough extends northwestward into Deaf Smith County and contains 10,000 to 11,000 feet of sedimentary rock (Dutton, 1979).

The pre-Permian section can consist of basal Cambrian marine sandstone, Cambro-Ordovician shallow-shelf carbonates, Mississippian carbonates, and Pennsylvanian interlayered clastics and carbonates and can range in thickness from 0 to over 6,000 feet. The Permian section consists of marine clastics, evaporites, and carbonates, totaling approximately 7,000 feet in thickness. The remainder of the section comprises terrestrial deposits of Mesozoic to Holocene age (principally Triassic and Tertiary), ranging in thickness from 500 to 2,200 feet.

The Dalhart Basin lies to the north and contains about 9,000 feet of sedimentary rock. There is no distinct structural boundary between the

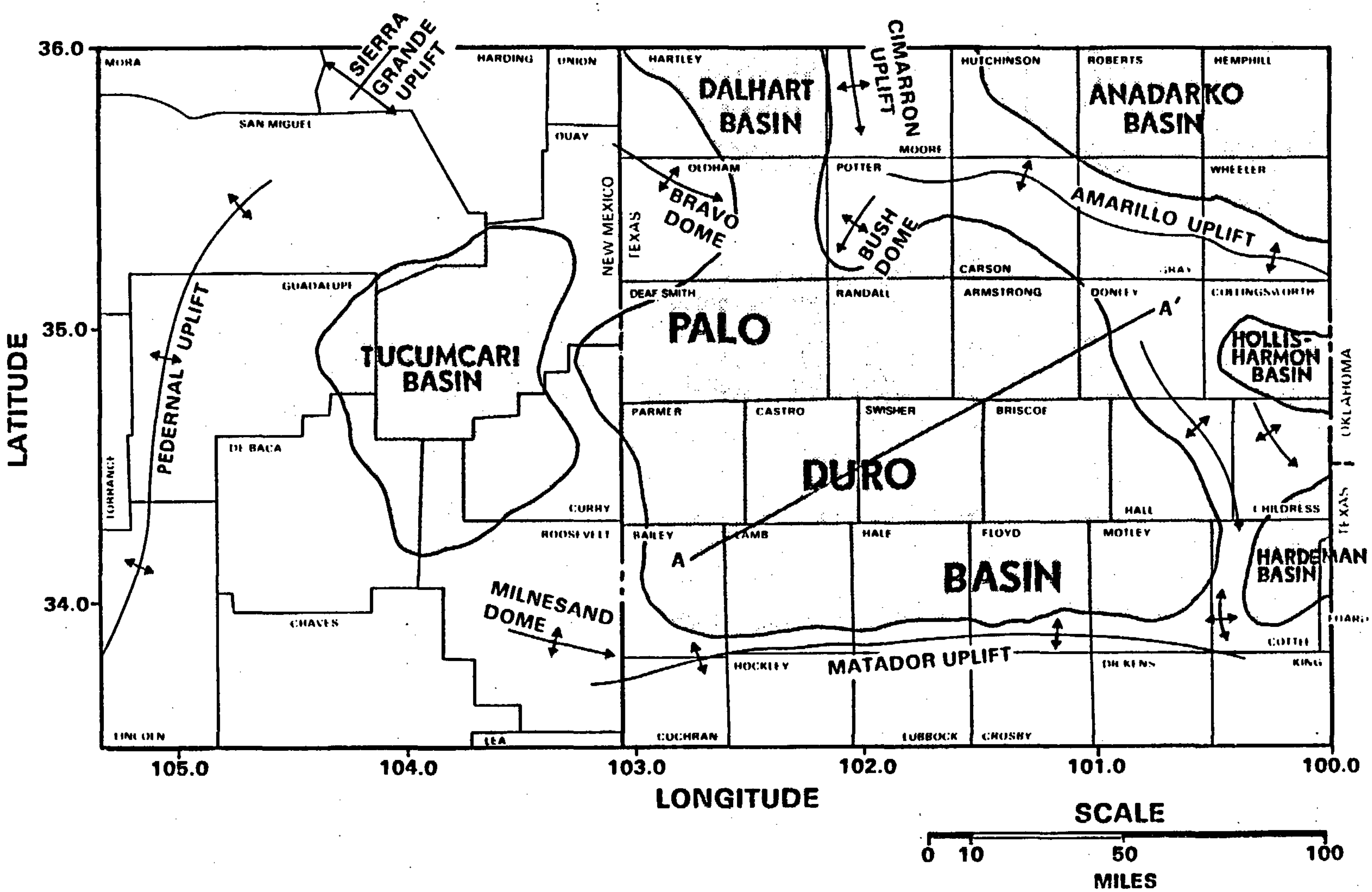


Figure 2-1. Major Tectonic Features and Major Basins in the Study Area.

Palo Duro and Dalhart Basins. A connecting seaway appears to have been open between the basins from Early Pennsylvanian into Late Permian.

The Palo Duro Basin appears to have been structurally separated from the Tucumcari Basin to the west only during the Early Pennsylvanian. The nature of the boundary is uncertain, but some faults have been reported. To the east, the Palo Duro Basin is separated from the Hollis-Harmon and the Hardeman Basins by a north-south trending basement high and an associated faulted zone. These faults developed in Late Mississippian to Early Pennsylvanian. By Late Pennsylvanian, the basins were stratigraphically continuous.

The Matador Uplift separates the Palo Duro Basin from the Midland Basin to the south. The uplift is approximately 200 miles long with the Milnesand Dome at its western end. It has a Precambrian core and consists of uplifted blocks bounded by faults. The uplift acted as a boundary between the shallow-shelf facies of the Palo Duro Basin and the deep-basin facies of the Midland Basin. Geologic units younger than Pennsylvanian are continuous across the uplift. The Pennsylvanian section is thinner over the uplift and is absent in a few areas.

The Amarillo Uplift structurally separates the Palo Duro Basin from the Anadarko Basin to the northeast. The uplift is the most prominent tectonic feature in the area, with thousands of feet of structural relief with respect to the basins and with considerable internal relief among isolated peaks and saddles. It is bounded by major faults and has a Precambrian core. Geologic units younger than Pennsylvanian are continuous across the uplift. The Wolfcamp section is thinner over the uplift but the upper dolomitic strata are continuous across it. The Pennsylvanian section is not present over the uplift.

Although most of these basins are separated from the Palo Duro Basin by distinct structural features, all the basins except the Anadarko Basin were stratigraphically continuous by Late Pennsylvanian, and by Late Wolfcampian all the basins were stratigraphically continous. As a result, the regional deep-basin flow system is interbasinal with respect to all the basins within the study area.

2.4.2 Hydrostratigraphic Units

2.4.2.1 General

The various geologic units in the Palo Duro Basin area were grouped into three major hydrostratigraphic units, labeled A, B, and C on Figure 2-2, based on stratigraphy and grouped by similar lithologies. These three hydrostratigraphic units maintain regional hydrologic importance throughout the area, as shown on a generalized southwest-northeast cross section (Figure 2-3).

2.4.2.2 Shallow Freshwater Flow System - HSU A

Hydrostratigraphic Unit A (HSU A) is the shallowest of the major hydrostratigraphic units and consists of Holocene fluvial and lacustrine deposits; Quaternary loess, dune sand, and alluvium; the Tertiary Ogallala Formation; the Dakota Group and Fredricksburg and Trinity Formations of Cretaceous age; the Morrison and Exeter Formations of Jurassic age; and the Dockum Group of Triassic age (see Figure 2-2).

The Ogallala Formation and Dockum Group are the most important aquifer materials in HSU A. The Ogallala Formation is a regionally extensive alluvial deposit of sand, gravel, silt, and clay that extends eastward from the Rocky Mountains. The upper part of the Ogallala Formation is cemented with carbonate and forms the caprock of the High Plains. The Ogallala Formation is the major freshwater aquifer in the southern High Plains region of Texas and New Mexico.

The sandstones, conglomerates, and shales of the Dockum Group were deposited in fluvial, alluvial fan, and lacustrine environments. These materials are not as regionally important as the Ogallala Formation but locally furnish significant quantities of water to wells.

Even though confined, semiconfined, and unconfined flow conditions exist locally in HSU A, on a regional scale it comprises a shallow, usually freshwater flow system that is a maximum of 2,200 feet thick beneath the High Plains and generally less than 1,000 feet thick beneath the Rolling Plains and Canadian River Valley (see Figure 2-3).

ERA	SYSTEM	SERIES	GROUP	FORMATION	HYDROSTRATIGRAPHIC UNIT (HSU)
CENOZOIC	QUATERNARY			RECENT FLUVIAL AND LACUSTRINE DEPOSITS	FRESHWATER FLOW SYSTEM HSU A
	TERTIARY			OGALLALA	
MESOZOIC			DAKOTA		
				FREDRICKSBURG	
				TRINITY	
	JURASSIC			MORRISON	
				EXETER	
	TRIASSIC		DOCKUM	TRUJILLO	
				TECOVAS	
PALEOZOIC	PERMIAN	OCHOA		DEWEY LAKE	SHALE AND EVAPORITE AQUITARD HSU B
				ALIBATES	
		GUADALUPE	ARTESIA/ WHITEHORSE	SALADO	
				YATES	
				SEVEN RIVERS	
				QUEEN/GRAYBURG	
				SAN ANDRES/BLAINE	
		LEONARD	CLEAR FORK	GLORIETA	
				UPPER CLEAR FORK	
				TUBB	
				LOWER CLEAR FORK	
				RED CAVE	
			WICHITA		
		WOLFCAMP			DEEP-BASIN FLOW SYSTEM HSU C
	PENNSYLVANIAN	CISCO			
		CANYON			
		STRAWN			
		ATOKA/BEND			
		MORROW			
	MISSISSIPPIAN	CHESTER			
		MERAMEC			
		OSAGE			
	ORDOVICIAN		ELLENBURGER		
	CAMBRIAN		UNNAMED SANDSTONE		
	PRECAMBRIAN				

LEGEND:
UNCONFORMITY ----

SOURCES: HANDFORD AND DUTTON, 1980; PRESLEY, 1980; NICHOLSON, 1960; TAIT ET AL, 1962; TOTTEN, 1956; KELLEY AND TRAUGER, 1972.

Figure 2-2. Generalized Hydrostratigraphic Column for the Palo Duro Basin Area of Texas and New Mexico.

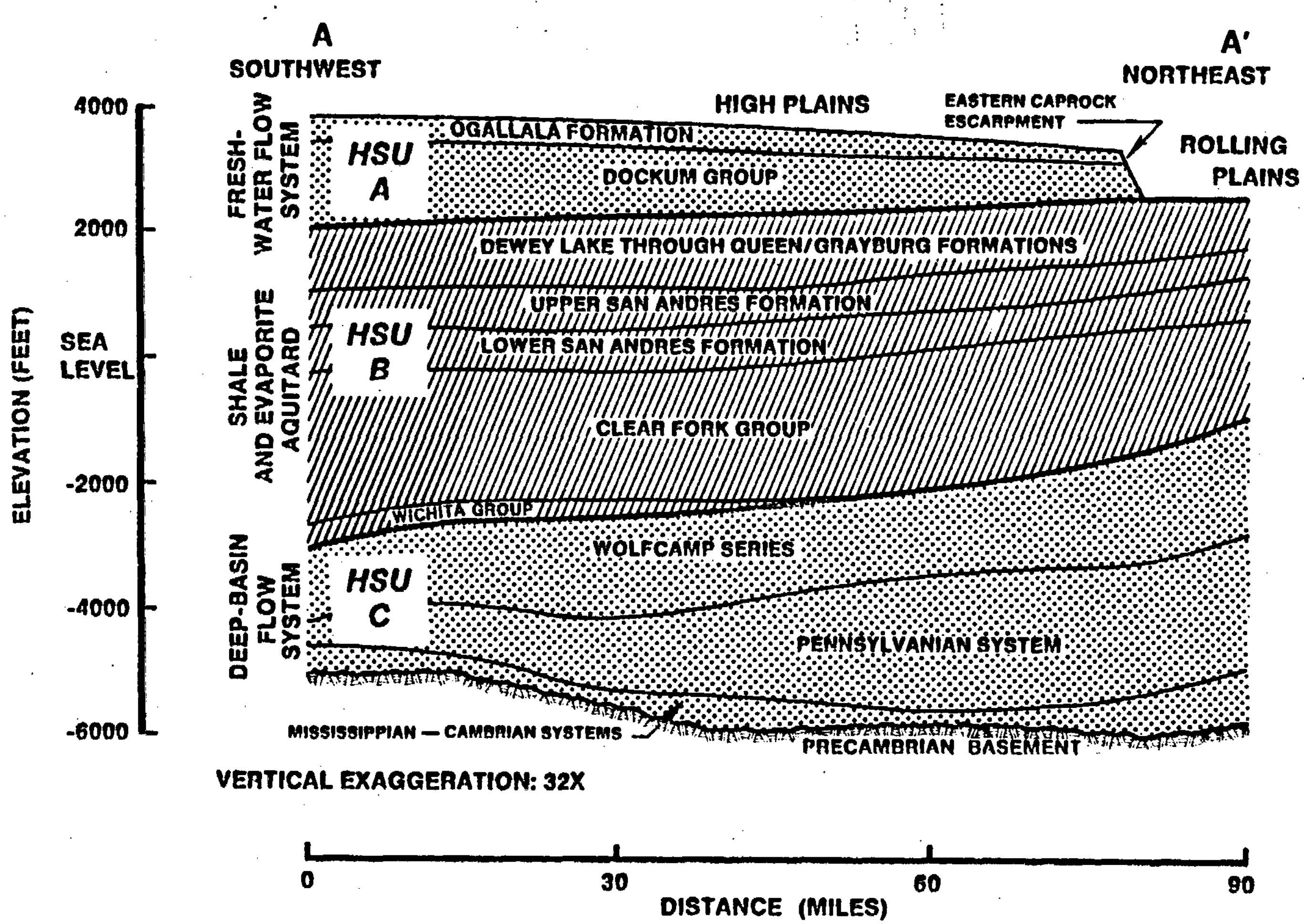


Figure 2-3. Generalized Hydrostratigraphic Cross Section of the Study Area Showing the Three Major Hydrostratigraphic Units.

2.4.2.3 Shale and Evaporite Aquitard - HSU B

The Triassic/Permian boundary marks the top of Hydrostratigraphic Unit B (HSU B), which consists of a thick sequence of Upper Permian shales, siltstones, and bedded deposits of halite and anhydrite that grade into shallow marine carbonates to the south in the Midland Basin. HSU B consists of the Dewey Lake, Alibates, Salado, Yates, Seven Rivers, Queen/Grayburg, San Andres/Blaine, Glorieta, Upper Clear Fork, Tubb, Lower Clear Fork, Red Cave, and Wichita Formations (see Figures 2-2 and 2-3). These strata are characterized by extremely low permeability and vertical or nearly vertical flow gradients. They occur at a depth of 500 to 2,200 feet beneath the High Plains and crop out in the Rolling Plains.

On a regional scale, these strata act as a major confining unit impeding flow between the shallow freshwater flow system and the deep-basin flow system. The proposed repository host rock occurs as a thick salt unit within HSU B in the Lower San Andres Formation.

2.4.2.4 Deep-Basin Flow System - HSU C

The bottom of the Wichita Group marks the top of Hydrostratigraphic Unit C (HSU C), the deep-basin flow system. Where the Wichita Group is absent, the bottom of the Red Cave Formation marks the top of HSU C. HSU C can consist of the Lower Permian Wolfcamp Series; the Cisco, Canyon, Strawn, Atoka/Bend, and Morrow Series of Pennsylvanian age; the Chester, Meramec, and Osage Series of Mississippian age; the Ellenburger Group of Ordovician age; and older deposits of Cambrian age (see Figures 2-2 and 2-3). Locally Devonian and Silurian strata may be present and are considered part of HSU C.

HSU C consists predominantly of Pennsylvanian marine-shelf carbonates and fluvial and deltaic arkosic sandstones, locally known as "granite wash," which are interbedded with siltstones and shales. Distribution of the coarse clastic facies was controlled by erosion of faulted granitic and gabbroic Precambrian basement highlands that were uplifted along the boundaries of the Palo Duro Basin during the Early Pennsylvanian. Down dip from the peripheral areas of clastic sedimentation, and intertonguing with them, are shelf carbonates that grade basinward into thicker more vertically persistent shelf-margin carbonates that border the basin. Geophysical logs show that the Pennsylvanian System is thinner or, in some areas, absent over the Matador Uplift and Milnesand Dome and is completely absent over the Amarillo Uplift.

Directly overlying the Pennsylvanian strata are the Lower Permian carbonates and clastics of the Wolfcamp Series. Geophysical logs show that these materials are continuous across the Palo Duro Basin, Matador Uplift, Bravo Dome, and Amarillo Uplift. The Early Permian (Wolfcampian) was the only portion of the Permian Period that involved further uplift and erosion of the basement highlands. As a result, coarse clastic facies also are found in the Wolfcamp Series materials bordering the Precambrian basement highlands. The top of the Wolfcamp Series marks the top of HSU C. During mid-Permian time, the various sub-basins that make up the Permian Basin filled with sediment, and the subsequent deposition of shelf carbonates, shelf-margin clastics, and evaporites, which form HSU B, occurred through the remainder of the Permian Period.

On a regional scale, HSU C acts as a deep, confined aquifer complex that transmits fluid laterally and probably transmits and accepts small quantities of leakage to and from HSU B. HSU C is underlain by Precambrian crystalline rocks of various lithology, which locally are porous and permeable enough to store and transmit oil and gas, but regionally are assumed to act as a lower confining layer to ground-water flow.

Assuming an accidental or natural release of radionuclides from the proposed repository sites, the permeable clastic and carbonate facies in the Wolfcamp Series and Pennsylvanian System are the two downgradient aquifers capable of laterally transmitting radionuclides away from the proposed sites. Consequently, potentiometric surfaces were constructed for the Wolfcamp Series and Pennsylvanian System. It should be noted that hydraulic heads in the Ogallala/Dockum freshwater flow system are approximately 800 to 2,000 feet greater than equivalent freshwater heads in the deep-basin aquifers (SWEC, 1983). As a result, ground-water movement through the shale and evaporite aquitard will be downgradient to the deep-basin flow system. It also should be noted that at the proposed repository sites approximately 2,000 to 2,500 feet of shales and evaporites lie between the host rock and the top of the Wolfcamp aquifer.

2.5 PREVIOUS INVESTIGATIONS

Whereas numerous hydrogeologic investigations have been performed in the Palo Duro Basin area in HSU A to determine the hydrologic characteristics of the Ogallala Formation and the shallow freshwater flow system, few investigations have been performed to evaluate the hydrologic characteristics of HSU B or HSU C. Even though numerous test holes, wildcat wells, and production wells have been drilled in the oil and gas field areas surrounding the Palo Duro Basin, the wells were neither constructed nor the production zones tested for the specific purpose of obtaining hydrogeologic information. However, some data routinely obtained during pressure testing of oil and gas exploration wells can be used to determine some hydrologic characteristics. As part of the ongoing program to evaluate the Permian Basin as a potential site for a high-level nuclear-waste repository, the Department of Energy (DOE) has drilled eight wells specifically designed to obtain geologic and hydrologic data.

DST data have been used in several hydrogeologic investigations to calculate potentiometric levels and permeability. A description of DST methods, including the mathematical development of appropriate analytical equations, is given in Earlougher (1977). Bredehoeft (1965) and Hackbarth (1978) discuss the use of DST data in hydrogeologic investigations.

Several studies using DST data to analyze regional flow patterns have been published in refereed journals. McNeal (1965) used DST data to evaluate the hydrodynamics of several units in the Permian Basin south of the Matador Uplift and presents potentiometric surfaces for the Ellenburger Group, Devonian System, Mississippian limestone, Strawn Series, Wolfcamp Series, and San Andres Formation. Hanshaw and Hill (1969) used DST data to study the geochemistry and hydrodynamics of the Paradox Basin area. Hitchon (1969a and 1969b) used FSIP data that were believed to represent true formation pressures to evaluate the effects of topography and geology on the flow systems in the western Canada sedimentary basin. Hitchon and Hays (1971) used DST data to evaluate the regional hydrodynamics of the Surat Basin, Australia. Bond (1972) used DST data to evaluate the hydrodynamics of deep-basin aquifers in the Illinois Basin. Toth (1978) used DST data to identify gravity-induced cross-formational flow in the Red Earth region in Alberta, Canada. Bassett and Bentley (1982) used DST data to construct a very generalized potentiometric surface of the Wolfcamp aquifer for a smaller area in the Palo Duro Basin than described in this report. Toth and Millar (1983) used DST data to identify what they believed to represent anachronous transient formation pressures that are approaching equilibrium with modern boundary conditions.

Other studies not published in refereed journals but using DST data to evaluate the deep-basin hydrology of the Palo Duro Basin area have been published by Handford (1980), Bentley (1981), Bassett and Bentley (1983), and Devary (1983). Handford (1980) used preliminary DST data to construct potentiometric surfaces of the Wolfcamp and Pennsylvanian strata (excluding granite wash) in selected parts of the Palo Duro Basin area. Bentley (1981) used DST data to construct very generalized regional potentiometric surfaces of the Wolfcamp and Pennsylvanian aquifers for a smaller area in the Palo Duro Basin than described in this report. Bassett and Bentley (1983) used the Bentley (1981) Wolfcamp potentiometric surface in a separate report dealing with the hydrodynamics and geochemistry of the deep-basin aquifers in the Palo Duro Basin. Devary (1983) used almost the same DST data as originally used by Bentley (1981) to construct a regional Wolfcamp potentiometric surface using kriging techniques.

2.6 COMPUTER PROGRAMS

2.6.1 SURFACE II GRAPHICS SYSTEM

In this study, three sets of potentiometric-surface maps are produced corresponding to successive refinement of the DST data base. In order to campare these maps, it was necessary to use a computer mapping program to assure consistency in contouring the data. The SURFACE II GRAPHICS SYSTEM (Sampson, 1978) was used for this purpose and was progammed to apply the same contouring biases to each set of potentiometric-surface maps. SURFACE II is a computer program qualified for Nuclear Safety Related use under SWEC QA procedures. SURFACE II produces contour maps showing the continuous form of data defined by X, Y, and Z coordinate values. The irregularly spaced potentiometric data (original Z values) calculated from the DST data are transformed to a regular X-Y grid, and the original Z values are used to calculate Z' values at regularly spaced grid nodes. The

Z' values then are contoured to produce potentiometric-surface maps. The density of the regular grid and the manner in which the Z' values are calculated are specified by the program user.

The mathematical procedures used to calculate the Z' values assigned to the grid nodes are discussed in detail in Sampson (1978). In general terms, the slope of the surface at each nearby original Z value is estimated by regression analysis, and the slopes then are projected to the grid nodes. To preserve the integrity of the original potentiometric data, a distance-weighting function of $W = 1/D^6$ was used, where W is the weight assigned to the original Z value at a distance D from a grid node. Using this procedure, Z' values are calculated by a distance-weighted average of slope projections of adjacent original Z values. (A disadvantage of using slope projections is that depressions or mounds may be generated in areas where no original Z values exist.)

SURFACE II contains an error analysis subroutine (ERAN) that is used to evaluate the "goodness of fit" of the Z' values relative to the original Z values. ERAN computes the maximum positive error, maximum negative error, mean error, root-mean-squared error, standard deviation, variance, percent relative error, skewness, kurtosis, and sum-of-squares error of the difference between the Z' values and the original Z values. It also computes the absolute error of many of these statistical measures. In addition, ERAN plots a histogram of the error distribution, a scatter diagram of original Z values versus Z' values, and a scatter diagram of the original Z values versus the difference between original Z values and Z' values. ERAN also lists for each original data point the X value (longitude), Y value (latitude), Z value (original potentiometric value), Z' value (gridded potentiometric value), the difference between Z and Z' values, and the standardized difference between Z and Z' values. Notwithstanding the sophisticated error analysis capability of SURFACE II, the acceptability of all maps was determined by comparing the contoured surface to the original data.

SURFACE II contains other subroutines that are used to designate contour intervals, label contour lines, smooth contoured surfaces, draw outlines of geographic features, and list the Z' and/or Z values used in constructing contour maps. SURFACE II does not hachure closed depressions unless the entire depression is contained within the borders of the map.

Appendix A lists the specific SURFACE II commands used to construct all the potentiometric-surface maps presented in this report. These commands were selected after testing various combinations of commands because they preserved the integrity of the original potentiometric data and produced a legible, interpretable map.

The Pennsylvanian potentiometric surfaces produced by SURFACE II have been modified to show the outline of the Amarillo Uplift and other areas where Pennsylvanian strata are absent.

2.6.2 STATISTICAL ANALYSIS SYSTEM

The STATISTICAL ANALYSIS SYSTEM (SAS) program (SAS Institute Inc., 1979) was used to calculate all statistical measures referenced in the report. SAS is a non-Nuclear Safety Related program that is generally accepted as an industry standard. It has been installed by over 6,000 users worldwide, including the Nuclear Regulatory Commission.

2.6.3 TRENDS

The MULTIPLE REGRESSION AND GEOLOGIC TREND ANALYSIS (TRENDS) program (Esler and others, 1968) was used in the planar regression studies. TRENDS is a Nuclear Safety Related program qualified in accordance with SWEC quality assurance procedures.

3 DRILL-STEM TEST CLASSIFICATION AND MASTER FILE

3.1 PURPOSE OF CLASSIFICATION SCHEME

A screening process and classification system were devised and used to evaluate the quality of the DST data. The purpose of this system was to eliminate dubious data from improperly run tests, incomplete shut-in pressure and shut-in time records, poorly calibrated or malfunctioning equipment, and misreported results.

The screening process was based on stringent criteria for the duration of ISIT and FSIT and for agreement of FSIP with ISIP. The time duration criteria were used to screen out tests that were run for such a short time that pressure equilibrium probably could not be approached except in extremely permeable strata. The pressure agreement criterion was used to screen out tests that did not appear to approach pressure equilibrium. Used together, the time duration and pressure agreement criteria should select DSTs that were run for a sufficiently long time that pressure equilibrium was approached or attained.

3.2 CLASSIFICATION SCHEME

Because DST data were used to calculate potentiometric levels based on formation pressures, it was necessary to select those DST data that most nearly represented the formation pressure in the tested geologic unit. Unfortunately, Class 1 data, considered to be the most reliable estimate of formation pressure, were limited to the 27 available DSTs that had complete records of pressure change with time. Horner plots constructed from these data were used to calculate extrapolated formation pressures.

Shut-in time and shut-in pressure data were used to separate DSTs with incomplete records into three classes. Class 2 required ISIT and FSIT to be greater than or equal to 60 minutes and FSIP to agree within ±5 percent of ISIP. Class 2 tests represent the second-best data.

Class 3 required ISIT and FSIT to be greater than or equal to 30 minutes but less than 60 minutes and FSIP to agree within ±5 percent of ISIP. Class 3 tests represent intermediate quality data.

Class 4 tests represent the worst quality data and includes all tests which did not comply with the criteria for Class 1, 2, or 3. Class 4 tests either lacked a value of ISIP, FSIP, ISIT, or FSIT, or did not meet the shut-in time or shut-in pressure agreement criteria for any of the other classes.

Table 3-1 summarizes the DST classification scheme. Only Class 1, 2, and 3 tests were used in the hydrogeologic investigations included in this report. In counties where greater than 25 Class 1 and 2 DSTs were available, no Class 3 DSTs were added to the data base.

ISIP values do not necessarily approximate true formation pressures as closely as extrapolated formation pressure values obtained from Horner plots. In most DSTs where a continuous record of pressure change is recorded, ISIP is greater than FSIP but less than the extrapolated formation pressure. (In the PI data base, ISIP was greater than or equal to FSIP in 82 percent of the Class 2 and 3 DST data.) Consequently, heads calculated from ISIP values will be less than those based on extrapolated formation pressures but greater than those calculated from FSIP values. (In the 17 DSTs where heads based on extrapolated formation pressures can be compared with heads based on ISIPs, heads based on ISIPs were an average of 97 feet less than heads based on extrapolated formation pressures.) It should be noted that 19 Class 1 DSTs have been performed in the Wolfcamp. Most of these tests were performed in DOE-sponsored wells in Deaf Smith, Swisher, Donley, and Randall Counties, Texas. Only one Class 1 DST has been performed in the Pennsylvanian. Instead of using extrapolated formation pressures to calculate heads for these DSTs, whenever possible ISIP values measured from either DST charts or Horner plots were used. This assured that the method used to calculate heads from Class 1 DSTs was consistent with the method used to calculate heads in adjacent wells from Class 2 and 3 DSTs because inclusion of heads based on extrapolated formation pressures produced small mounds in the potentiometric surfaces. This was considered critical to the determination of horizontal hydraulic gradients in the Wolfcamp Series and Pennsylvanian System in the proposed repository site areas because heads based on extrapolated formation pressure when combined with heads in neighboring wells based on ISIP would produce fallacious gradients.

Table 3-1. DST Classification Scheme

Class	Criteria
1	a. Horner plot
2	a. ISIT and FSIT ≥ 60 minutes b. FSIP = ISIP ± (0.05 x ISIP)
3	a. ISIT and FSIT ≥ 30 minutes but < 60 minutes b. FSIP = ISIP ± (0.05 x ISIP)
4	a. All other data

3.3 CLASSIFICATION RESULTS

For this report, 5,502 DSTs from 1,971 wells in 43 counties in Texas and New Mexico were evaluated, screened, and classified. Class 1 tests comprised less than 0.5 percent of the total. Approximately 12 percent of the tests qualified as Class 2, whereas approximately 7 percent of the tests qualified as Class 3. Class 4 tests comprised nearly 80 percent of the total. Consequently, only 20 percent of the total amount of DST data qualified for use in this hydrogeologic investigation. Table 3-2 summarizes the results of the DST classification on a state and county basis.

3.4 MASTER FILE OF GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA

A master file of the DST data used in this report is included as Appendix B. The following data from 841 DSTs were compiled in the master file: well number, test number, classification, latitude, longitude, ground elevation, depth to top of tested interval, depth to bottom of tested interval, midpoint depth and elevation of tested interval, ISIP, FSIP, equivalent freshwater head, tested formation, status, year of test, HSU, and topographic setting. All these categories are defined in the legend included in Appendix B. Many categories are discussed in greater detail later in this report. For Class 1 data, the extrapolated formation pressure is listed under the ISIP heading.

Table 3-2. Results of DST Classification

County	No. Wells	No. DSTs	Class 1	Class 2	Class 3	Class 4
Texas						
Armstrong	6	9	0	0	0	9
Bailey	6	10	0	0	0	10
Briscoe	4	10	1	1	2	6
Carson	14	27	1	1	0	25
Castro	9	19	3	2	1	13
Childress	33	48	1	9	2	36
Cochran	41	80	0	7	3	70
Collingsworth	3	5	0	0	0	5
Cottle	76	116	1	23	17	75
Crosby	28	58	0	9	12	37
Deaf Smith	7	15	3	0	1	11
Dickens	33	60	0	7	7	46
Donley	13	28	2	1	6	19
Floyd	23	52	1	6	5	40
Foard	5	19	0	0	6	13
Gray	47	395	0	38	19	338
Hale	21	56	1	5	10	40
Hall	14	28	1	1	2	24
Hartley	47	138	2	10	4	122
Hemphill	87	236	0	26	18	192
Hockley	188	560	0	91	54	415
Hutchinson	41	174	0	6	15	153
King	152	307	0	36	52	219
Lamb	40	84	0	13	5	66
Lubbock	78	182	0	22	13	147
Moore	11	28	0	0	1	27
Motley	41	86	0	2	5	79
Oldham	37	123	3	15	0	105
Parmer	1	2	0	0	0	2
Potter	15	49	0	0	4	45
Randall	10	33	1	0	2	30
Roberts	267	902	0	59	19	824
Swisher	9	26	6	4	1	15
Wheeler	68	288	0	62	1	225
Subtotal	1,475	4,253	27	456	287	3,483

Table 3-2. (Continued)

County	No. Wells	No. DSTs	Class 1	Class 2	Class 3	Class 4
New Mexico						
Chaves	181	457	0	96	33	328
Curry	10	20	0	3	3	14
DeBaca	8	15	0	3	0	12
Guadalupe	4	12	0	0	2	10
Harding	3	4	0	1	0	3
Lea	116	330	0	60	35	235
Quay	4	6	0	2	0	4
Roosevelt	160	377	0	56	32	289
San Miguel	10	28	0	0	6	22
Subtotal	496	1,249	0	221	111	917
Total	1,971	5,502	27	677	398	4,400
Percent		100	0.49	12.30	7.25	79.96

4 WOLFCAMP AND PENNSYLVANIAN POTENTIOMETRIC SURFACES

4.1 GENERAL

Because of their regional extent and position as downgradient regional aquifers beneath the proposed host rock, potentiometric surfaces were constructed for the Wolfcamp Series and Pennsylvanian System. Construction of these maps was based on calculation of equivalent freshwater heads from ISIP data. In wells where more than one DST was performed in either the Wolfcamp or the Pennsylvanian aquifer, it was necessary to select only one head value per well per aquifer. In wells where there were three or more tests performed in the same aquifer, the head value closest to the average of the head values was selected. In wells where there were two tests in the same aquifer, the head value closest to the head values in adjacent wells was selected.

The following equations were used to calculate equivalent freshwater heads:

$$HH = (ISIP)\ (C/P) \tag{4-1}$$

where, HH = Freshwater hydrostatic head above tested interval midpoint (ft),

ISIP = Initial shut-in pressure (psi),

C = Constant (144 in^2/ft^2), and

P = Unit weight of fresh water (62.4 lb/ft^3).

$$EFWH = ELEV - MDPT + HH \quad (4\text{-}2)$$

where, EFWH = Equivalent freshwater head
(feet relative to mean sea level),
ELEV = Ground-surface elevation
(feet relative to mean sea level), and
MDPT = Midpoint depth of tested interval
(feet below ground surface).

MDPT was assumed to be relative to the ground-surface elevation at the well head. However, in many cases the reported depths of tested intervals were measured from the derrick floor or Kelly Bushing, which usually is 10 to 15 feet above ground level. As a result, many of the equivalent freshwater heads used in this report may be 10 to 15 feet too high. Since it is not possible to tell consistently what datum MDPT is relative to, the 10 to 15 foot error (which represents approximately 0.5 percent of the average head value of the Wolfcamp and Pennsylvanian aquifers) was accepted.

The potentiometric-surface maps presented in this report represent composite maps of heads calculated from DSTs performed from 1954 through early 1983. It was necessary to combine DST data from these years because of the spatial and temporal distribution of the data. This approach appears to be valid because the Wolfcamp and Pennsylvanian aquifers probably are steady state except where locally disturbed by oil and/or gas production.

Separate potentiometric surfaces were constructed for the Wolfcamp Series and Pennsylvanian System because the permeable zones in these units commonly are separated by several hundred feet of shale and argillaceous limestone which probably act as a leaky confining layer between the permeable zones. Adjacent to the uplifts, however, permeable zones in these aquifers may be in hydraulic connection where coarse-grained clastics were deposited during both the Pennsylvanian and Wolfcampian. This also may occur in Randall County, Texas, where a reef complex extends from the

Pennsylvanian through the Wolfcampian, as well as in other local areas where Pennsylvanian carbonates are continuous with Wolfcampian carbonates.

Areas where Pennsylvanian strata are absent, as shown on the Pennsylvanian potentiometric surfaces, were delineated using geophysical logs.

4.2 INITIAL WOLFCAMP AND PENNSYLVANIAN POTENTIOMETRIC SURFACES

Regional potentiometric surfaces for the Wolfcamp Series and Pennsylvanian System initially were constructed using head values calculated from all the ISIP data (118 Wolfcamp and 257 Pennsylvanian). As shown on Figure 4-1 for the Wolfcamp and on Figure 4-2 for the Pennsylvanian, these potentiometric surfaces contain many large local mounds and depressions. The configuration of these surfaces was not considered reasonable on a regional scale due to the unrealistic local variations in flow directions and hydraulic gradients created by the mounds and depressions. In many cases, potentiometric levels in adjacent wells differ by 1,000 to 10,000 feet. To better understand the causes of the mounds and depressions, analysis of pressure-depth data from the deep-basin DST data was undertaken.

4.3 PRESSURE-DEPTH DATA

4.3.1 <u>Theoretical Pressure-Depth Relationships</u>

Hydrostatic pressure is caused by the unit weight of fluid and the height of the fluid column above the measurement point. Hydrostatic pressure gradients vary according to the density of fluid. Varying concentrations of dissolved solids and gases, and temperature differences affect hydrostatic pressure gradients. As a result, an increase in the content of dissolved solids increases hydrostatic pressure, whereas an increase in the content of dissolved gases or higher fluid temperatures decreases hydrostatic pressure.

The hydrostatic pressure gradient of fresh water or brackish water (<10,000 mg/l dissolved solids) is 0.433 psi/ft. The hydrostatic pressure

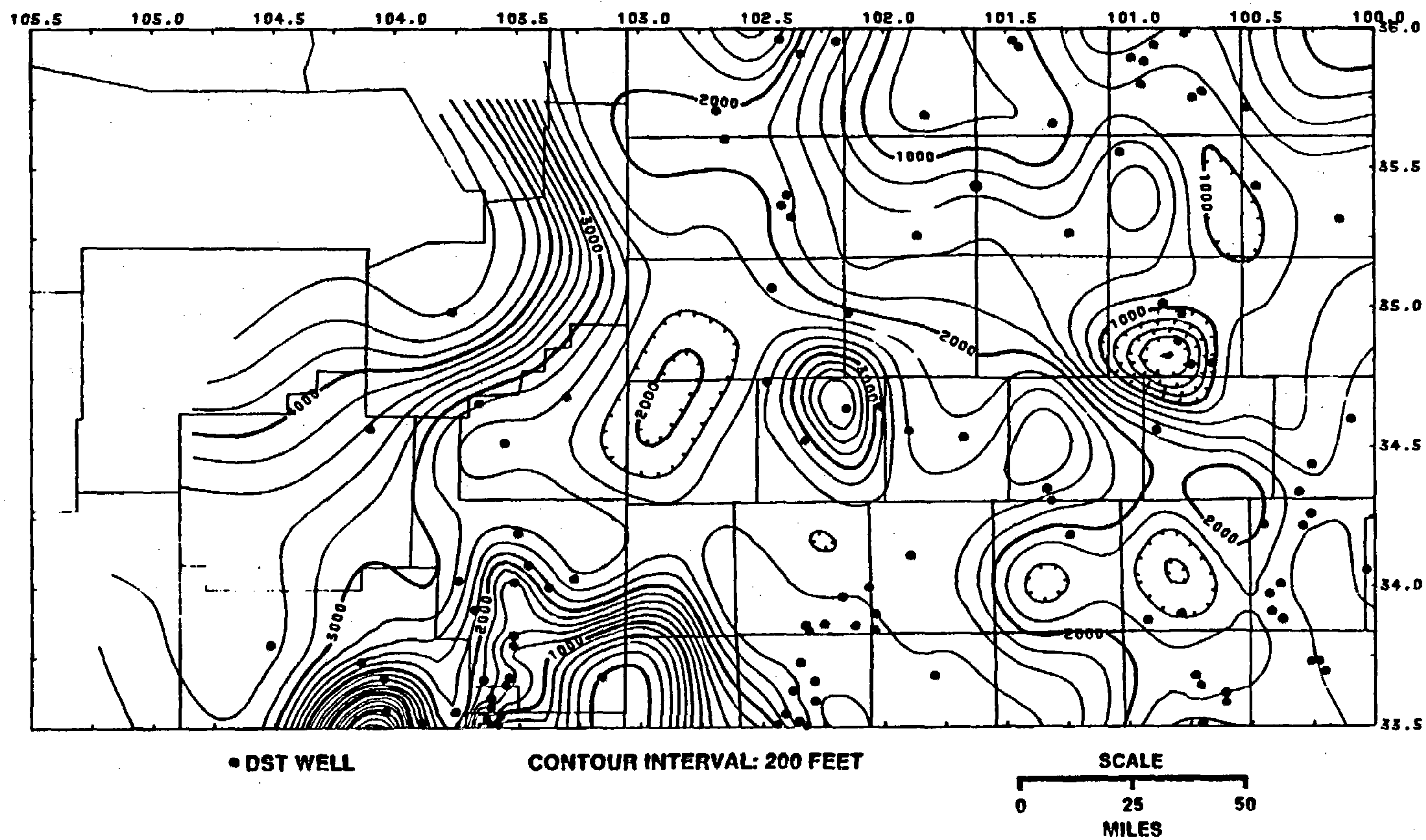


Figure 4-1. Initial Wolfcamp Potentiometric Surface.

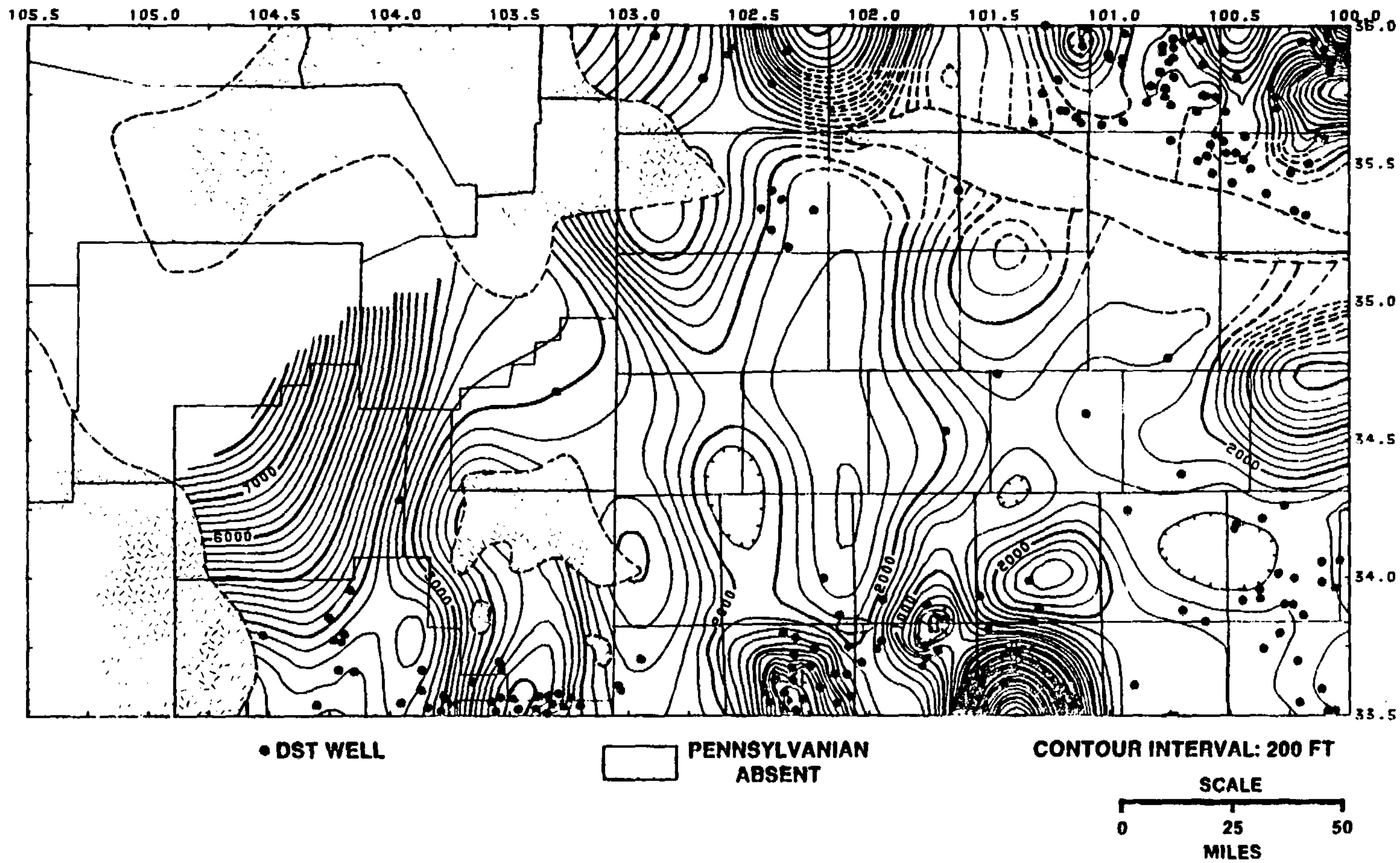


Figure 4-2. Initial Pennsylvanian Potentiometric Surface.

gradient of brine, with approximately 80,000 mg/l dissolved solids, is 0.465 psi/ft (Fertl, 1976).

Formation pressure is the pressure acting on formation fluids in pore spaces of the formation (Fertl, 1976). Normally, formation pressure is equal to the hydrostatic pressure exerted by a column of water extending from its potentiometric level down to the point of measurement. Abnormally high formation pressures, referred to as overpressures, are greater than normal hydrostatic pressures at a given depth. Abnormally low formation pressures, referred to as underpressures, are less than normal hydrostatic pressures at a given depth. Figure 4-3 is a pressure-depth diagram showing a range of hydrostatic pressure gradients for fresh water (0.433 psi/ft) and brine (0.496 psi/ft - approximately 200,000 mg/l dissolved solids) and the regions of overpressuring and underpressuring. Although brines ranging in density from 66.1 to 76.8 lb/ft^3 are known to exist in the deep-basin strata, neither the average hydrostatic pressure gradient nor its vertical or lateral variations have yet been determined. (The range of probable hydrostatic pressure gradients shown on the pressure-depth diagrams in this report are for use only as references and are not intended to indicate whether or not pressure-depth data are hydrostatic or hydrodynamic.)

Pressure-depth data obtained from DSTs can be plotted on a diagram similar to Figure 4-3 and used to evaluate and interpret pressure-depth relationships in a particular well, geographic region, or geologic unit. The linear regression lines and statistics shown on the pressure-depth diagrams in this report originally were plotted in the standard manner with the independent variable (depth) on the X-axis and the dependent variable (pressure) on the Y-axis. After the regression statistics were obtained, the axes were transformed to put depth on the Y-axis and pressure on the X-axis, the conventional format used by geologists and petroleum engineers. The linear regression lines plotted on many of the pressure-depth diagrams are not intended to be used to identify areas or zones where vertical ground-water movement is occurring. Rather, their intended use is to show statistically the general trend of the data. Identification of areas and zones of vertical ground-water movement will be discussed in another report after basin-specific fluid density data are used to construct basin-specific hydrostatic pressure gradients.

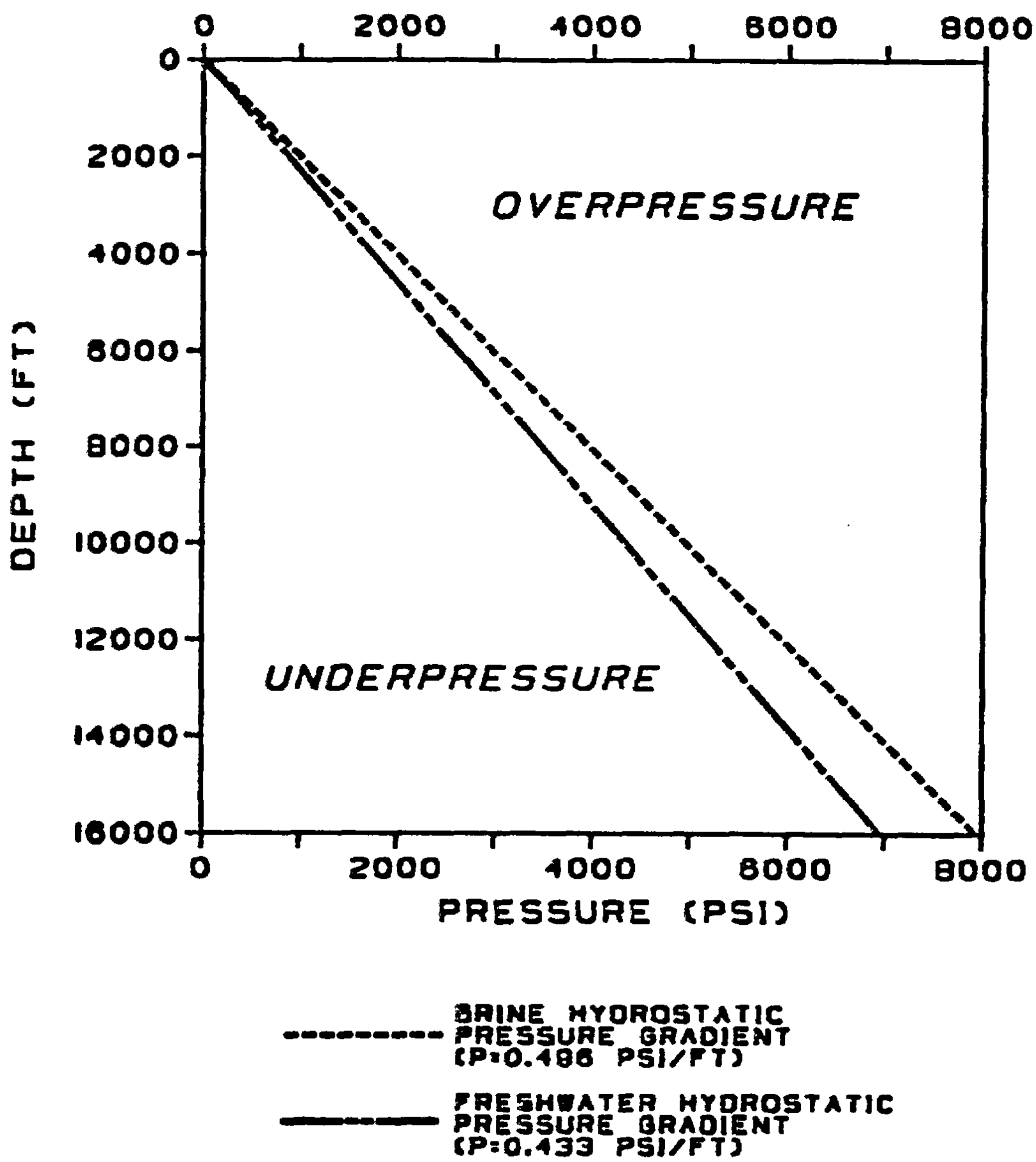


Figure 4-3. Generalized Pressure-Depth Diagram Showing the Range of Freshwater and Brine Hydrostatic Pressure Gradients and the Regions of Overpressuring and Underpressuring.

4.3.2 Pressure-Depth Diagrams From Counties in Texas and New Mexico

Pressure-depth diagrams were constructed, for each county in the study area that contained Class 1, 2, or 3 DST data, by plotting extrapolated formation pressure or ISIP (psi) against the depth of the tested interval midpoint (ft). The geologic unit tested by the DST is coded on the diagrams which are included in Appendix C.

4.4 WOLFCAMP AND PENNSYLVANIAN PRESSURE-DEPTH DATA

Figure 4-4 is a plot of Wolfcamp pressure-depth data. Figure 4-5 is a plot of Pennsylvanian pressure-depth data. These figures show that almost all the Wolfcamp and Pennsylvanian pressure-depth data are underpressured with respect to the range of hydrostatic pressure gradients shown on the diagrams and that some of the data are grossly underpressured. (The terms "grossly underpressured," "grossly overpressured," "abnormally pressured," and "aberrant data" are used in this report as general terms to refer to those data that do not lie along the general trend of the majority of the Wolfcamp and Pennsylvanian data, as shown on Figures 4-4 and 4-5. The term "normally pressured" is used as a general term to refer to those data that lie along the general trend of the majority of the Wolfcamp and Pennsylvanian data, as shown on Figures 4-4 and 4-5. None of these terms has hydrodynamic connotations.)

Heads calculated from grossly overpressured data are responsible for the potentiometric mounds seen on Figures 4-1 and 4-2. Similarly, heads calculated from grossly underpressured data are responsible for the potentiometric depressions seen on these figures. In many cases, these heads are 1,000 to 10,000 feet greater than or less than heads in adjacent wells in the same geologic unit at a similar depth.

Elimination of local exceptionally high and exceptionally low heads would produce more reasonable regional potentiometric surfaces. Elimination of these data could be based on (1) arbitrarily set limits of hydrostatic pressure gradients that reduce the range of acceptable formation pressures, or (2) on statistical analysis of normal and aberrant formation pressures or heads, or (3) on analysis of the hydrodynamics of

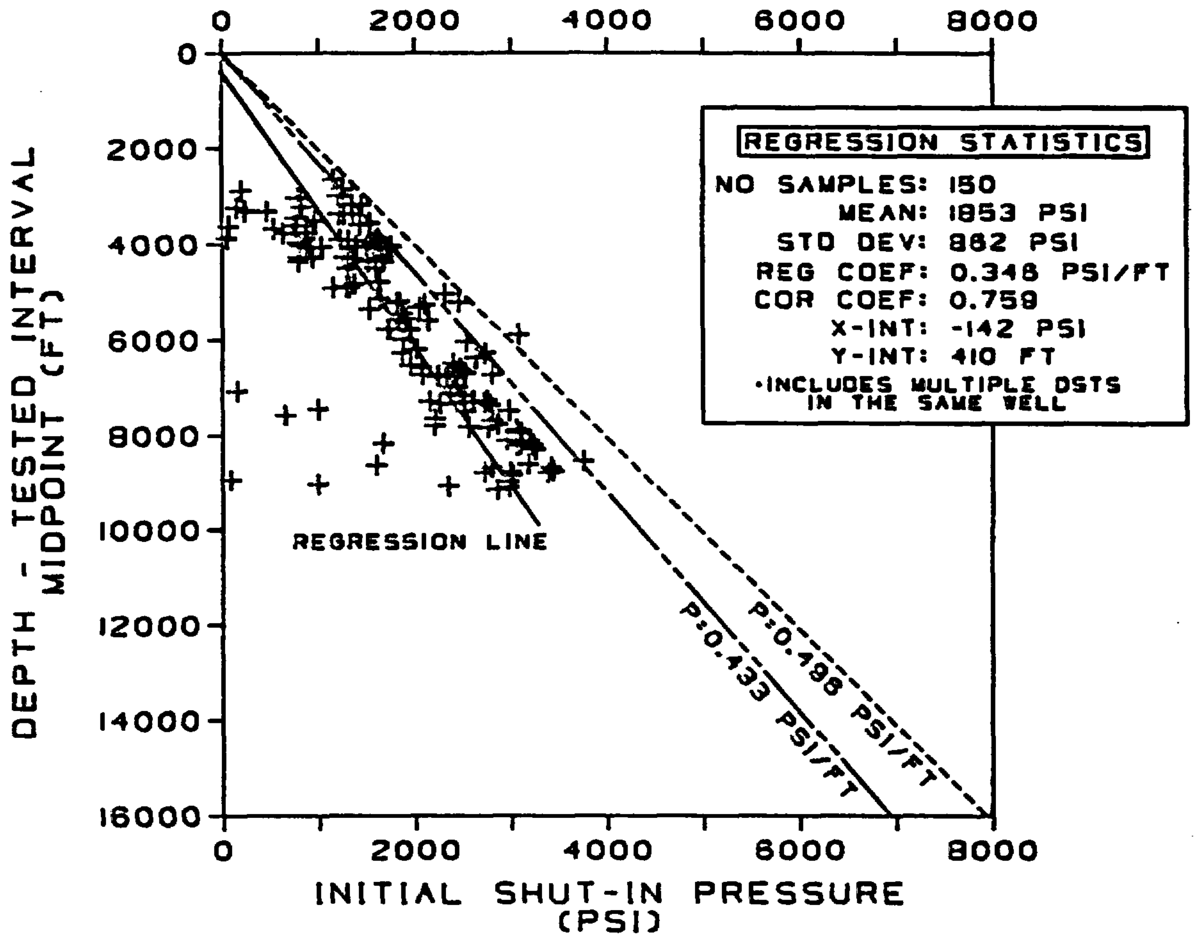


Figure 4-4. Pressure-Depth Diagram and Linear Regression of Wolfcamp DST Data.

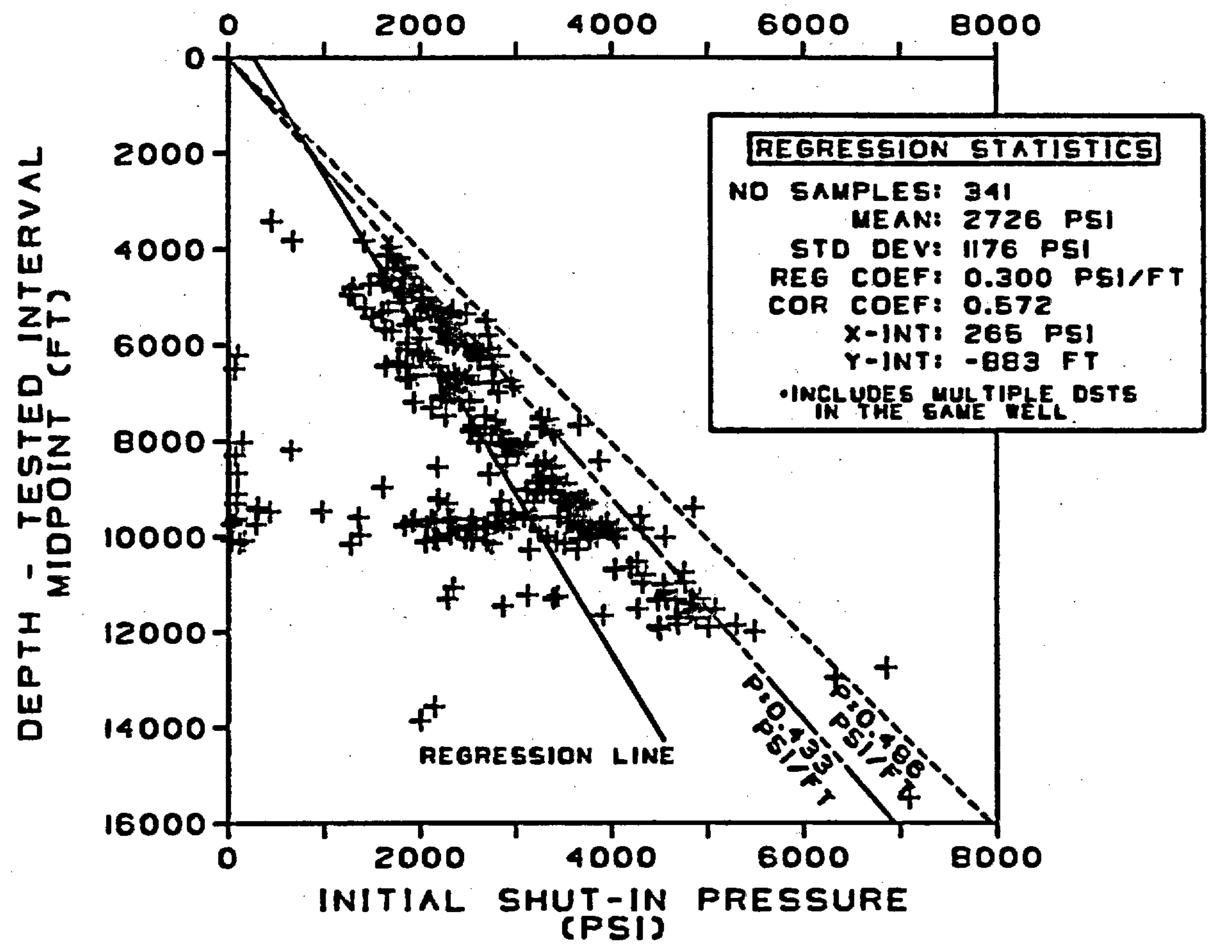


Figure 4-5. Pressure-Depth Diagram and Linear Regression of Pennsylvanian DST Data.

the local flow system around the wells. The third method was chosen to eliminate or select as much data as possible due to the physical relationships controlling the hydrodynamics of the deep-basin flow system, rather than due to compliance or noncompliance with statistical tests or arbitrarily set hydrostatic pressure gradients which ignore the physical mechanisms that relate formation pressures and hydrodynamics, and therefore, may eliminate or select both valid and invalid data.

4.5 ABNORMAL FORMATION PRESSURES

Most literature concerning abnormal formation pressures addresses their relationship to oil and gas reservoirs (Dickey and Cox, 1977; Bradley, 1975), their geologic significance (Harkins and Baugher, 1969; Lewis and Rose, 1970; Magara, 1971; Russell, 1972; Berry, 1973; Dickinson, 1953; Hanshaw and Bredehoeft, 1968; Bredehoeft and Hanshaw, 1968; Sharp, 1983; Neuzil and Pollock, 1983; Koppula, 1983), or their hydrodynamic significance (Toth, 1978; Toth and Millar, 1983). These authors have proposed several theories about the origin of abnormal formation pressures which are listed below:

(1) Epeirogenic movements with associated erosion and/or deposition
(2) Tectonic compression
(3) Sediment compaction
(4) Temperature changes causing thermal expansion or contraction of fluids
(5) Osmosis
(6) Chemical dissolution or precipitation
(7) Mineral phase changes
(8) Carbonization of organics
(9) Buoyancy due to the presence of hydrocarbons
(10) Ascending or descending gound-water motion
(11) Withdrawal or injection of fluids

According to these authors, evidence exists to support all these purported causes of abnormal formation pressure. It is very difficult, however, on a local or well-by-well basis, to determine which cause has affected a particular abnormally pressured DST and not a normally pressured DST in the same geologic unit at a similar depth in the same well or in adjacent wells, especially for the first ten causes listed above. It is possible, however, to determine whether a DST at a particular depth has been affected by the withdrawal or injection of fluids.

The distribution of DST wells relative to the distribution of oil and gas production fields, as shown on Figure 4-6, suggested that some DSTs may have been performed in strata where extraction of formation fluids from production zones may have reduced formation pressures to the extent that formation pressures recorded by the DSTs appear to be grossly underpressured.

4.6 WOLFCAMP AND PENNSYLVANIAN POTENTIOMETRIC SURFACES AFTER CULLING DEPRESSURED DST DATA

4.6.1 Culling of Depressured DST Data

As Figure 4-6 shows, many DSTs were performed in areas that currently produce or historically produced oil and/or gas from strata with sufficient porosity to serve as a reservoir and sufficient permeability to transmit oil or gas to production wells. Depending on the hydrologic characteristics of the reservoir, DSTs performed in these strata subsequent to the commencement of oil or gas extraction might be affected by depressuring of the reservoir. As a result, these DSTs would record abnormally low FSIP and ISIP values that may be valid formation pressures but actually represent temporal pressures in local depressurized zones within a regional flow system that is probably steady state. (The term "temporal pressure" is used instead of "transient pressure" because the recorded formation pressure may or may not be transient with respect to the pumping stress.)

Heads calculated from DSTs performed in a depressurized zone would be abnormally low compared to heads calculated from DSTs in nearby wells in the same geologic unit but not within the depressurized zone. Consequently, identification and deletion of heads calculated from DSTs

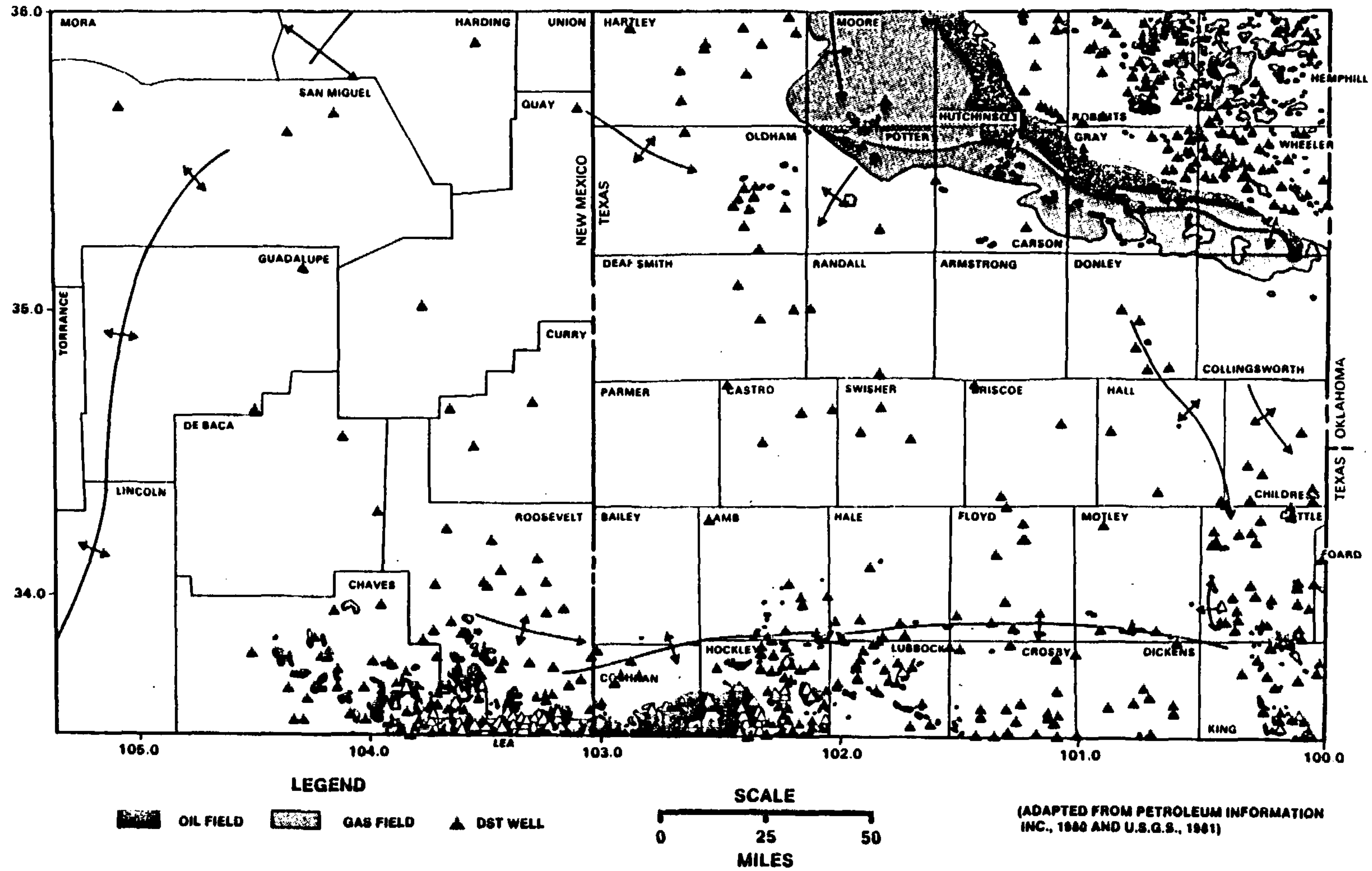


Figure 4-6. Location of DST Wells Relative to the Location of Major Oil and Gas Fields in the Study Area.

performed in local depressurized zones in the Wolfcamp Series and Pennsylvanian System are critical to the construction of their regional potentiometric surfaces.

Pressure-depth data from Hockley County, Texas, are shown on Figure 4-7A. Note that almost all the data are underpressured with respect to the range of probable hydrostatic pressure gradients and that some of the Clear Fork data at a depth of 6,800 to 7,300 feet and many of the Pennsylvanian data at a depth of 9,800 to 10,000 feet are grossly underpressured. This suggested that DSTs performed in these zones may be depressured due to the extraction of oil and/or gas. To verify this contention, property ownership maps showing the locations of oil and gas production wells and wildcat wells in a given county were obtained from PI. By determining the locations of DST wells relative to the locations of oil and gas fields, the depth of production zone(s), the depth interval of the DSTs, and the discovery date of the field(s), it was possible to identify DSTs and test intervals where formation pressures were decreased by oil and/or gas production.

Oil production from Pennsylvanian strata in Hockley County, Texas, provides an example of this method and how it was used to identify depressured DSTs. Table 4-1 lists the number of oil fields and the cumulative volume of oil production prior to January 1, 1980, from five geologic units in Hockley County. As the table shows, a tremendous volume of oil, 43,677,657 barrels, has been extracted from 21 fields producing from Pennsylvanian strata (Texas Railroad Commission, 1979).

Figure 4-8 shows the outline of the major Pennsylvanian oil fields in Hockley County, the depth to production zone(s) in each field, the locations of many of the DST wells, and the midpoint depth of the DSTs. Seemingly depressured DSTs, as seen on the Hockley County pressure-depth diagram (Figure 4-7A), are marked with a circular dot, whereas normally pressured DSTs are marked with a square dot. (ISIP values for each DST are listed in Appendix B.) Figure 4-8 shows that seemingly depressured DSTs consistently were recorded at depths where oil production was occurring in one or more nearby oil fields and that normally pressured DSTs consistently were recorded at depths above or below the depth(s) of oil production. Figure 4-7A shows that seemingly depressured DSTs occur only at the same

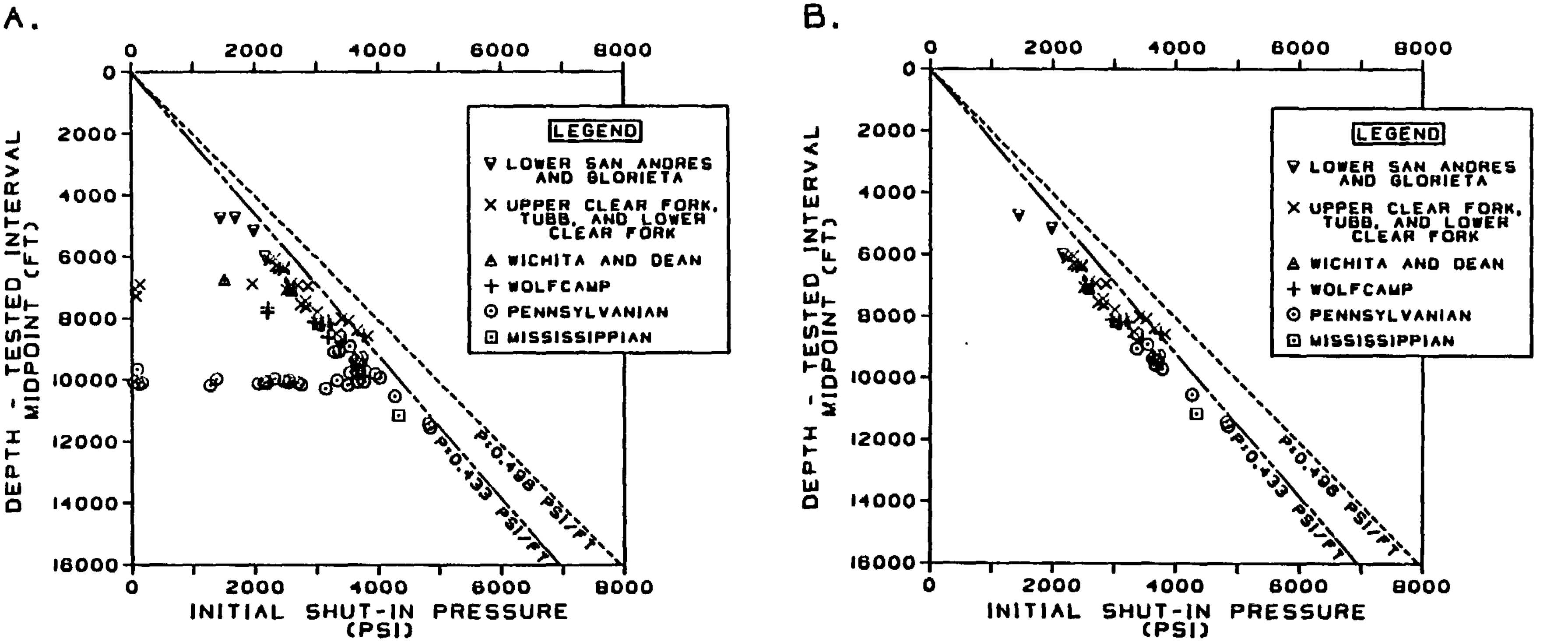


Figure 4-7. A. Pressure-Depth Diagram and Linear Regression of DST Data, Hockley County, Texas; B. Pressure-Depth Diagram and Linear Regression of DST Data after Culling Depressured Data, Hockley County, Texas.

Table 4-1. Cumulative Crude Oil Production Prior to January 1, 1980, Hockley County, Texas*

Geologic Unit	Cumulative Production (Barrels)	Number of Fields
San Andres	13,434,078	7
Clear Fork	32,730,542	24
Wichita	518,713	4
Wolfcamp	556,325	12
Pennsylvanian	43,677,657	21
Total	90,687,547	68

*Compiled from Texas Railroad Commission, 1979.

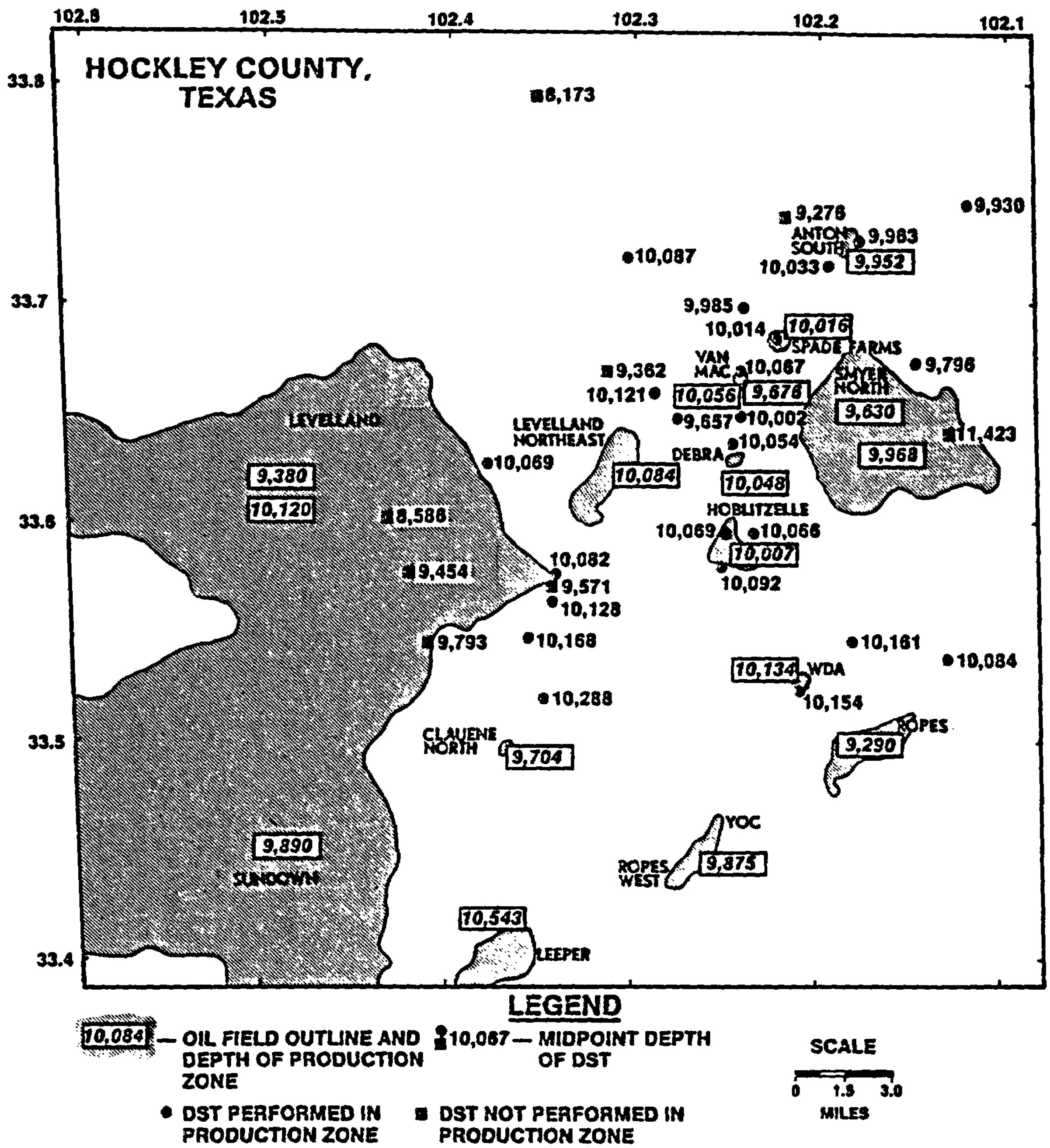


Figure 4-8. Location and Depth of Depressured and Normally Pressured Pennsylvanian DST Data Relative to the Location and Depth of the Major Pennsylvanian Oil Fields, Hockley County, Texas.

depths as grossly underpressured Pennsylvanian DSTs. Deletion of the exceptionally low heads calculated from these depressured DSTs will eliminate the large depression in Hockley County seen on the initial Pennsylvanian potentiometric surface (Figure 4-2).

This method was repeated for production zones in the other geologic units in Hockley County. Figure 4-7B shows the remaining pressure-depth data from Hockley County after deletion of the depressured DSTs. Because of the success of this method in Hockley County, property ownership maps for all the counties in the study area were purchased from PI, and oil and gas production data and production depth data were obtained from various sources (Texas Railroad Commission, 1979; Roswell Geological Society, 1956, 1960, 1977; New Mexico Oil and Gas Engineering Committee, 1981). These data were used to identify DSTs in various geologic units throughout the study area that were depressurized due to oil and/or gas production. In Appendix B, the "STATUS" of these DSTs is listed as "DEPR" which is defined in the legend as "depressurized due to extraction of oil and/or gas in adjacent areas in the same geologic unit at a similar depth." Table 4-2 shows that 23 depressured DSTs were culled from the Wolfcamp data set and 120 depressured DSTs were culled from the Pennsylvanian data set.

It should be noted that some normally pressured DSTs were recorded at depths of oil production in nearby fields. However, these DSTs were performed prior to development of the oil field(s) and, therefore, prior to depressuring of the reservoir. Some normally pressured DSTs also were recorded at depths of oil production after the commencement of development, but apparently either at a distance beyond the depressurized zone or in strata that are discontinuous or separated from the production zone by a confining unit that does not rapidly transmit the pressure reduction.

The depressured zones represent localized zones where oil and/or gas extraction have produced temporal formation pressures which do not appear to be transmitted vertically to a great extent. As an example, Figure 4-9 shows four wells in Hockley County where multiple DSTs were performed in Pennsylvanian strata in the same well. In each case, the depressured zone seemingly is very limited vertically; the reduced formation pressure in the depressured zone has not been sufficiently transmitted vertically to affect the overlying DST which is normally pressured. This same relationship was

Table 4-2. Number of Depressured, Grossly Underpressured, Grossly Overpressured, and Normally Pressured Wolfcamp and Pennsylvanian DSTs

Geologic Unit	Total No. DSTs	Depres-sured	Grossly Under-pressured	Grossly Over-pressured	Normally Pressured
Wolfcamp	150	23	11	9	107*
Pennsylvanian	341	120	10	24	187*

*Includes multiple normally pressured DSTs in the same well.

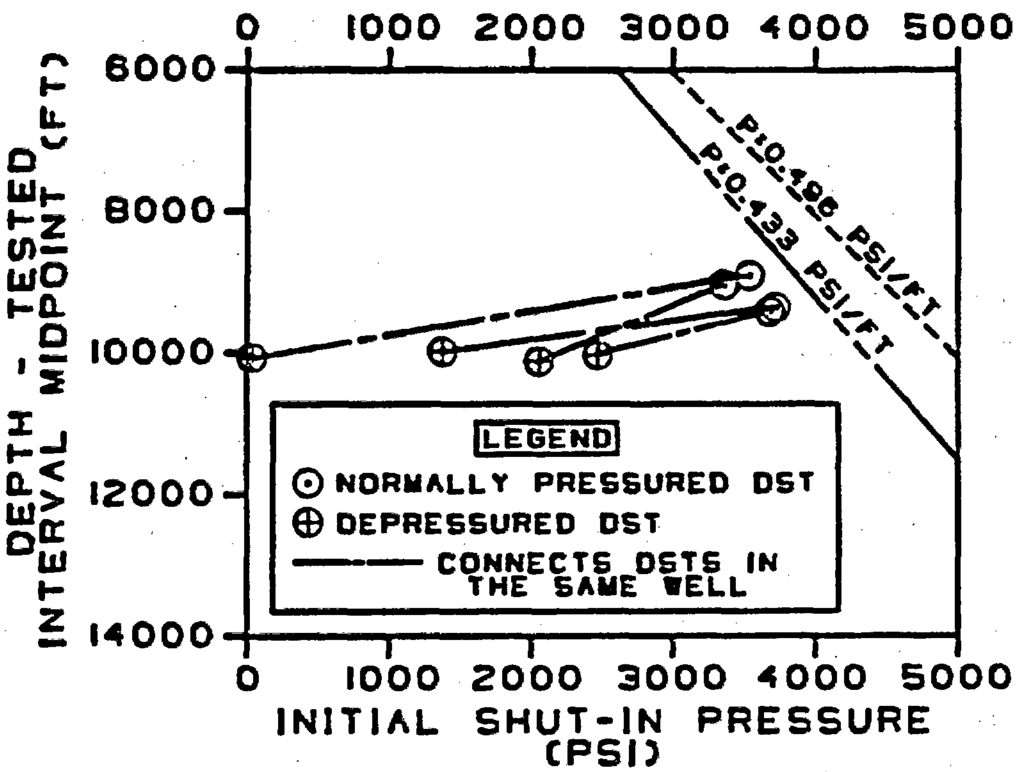


Figure 4-9. Pressure-Depth Diagram Showing Four Wells Having Multiple Pennsylvanian DSTs, Hockley County, Texas.

observed in 12 other wells in 7 other counties and may indicate that the strata overlying the production zone acts not only as a flow barrier retarding the flow of fluids but also as a pressure barrier retarding the equalization of pressures.

4.6.2 Wolfcamp and Pennsylvanian Potentiometric Surfaces After Culling Depressured DST Data

Depressured DSTs were culled from the Wolfcamp and Pennsylvanian data sets because the depressured zones are limited in lateral and vertical extent and represent local temporal aberrations in the regional deep-basin flow system. Figures 4-10 and 4-11 show the Wolfcamp and Pennsylvanian pressure-depth data, respectively, after culling depressured DSTs from the data sets.

Figures 4-12 and 4-13 show the Wolfcamp and Pennsylvanian potentiometric surfaces, respectively, after culling head values calculated from depressured DSTs. The Wolfcamp map is based on 99 head values, whereas the Pennsylvanian map is based on 168 head values. Figures 4-14 and 4-15 list the equivalent freshwater head values and the locations of the depressured DSTs culled from the Wolfcamp and Pennsylvanian data sets, respectively. Although these potentiometric surfaces are a marked improvement over those shown on Figures 4-1 and 4-2 because local temporal variations in head have been eliminated, they still contain a few local prominent mounds and depressions with seemingly abnormal heads. Additional data refinement was believed necessary to produce regional potentiometric surfaces.

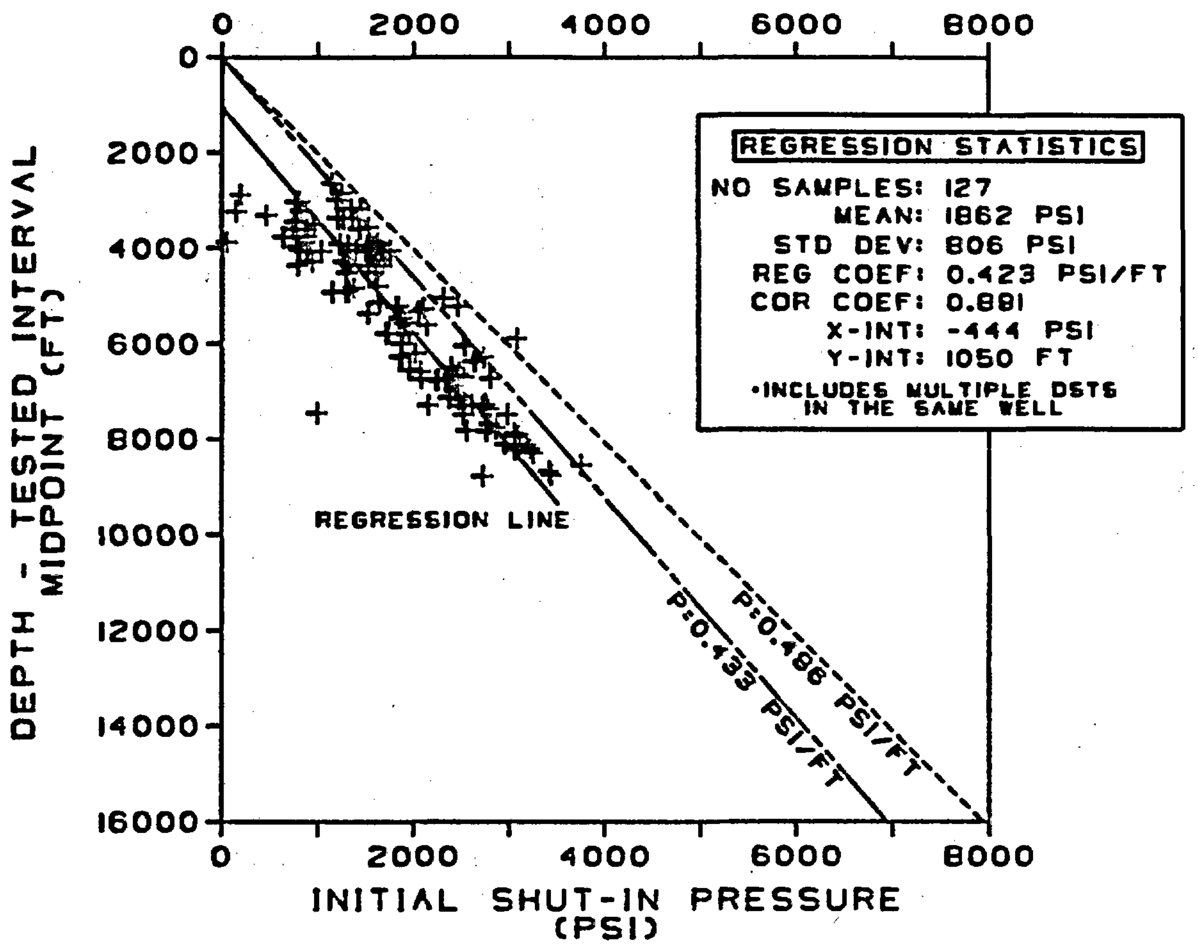


Figure 4-10. Pressure-Depth Diagram and Linear Regression of Wolfcamp DST Data after Culling Depressured Data.

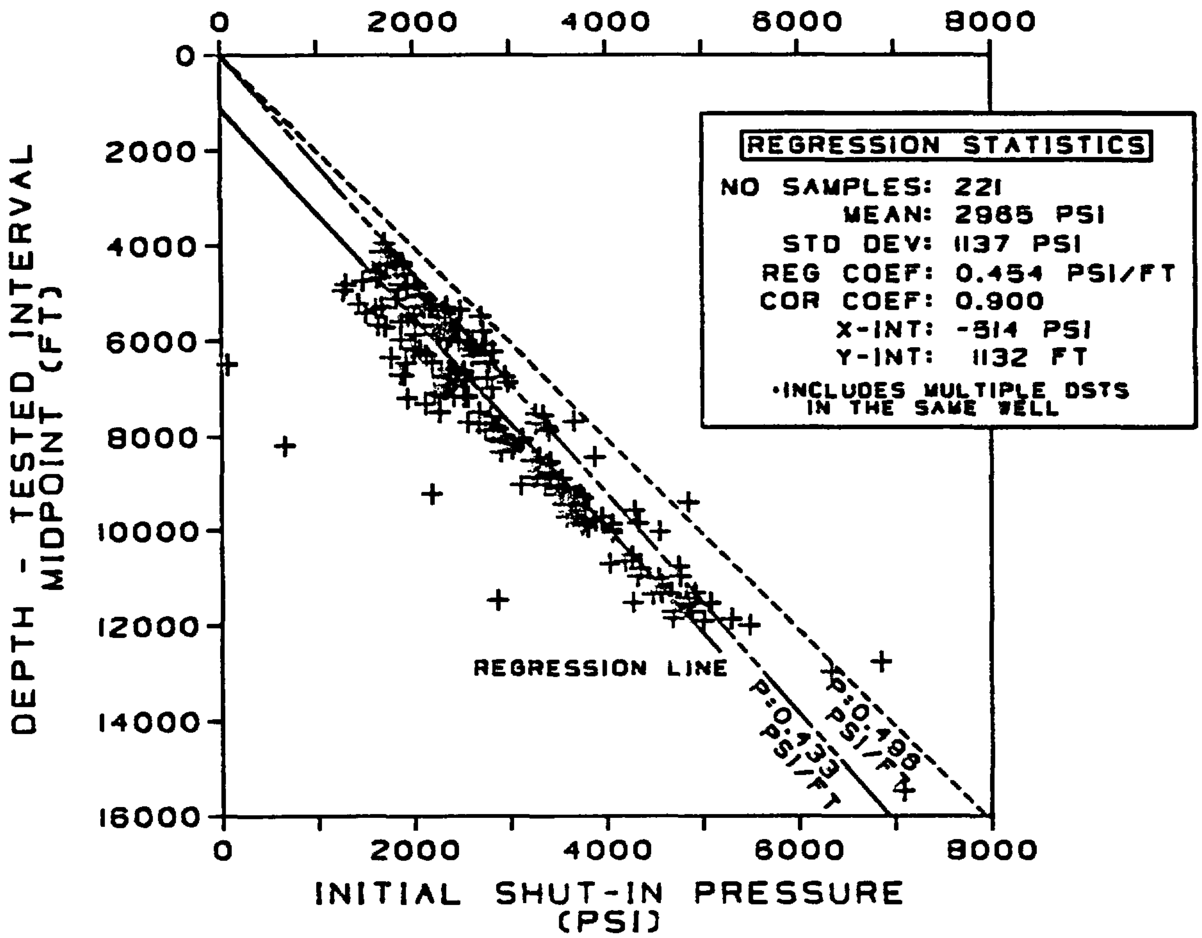


Figure 4-11. Pressure-Depth Diagram and Linear Regression of Pennsylvanian DST Data after Culling Depressured Data.

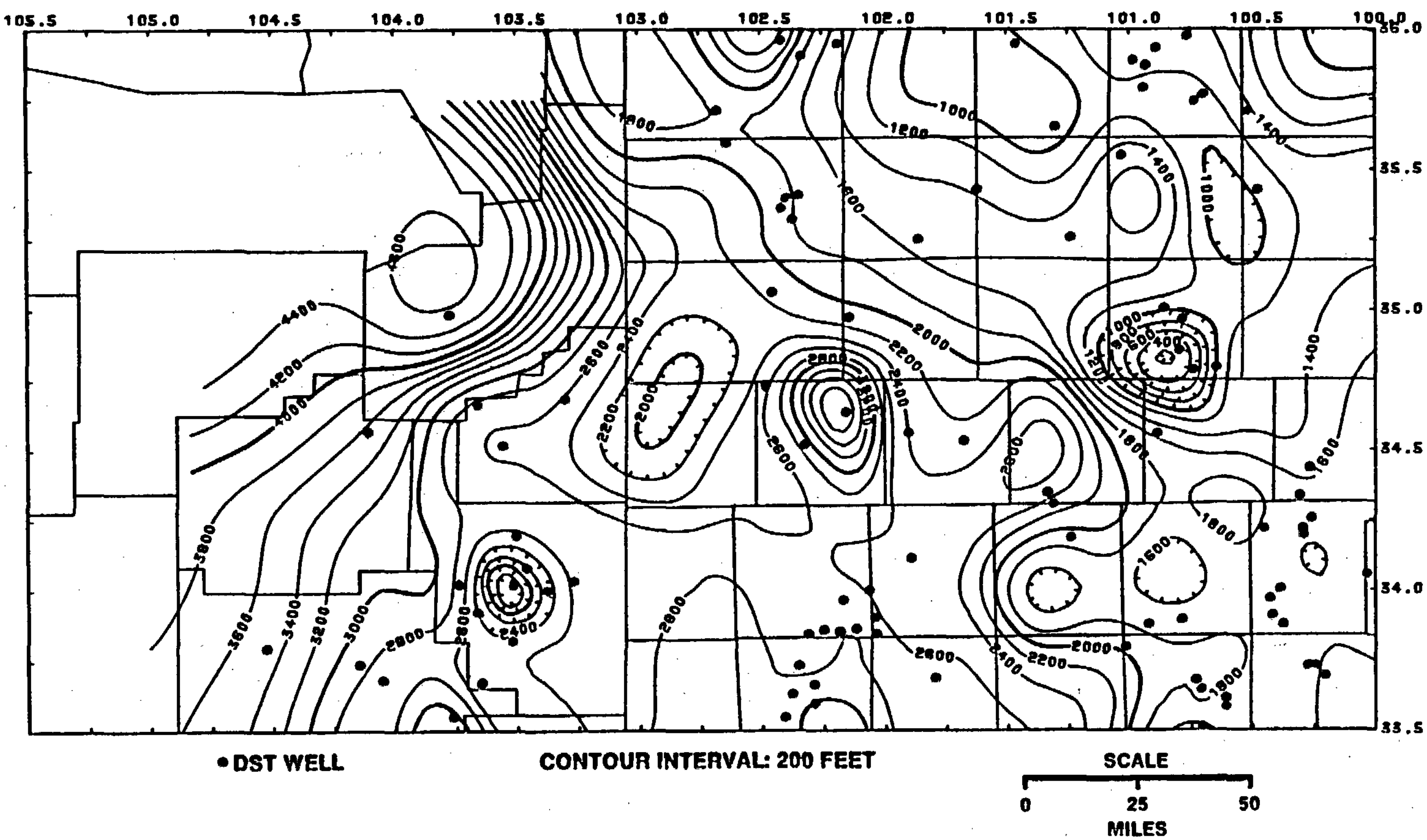


Figure 4-12. Wolfcamp Potentiometric Surface after Culling Depressured DST Data.

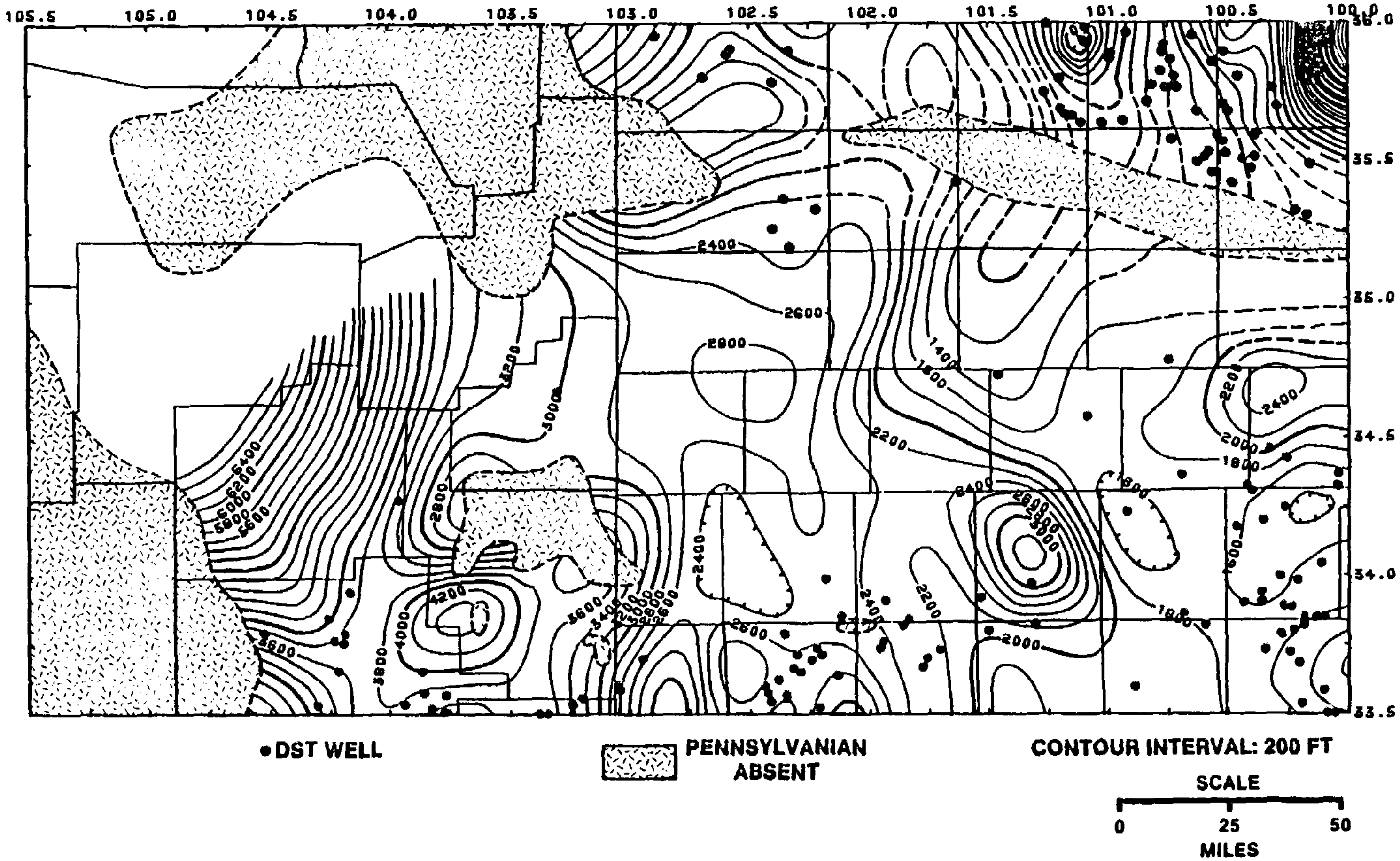


Figure 4-13. Pennsylvanian Potentiometric Surface after Culling Depressured DST Data.

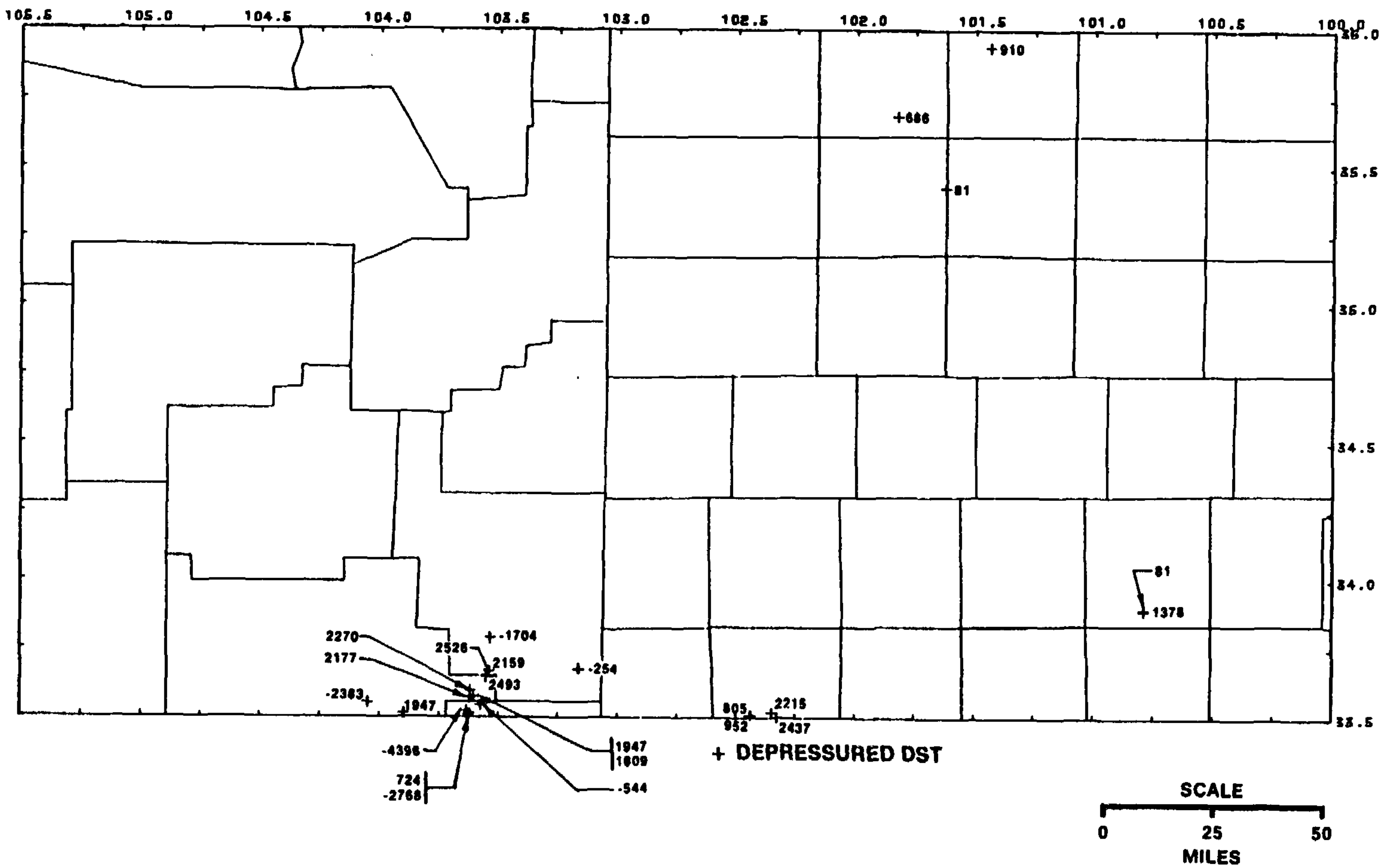


Figure 4-14. Equivalent Freshwater Head Values and Locations of Wolfcamp DSTs Culled Due to Depressuring.

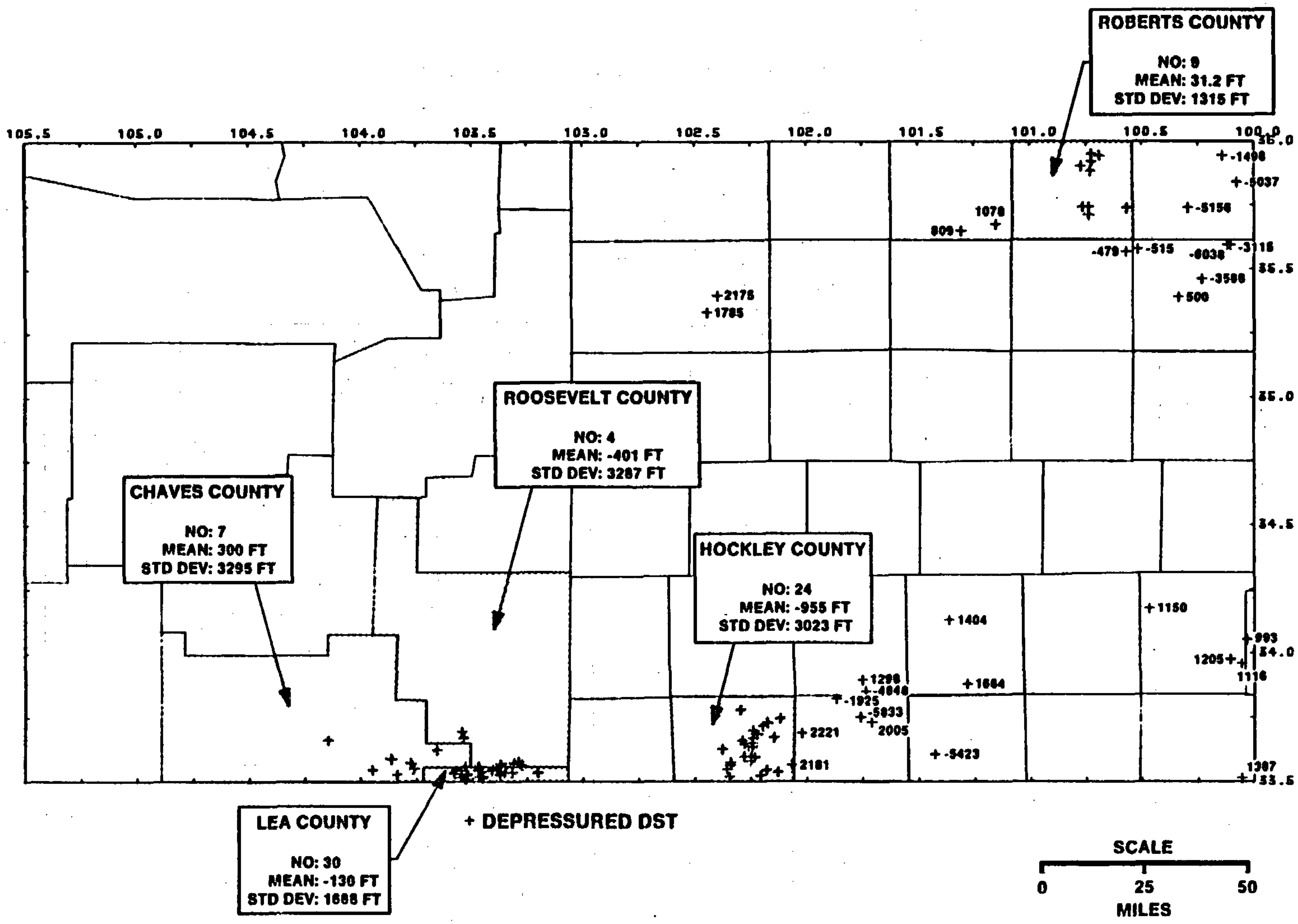


Figure 4-15. Equivalent Freshwater Head Values and Locations of Pennsylvanian DSTs Culled Due to Depressuring.

4.7 WOLFCAMP AND PENNSYLVANIAN POTENTIOMETRIC SURFACES AFTER CULLING DEPRESSURED, GROSSLY UNDERPRESSURED, AND GROSSLY OVERPRESSURED DST DATA

4.7.1 Culling of Grossly Underpressured and Grossly Overpressured DST Data

Because of the difficulty in attributing local abnormally pressured data to a specific cause other than depressuring due to oil or gas extraction, deletion of additional abnormal DST data and subsequent refinement of the Wolfcamp and Pennsylvanian potentiometric surfaces were based on comparison of abnormal ISIPs and heads with normal ISIPs and heads at a similar depth in the same geologic unit in the same well and/or in adjacent wells. Although this method does not take into account local hydrodynamics, it does evaluate local abnormally pressured DSTs with local normally pressured DSTs.

Figures 4-10 and 4-11 show several grossly underpressured DSTs not attributable to depressuring and several grossly overpressured DSTs. Heads calculated from some of these DSTs are as much as 9,000 feet greater than to 4,000 feet less than nearby normally pressured DSTs. This produces the hydrologically improbable cases where some heads are higher than the outcrop elevation of the Wolfcamp and Pennsylvanian strata in the recharge area in east-central New Mexico and some heads are lower than the outcrop elevation of the Wolfcamp and Pennsylvanian strata in the discharge area reported by Levorsen (1967) in south-central Oklahoma. For the construction of regional potentometric-surface maps, the deletion of these local abnormally pressured DSTs is justified, although the cause for their abnormality is problematic. In other cases, where the difference between heads calculated from abnormally pressured DSTs and normally pressured DSTs is less than 1,000 feet, the deletion of these local abnormally pressured DSTs is more subjective.

Reasons for gross overpressuring and gross underpressuring of DSTs are problematic, particularly when other DSTs at a similar depth in the same geologic unit in the same well and/or in adjacent wells are normally pressured, but may be related to one or more of the causes described in

Section 4.5. It is possible that some grossly overpressured DSTs are the result of failed packer seals which allowed drilling mud to invade the tested zone and, therefore, caused abnormally high formation pressures to be recorded. Consequently, these tests would appear to be overpressured. It is probable in a large data base that several tests may have failed in this manner and still have satisfied the screening criteria for Class 2 or 3. It also is possible that some grossly underpressured DSTs were performed in strata that are sufficiently impermeable that even though the shut-in time duration and shut-in pressure agreement criteria were satisfied for Class 2 or 3, the tests were not run long enough for pressure equilibrium to be approached. Consequently, these tests would record abnormally low shut-in pressures and would appear to be grossly underpressured. Although the probability is low that these DSTs would satisfy the pressure agreement criterion, in a large data base a few tests with this anomaly would be expected.

Table 4-2 shows that the Wolfcamp data set contained 20 locally aberrant DSTs, 11 grossly underpressured and 9 grossly overpressured, whereas the Pennsylvanian data set contained 34 aberrant DSTs, 10 grossly underpressured and 24 grossly overpressured. Figures 4-16 and 4-17 list the equivalent freshwater head values and show the locations of the local grossly underpressured and grossly overpressured DSTs culled from the Wolfcamp and Pennsylvanian data sets, respectively.

Figure 4-16 shows that the grossly underpressured and grossly overpressured Wolfcamp data are located in the peripheral parts of the Palo Duro Basin. Most of the grossly underpressured Wolfcamp data are located in Donley County, Texas, and in Chaves County, New Mexico, whereas most of the grossly overpressured Wolfcamp data are located in Lamb and Briscoe Counties, Texas. Figure 4-17 shows that the grossly underpressured and grossly overpressured Pennsylvanian data also are located in the peripheral parts of the Palo Duro Basin. Most of the grossly underpressured Pennsylvanian data are located in Cottle and Hartley Counties, Texas, whereas most of the grossly overpressured Pennsylvanian data are located in Chaves County, New Mexico, and in the Anadarko Basin area in Roberts, Wheeler, and Hemphill Counties, Texas.

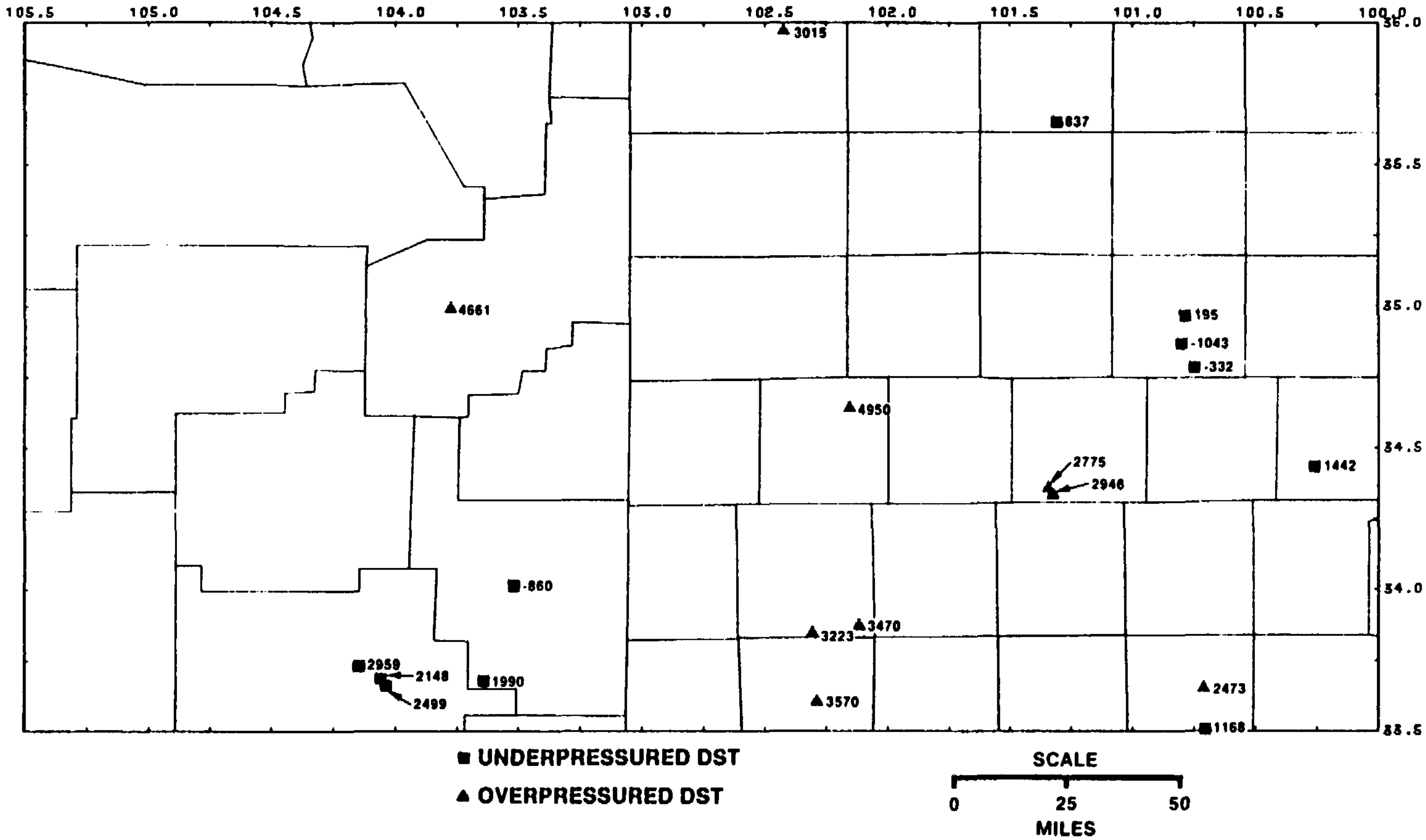


Figure 4-16. Equivalent Freshwater Head Values and Locations of Wolfcamp DSTs Culled Due to Gross Underpressuring or Gross Overpressuring.

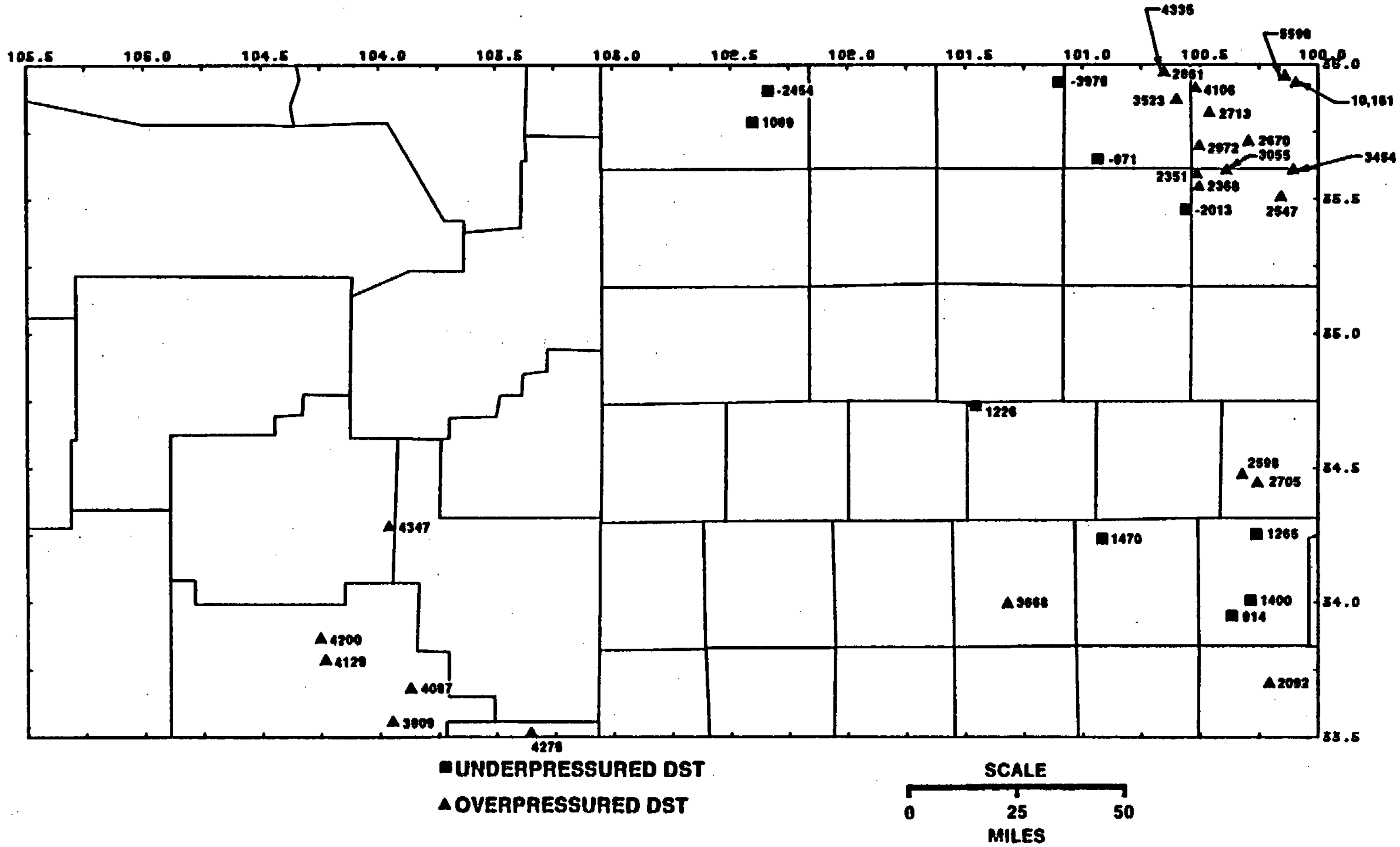


Figure 4-17. Equivalent Freshwater Head Values and Locations of Pennsylvanian DSTs Culled Due to Gross Underpressuring or Gross Overpressuring.

In general, the distribution of grossly underpressured and grossly overpressured DSTs is similar to the distribution of all the DSTs. Comparison of Figures 4-16 and 4-17 with Figure 4-6 shows that most of the grossly underpressured and grossly overpressured DSTs occur in the major oil and gas producing areas where most of the DSTs have been performed. This similarity simply may reflect this sampling bias. Alternatively, it may reflect the greater geologic complexity of the major oil and gas producing areas.

In Appendix B, the "STATUS" of these DSTs is listed either as "UNDE," which is defined in the legend as "grossly underpressured with respect to data in adjacent areas in the same geologic unit at a similar depth but not attributable to oil or gas extraction," or as "OVER," which is defined in the legend as "grossly overpressured with respect to data in adjacent areas in the same geologic unit at a similar depth.

Figures 4-18 and 4-19 show the most refined Wolfcamp and Pennsylvanian potentiometric surfaces, respectively, after culling depressured, grossly underpressured, and grossly overpressured DST data. The Wolfcamp map is based on 82 head values, whereas the Pennsylvanian map is based on 145 head values. Regional and some local variations in flow directions and hydraulic gradients can be seen. The prominent localized mounds and depressions shown on Figures 4-1 and 4-2 and on Figures 4-12 and 4-13 are not present. Figure 4-20 and 4-21 are pressure-depth diagrams of Wolfcamp and Pennsylvanian data, respectively after culling depressured, grossly underpressured, and grossly overpressured DSTs.

The closed depression on Figure 4-18 located in the northeast corner of the map is not an artifact of the computer contouring program. It may be real or it may be the result of not having data in the adjacent counties to the north and east. Expansion of the study area into Oklahoma and incorporation of these data should verify or negate the existence of this closed depression.

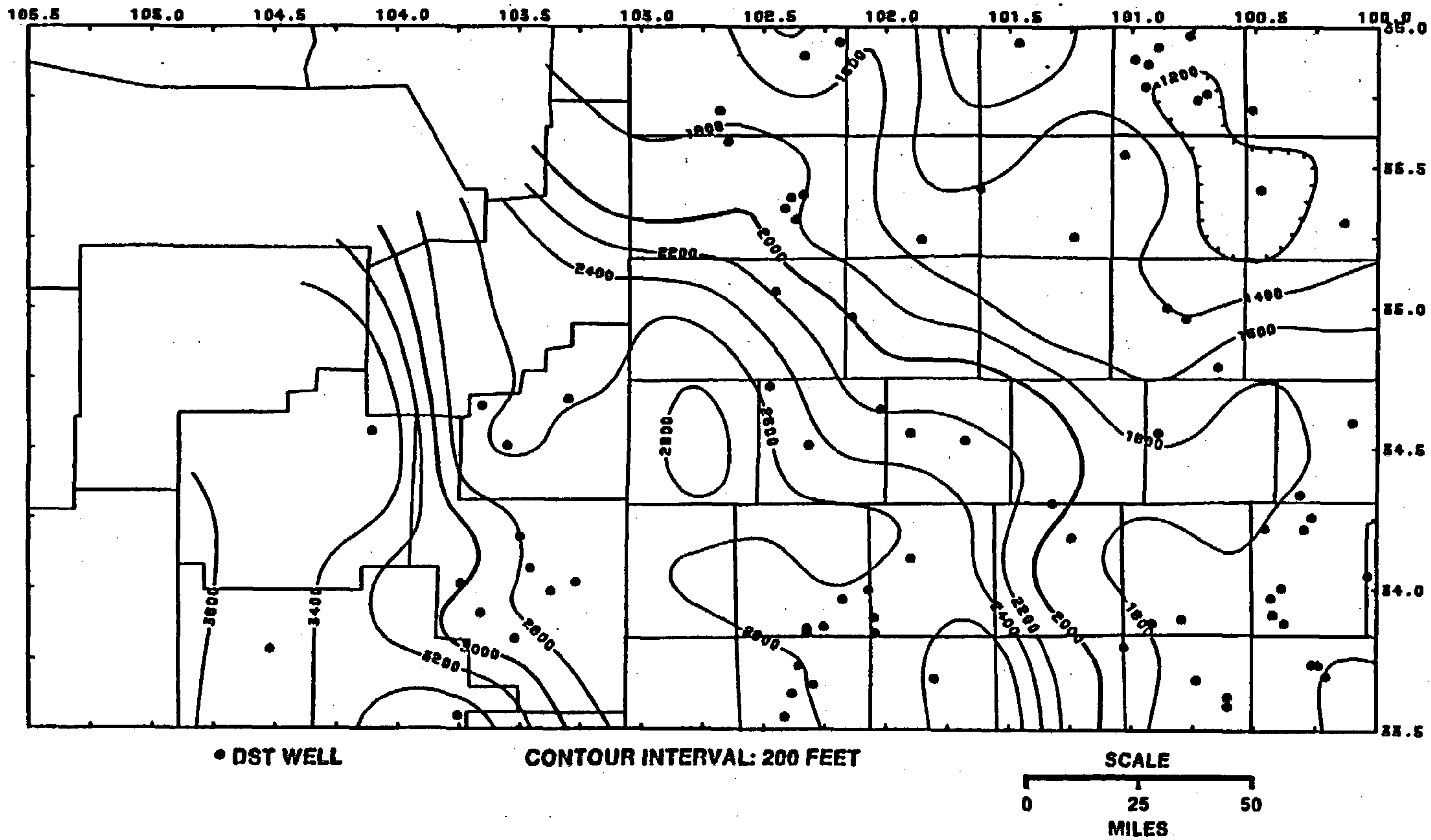


Figure 4-18. Wolfcamp Potentiometric Surface after Culling Depressured, Grossly Underpressured, and Grossly Overpressured DST Data.

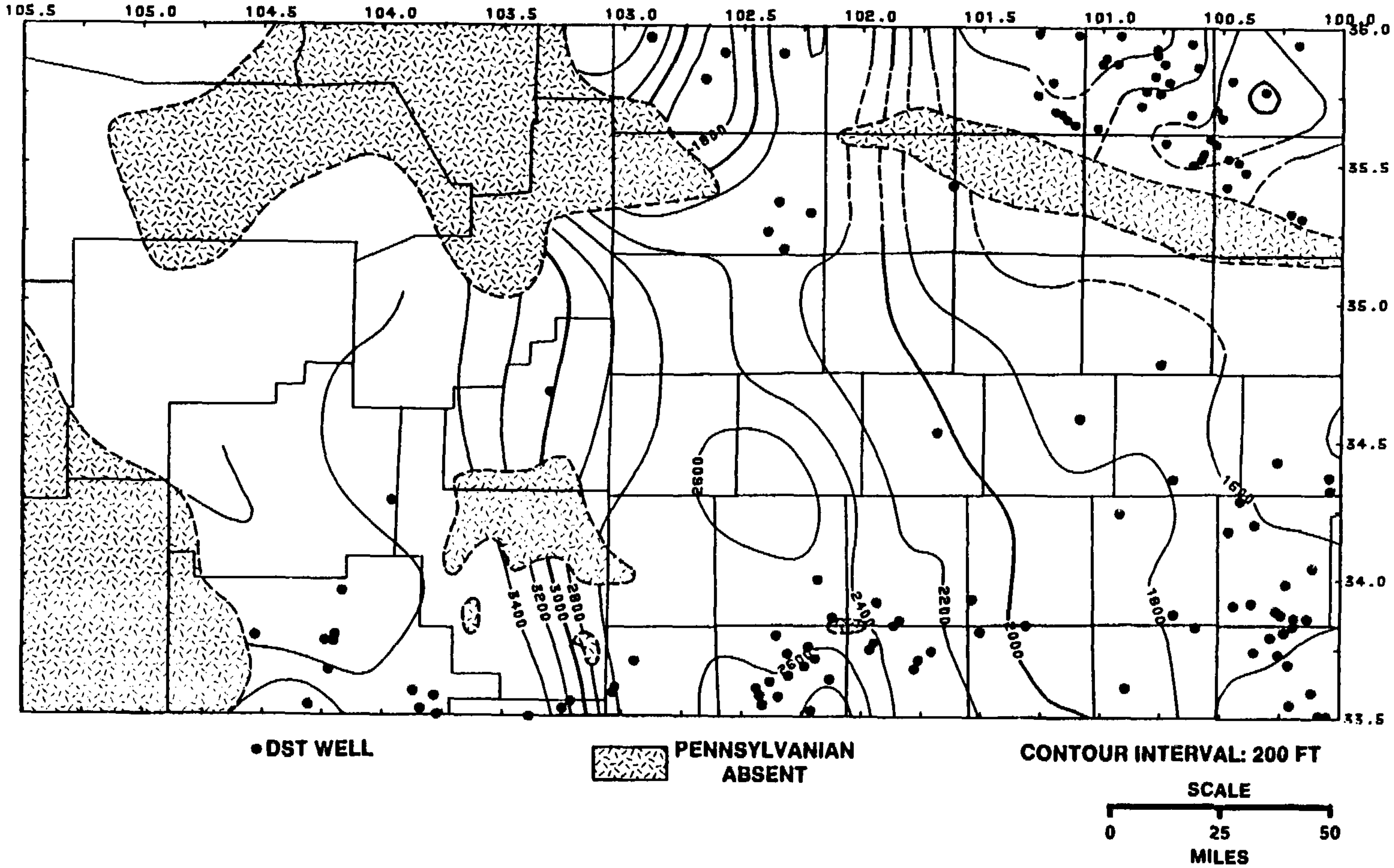


Figure 4-19. Pennsylvanian Potentiometric Surface after Culling Depressured, Grossly Underpressured, and Grossly Overpressured DST Data.

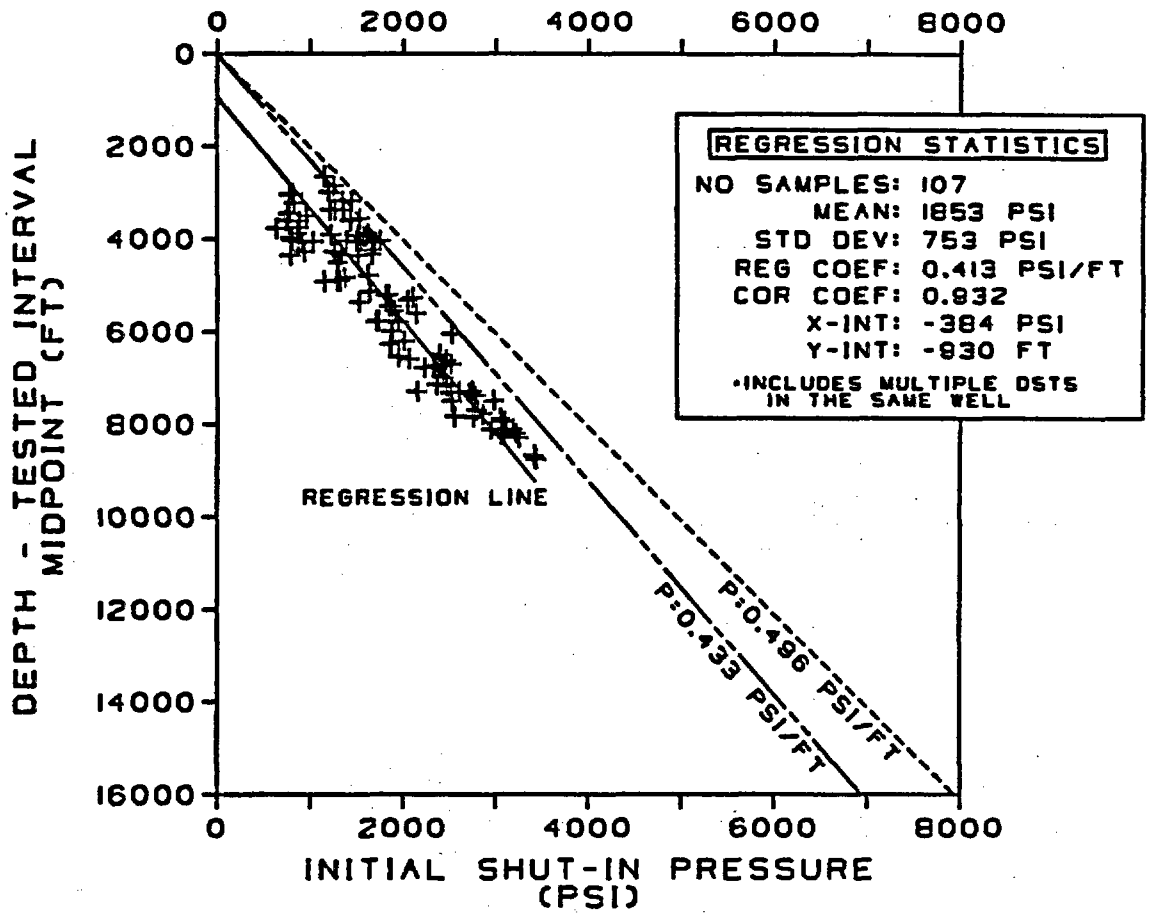


Figure 4-20. Pressure-Depth Diagram and Linear Regression of Wolfcamp DST Data after Culling Depressured, Grossly Underpressured, and Grossly Overpressured Data.

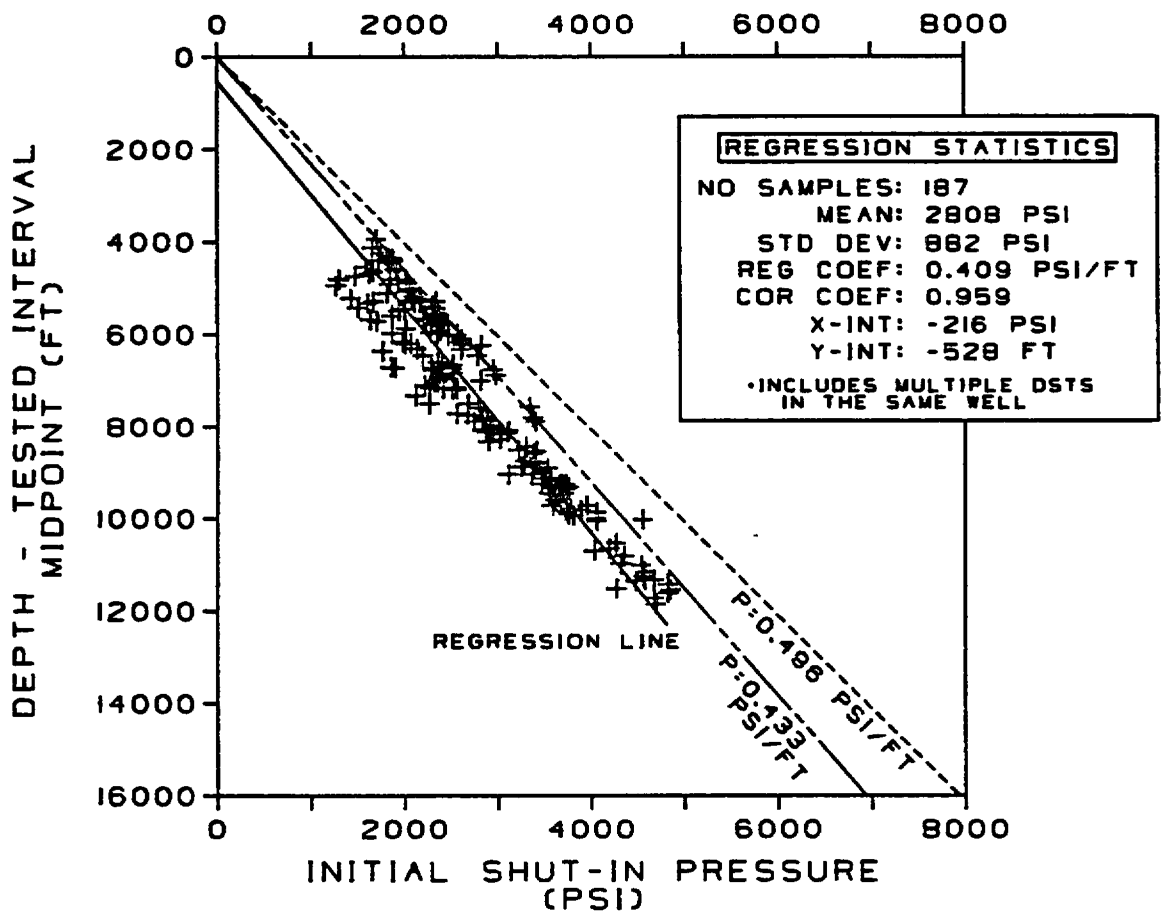


Figure 4-21. Pressure-Depth Diagram and Linear Regression of Pennsylvanian DST Data after Culling Depressured, Grossly Underpressured, and Grossly Overpressured Data.

4.8 STATISTICAL ANALYSIS OF CULLING PROCEDURES

Comparative analyses of the culling procedures were made using linear regression of pressure-depth data and error analysis of original head values versus gridded head values generated and contoured by SURFACE II.

Table 4-3 summarizes the regression statistics for Wolfcamp and Pennsylvanian ISIP data and shows changes in various statistical measures due to culling depressured, grossly underpressured, and grossly overpressured DST data. As expected, correlation between ISIP and midpoint depth shows a marked improvement as a result of the culling procedures corresponding to elimination of depressured data and local abnormally pressured data. The correlation coefficients shown on Table 4-3 show that most of the refinement in the DST data was due to culling depressured DSTs. The correlation coefficient for Wolfcamp data improved from 0.759 to 0.891, whereas the correlation coefficient for Pennsylvanian data improved from 0.572 to 0.900. Some additional refinement in the DST data was due to culling local grossly underpressured and grossly overpressured DSTs. The correlation coefficient for Wolfcamp data improved to 0.932, whereas the correlation coefficient for Pennsylvanian data improved to 0.959. Comparison of correlation coefficients indicates that most of the refinement of the potentiometric surfaces was based on eliminating DSTs affected by formation pressure reduction due to fluid extraction. (Hydrodynamic interpretations regarding deep-basin recharge and discharge areas and local areas of vertical ground-water movement based on analysis of pressure-depth data have been postponed until fluid density data from the study area are compiled and used to construct basin-specific hydrostatic pressure gradients).

The ERAN subroutine in SURFACE II calculates a variety of statistics for assessing the error in gridded head values versus original head values. Table 4-4 summarizes the error analyses from the head data used to construct the Wolfcamp and Pennsylvanian potentiometric surfaces. As expected, the maximum negative error, mean absolute error, root-mean-squared absolute error, and percent relative absolute error dramatically decrease due to culling depressured DSTs. Culling local grossly underpressured and grossly overpressured DSTs produced some minor

Table 4-3. Summary Statistics of Wolfcamp and Pennsylvanian ISIP Data Showing Changes Due to Culling Depressured, Grossly Underpressured, and Grossly Overpressured Data*

Geologic Unit	No. DSTs	Mean (psi)	Standard Deviation (psi)	Correlation Coefficient	Regression Coefficient (psi/ft)	X-Intercept (psi)	Y-Intercept (ft)
Wolfcamp							
1	150	1853	862	0.759	0.346	-142	410
2	127	1862	806	0.891	0.423	-444	1050
3	107	1852	753	0.932	0.413	-384	930
Pennsylvanian							
1	341	2726	1176	0.572	0.300	265	-883
2	221	2965	1137	0.900	0.454	-514	1132
3	187	2808	882	0.959	0.409	-216	528

*Includes multiple DSTs in the same well.

1. All data (before culling).
2. Depressured DST data culled.
3. Depressured, grossly underpressured, and grossly overpressured DST data culled.

Table 4-4. Summary of SURFACE II Error Analysis

Wolfcamp	1	2	3
No. Head Values	118	99	82
Maximum Negative Error (ft)	-3560	-356	-88.5
Maximum Positive Error (ft)	1790	574	271
Mean Absolute Error (ft)	128	29.7	12.0
Root-Mean-Squared Absolute Error (ft)	445	84.2	35.7
Percent Relative Absolute Error (%)	11.2	0.769	0.307

Pennsylvanian	1	2	3
No. Head Values	257	168	145
Maximum Negative Error (ft)	-7270	-784	-376
Maximum Positive Error (ft)	6510	1793	607
Mean Absolute Error (ft)	543	84.3	43.1
Root-Mean-Squared Absolute Error (ft)	1200	221	91.1
Percent Relative Absolute Error (%)	25.7	2.91	1.35

1 - All data (before culling)

2 - Depressured data culled

3 - Depressured, grossly underpressured, and grossly overpressured data culled

additional reduction in these statistical measures, as well as decreasing the maximum positive error.

As these statistical measures show, most of the improvement in the fit of the original Wolfcamp and Pennsylvanian head data relative to their gridded head data was due to culling those head values calculated from depressured DSTs. Some additional improvement was due to culling head values calculated from local grossly underpressured and grossly overpressured DSTs.

4.9 SUMMARY AND INTERPRETATION OF POTENTIOMETRIC SURFACES

Three sets of Wolfcamp and Pennsylvanian potentiometric surfaces are presented: Figures 4-1 and 4-2, Figures 4-12 and 4-13, and Figures 4-18 and 4-19, respectively. The maps were constructed using equivalent freshwater heads based on ISIP values. To assure consistency in the method used to calculate heads, ISIP values were used from complete DST records (Class 1), whenever possible, and from incomplete DST records (Class 2 and 3). Each set of maps represents a further refinement of the DST data sets based on the culling procedures previously discussed. Each level of data refinement produced potentiometric surfaces with less local variation in flow directions and hydraulic gradients. The potentiometric surfaces shown on Figures 4-1 and 4-2 represent the present configuration of the Wolfcamp and Pennsylvanian potentiometric surfaces, respectively, containing local temporal potentiometric data due to depressured DSTs and local aberrant potentiometric data due to grossly underpressured and grossly overpressured DSTs. The potentiometric surfaces shown on Figures 4-12 and 4-13 represent the present configuration of the Wolfcamp and Pennsylvanian potentiometric surfaces, respectively, after local temporal potentiometric data due to depressured DSTs were deleted, but still containing local aberrant potentiometric data due to local grossly underpressured and grossly overpressured DSTs. The potentiometric surfaces shown on Figures 4-18 and 4-19 are the most refined representation of the regional potentiometric surfaces of the Wolfcamp and Pennsylvanian aquifers, respectively, and probably closely approximate their regional configuration prior to oil and gas production.

Even though reestablishment of normal pressures in oil and gas production zones may take many years, determination of flow patterns and flow velocities, development of a conceptual hydrodynamic model of the deep-basin flow system, and calibration of numerical models using the potentiometric maps shown on Figures 4-18 and 4-19 are believed preferable to using the potentiometric surfaces shown on Figures 4-1 and 4-2 and on Figures 4-12 and 4-13, where local temporal and/or local aberrant potentiometric data severely perturb the regional potentiometric surfaces.

Preliminary permeability and lithologic data indicate that Wolfcamp equipotential patterns, as shown on Figure 4-18, appear to be controlled by transmissivity variations corresponding to facies changes in the Wolfcamp Series. The stacking of the 2,600 to 1,600-foot equipotential lines along the northwest-southeast trend shown on Figure 4-18 appears to correspond to an area where marine siltstones and shales were deposited throughout the Wolfcampian (Dutton, 1979). The lower transmissivity of these materials may contribute to the steepening of the hydraulic gradient in this area. The spreading out of equipotential lines in the southeastern, southwestern, and northeastern parts of the study area, as shown on Figure 4-18, appears to correspond to areas where carbonate shelf and shelf-margin carbonates were deposited and where greater thicknesses of sandstone and granite wash were deposited during the Wolfcampian (Dutton, 1979). The greater transmissivity of these materials may contribute to the flattening of the hydraulic gradient in these areas.

There does not appear to be much topographic control of equipotential patterns, as seen on Figure 4-18. Topographic relief across the High Plains/Rolling Plains escarpment does not appear to influence equipotential patterns in the Wolfcamp. However, the general southwest-northeast flow direction seen in the central part of the study area and the west-east flow direction seen in the southern part of the study area undoubtably are influenced by the location and elevation of the recharge area to the west and the location and elevation of the discharge area to the east.

Interpretation of the factors controlling equipotential patterns for the Pennsylvanian strata, as shown on Figure 4-19, is more difficult because of the poor distribution of the Pennsylvanian potentiometric data. Even though 145 data points were used to construct the Pennsylvanian potentiometric surface shown on Figure 4-19, compared to the 82 data points used to construct the Wolfcamp potentiometric surface shown on Figure 4-18, the Pennsylvanian data points are not as evenly distributed as the Wolfcamp data points. Most of the Pennsylvanian data are clustered in the Anadarko Basin area north of the Amarillo Uplift and in the Matador Uplift area. Very few data are located in the central part of the study area in the Palo Duro Basin. Hopefully, additional DST data obtained from PI from mid-1981 through early 1983 will improve the distribution of the Pennsylvanian data.

The greater transmissivity of the Pennsylvanian carbonates and the massive deposits of granite wash and sandstone along the margins of the Oldham Nose and Amarillo Uplift is expected to greatly influence equipotential patterns in the Pennsylvanian strata. Topographic relief across the High Plains/Rolling Plains escarpment is not expected to influence local equipotential patterns. However, the general southwest-northeast flow direction seen in the central part of the study area and the west-east flow direction seen in the southern part of the study area undoubtably are influenced by the location and elevation of the recharge area to the west and the location and elevation of the discharge area to the east.

4.10 COMPARISON OF WOLFCAMP AND PENNSYLVANIAN POTENTIOMETRIC SURFACES WITH PREVIOUSLY PUBLISHED POTENTIOMETRIC SURFACES

4.10.1 General Comparison of Methods

The authors believe that the potentiometric surfaces shown on Figures 4-18 and 4-19 and the methods used to construct these maps are an improvement over previously constructed potentiometric surfaces of the Wolfcamp and Pennsylvanian aquifers (Handford, 1980; Bentley, 1981; Bassett and Bentley, 1982 and 1983; and Devary, 1983). In these studies, depressured DSTs were not recognized.

Although no data were culled by Handford (1980), in the other studies seemingly abnormal head data were deleted based on a point-by-point comparison of seemingly acceptable heads versus seemingly unacceptable heads, or seemingly abnormal heads were deleted based on the difference between predicted head values using kriging techniques and original head values. Consequently, the potentiometric surfaces presented in these studies are neither precise representations of the Wolfcamp or Pennsylvanian potentiometric surfaces prior to oil and gas production, nor precise representations of the present Wolfcamp or Pennsylvanian potentiometric surfaces. Rather, the potentiometric surfaces presented in these studies represent an ill-defined combination of the two.

It should be noted that the DST data base used in this report and the DST data base(s) used by Handford (1980), Bentley (1981), Bassett and Bentley (1982 and 1983), and Devary (1983) are different. The data base used in this report contains DST data from the late 1970s and early 1980s and from the DOE-sponsored wells drilled and tested in 1982 and 1983, which the other data base(s) do not include.

Specific comparisons between the Wolfcamp and Pennsylvanian potentiometric surfaces produced by other authors with those included in this report will be made in the following section.

4.10.2 Specific Comparison of Methods and Results

At the proposed repository site areas in Deaf Smith and Swisher Counties, Texas, the potentiometric levels shown on Figures 4-18 and 4-19 are several hundred feet lower than the potentiometric levels shown by Bassett and Bentley (1982 and 1983) and Devary (1983) for the Wolfcamp, and by Bentley (1981) for the Wolfcamp and the Pennsylvanian. Perhaps this occurs because these authors used heads based on extrapolated formation pressures mixed with heads based on ISIP or FSIP.

The flow direction in the Wolfcamp and the Pennsylvanian at the proposed repository site areas, as shown on Figures 4-18 and 4-19, is more toward the north-northeast, toward the Amarillo Uplift (see Figure 2-1), than is shown by Bentley (1981) and Bassett and Bentley (1982 and 1983). This may be due to one or more of the following reasons:

(1) Inclusion of extrapolated formation pressures,

(2) Inclusion of depressured DSTs in oil and gas production zones,

(3) For the Wolfcamp aquifer, assuming no flow over the top of the Amarillo Uplift into the Anadarko Basin, in spite of the fact that

the upper, dolomitic part of the Wolfcamp is continuous across this area (although it is cut by faults), and

(4) Over-smoothing of the contour lines, to the extent that the integrity of the original potentiometric data is not preserved.

Heads and flow directions shown on Figure 4-1 for the Wolfcamp aquifer are similar to those shown by Handford (1980) for a smaller area of the Wolfcamp aquifer. In neither map have any head data been culled. Comparison of heads and flow directions from Figure 4-2 for the Pennsylvanian with those shown by Handford (1980) for the Pennsylvanian (excluding granite wash) is difficult because of the smaller area of Handford's map and the spotty distribution of Handford's contours.

Devary's (1983) potentiometric surfaces of the Wolfcamp Series were based on data obtained from the Texas Bureau of Economic Geology and previously contoured by Handford (1980) and Bentley (1981). Devary's initial Wolfcamp potentiometric surface, produced using point kriging, is similar to that shown on Figure 4-1; it contains local prominent mounds and depressions. Based on a generalized covariance analysis, Devary (1983, p. 15) noted that several head values near the Matador Uplift and Oldham Nose were "statistically significant outliers (i.e., the predicted minus observed head values were over 2.5 x sigma larger than expected)." Figure 4-6 shows that the Matador Uplift and eastern Oldham County are major areas of oil production. No doubt many of the statistical outliers mentioned by Devary (1983) are aberrant because the DSTs were performed in depressured zones. Devary (1983) refined his initial Wolfcamp potentiometric surface by using block kriging over a 5-mile by 5-mile block. This technique produced a potentiometric surface that "is quite smooth and regular" but still contained "the extreme variability of the potentiometric data near [the] Matador Arch and [the] Oldham Nose ..." (Devary, 1983, p. 17). Both of Devary's Wolfcamp potentiometric surfaces (Devary, 1983) had a northeast trending flow direction at the proposed nuclear-waste repository sites.

It should be noted that both of the Wolfcamp potentiometric surfaces produced by Devary (1983) were based on a data set from which 17 head values were deleted because of a lack of conformance between predicted heads based on kriging and observed heads. The data that were deleted had differences between kriged minus observed heads ranging between 181 to 1,762 feet. Although no deletion criteria were described, the justification given for the deletion of these data was that more reliable data were available from neighboring wells.

McNeal (1965) constructed potentiometric surfaces for seven deep-basin aquifers in the Midland Basin area of Texas, including potentiometric surfaces for the Wolfcamp Series and Strawn Series (a series within the Pennsylvanian System). Although McNeal's maps were constructed from DSTs, and heads calculated from depressured DSTs were deleted, direct comparison between the Wolfcamp and Pennsylvanian potentiometric surfaces presented in this report with those produced by NcNeal (1965) is not made because McNeal's study area borders the study area of this report only along the southernmost row of counties (Cochran, Hockley, Lubbock, Crosby, Dickens, and King Counties, Texas), and in this area McNeal's potentiometric contours are inferred and extrapolated from data further to the south in the Midland Basin. Consequently, direct comparison of the potentiometric maps included in this report with those in McNeal (1965) would be speculative and inconclusive.

5 PRESSURE-DEPTH ANALYSES

5.1 HIGH PLAINS/ROLLING PLAINS PRESSURE-DEPTH RELATIONSHIP

Figure 5-1 is a geographic reference map of the study area showing the locations of the High Plains and Rolling Plains. Figures 5-2A and 5-2B are pressure-depth diagrams of data from Cottle and Hale Counties, Texas, respectively (depressured, grossly underpressured, and grossly overpressured DST data have been deleted). Note that almost all the pressure-depth data from both counties are underpressured with respect to the range of probable hydrostatic pressure gradients. However, data from Hale County, located on the High Plains, are far more underpressured than data from Cottle County, located on the Rolling Plains. This relationship exists for other counties located on the Rolling Plains and High Plains and for individual DSTs within a county that straddles the High Plains and Rolling Plains (Figure 5-1 and Appendix C).

Figures 5-3A and 5-3B are pressure-depth diagrams plotting data from wells located on the Rolling Plains and High Plains, respectively (depressured, grossly underpressured, and grossly overpressured DST data have been deleted). These diagrams were compiled from DST data from all available geologic units in HSU B and HSU C and from "TOPOGRAPHIC SETTING" information listed in Appendix B. Note that, in the same manner as the Hale County/Cottle County example, data from the High Plains are far more underpressured than data from the Rolling Plains.

Pressure-depth data throughout the study area can be separated into two distinct populations, one from the High Plains and one from the Rolling Plains, as shown on Figures 5-3A and 5-3B and on Table 5-1 which summarizes the regression statistics listed on these figures. The cause of these population differences appears to be due to topographic relief across the High Plains/Rolling Plains escarpment which dramatically changes the depth from the ground surface to potentiometric levels in the deep-basin strata. This is manifest by the difference in the Y-intercept values of the regression lines, as listed on Table 5-1. The larger Y-intercept value for High Plains data reflects the greater depth from the ground surface to potentiometric levels in the deep-basin strata, whereas the smaller

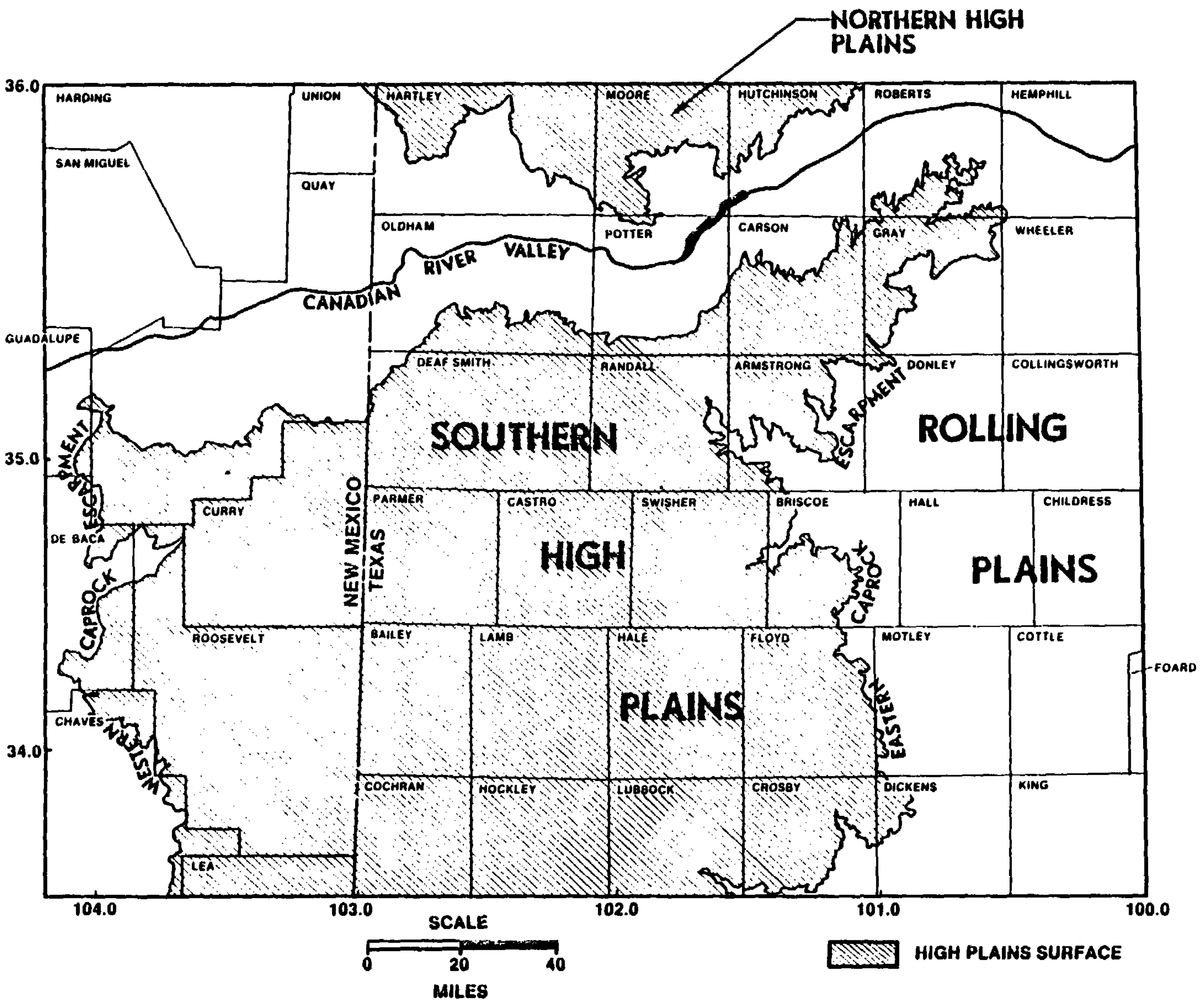


Figure 5-1. Location of the High Plains and Rolling Plains in the Study Area.

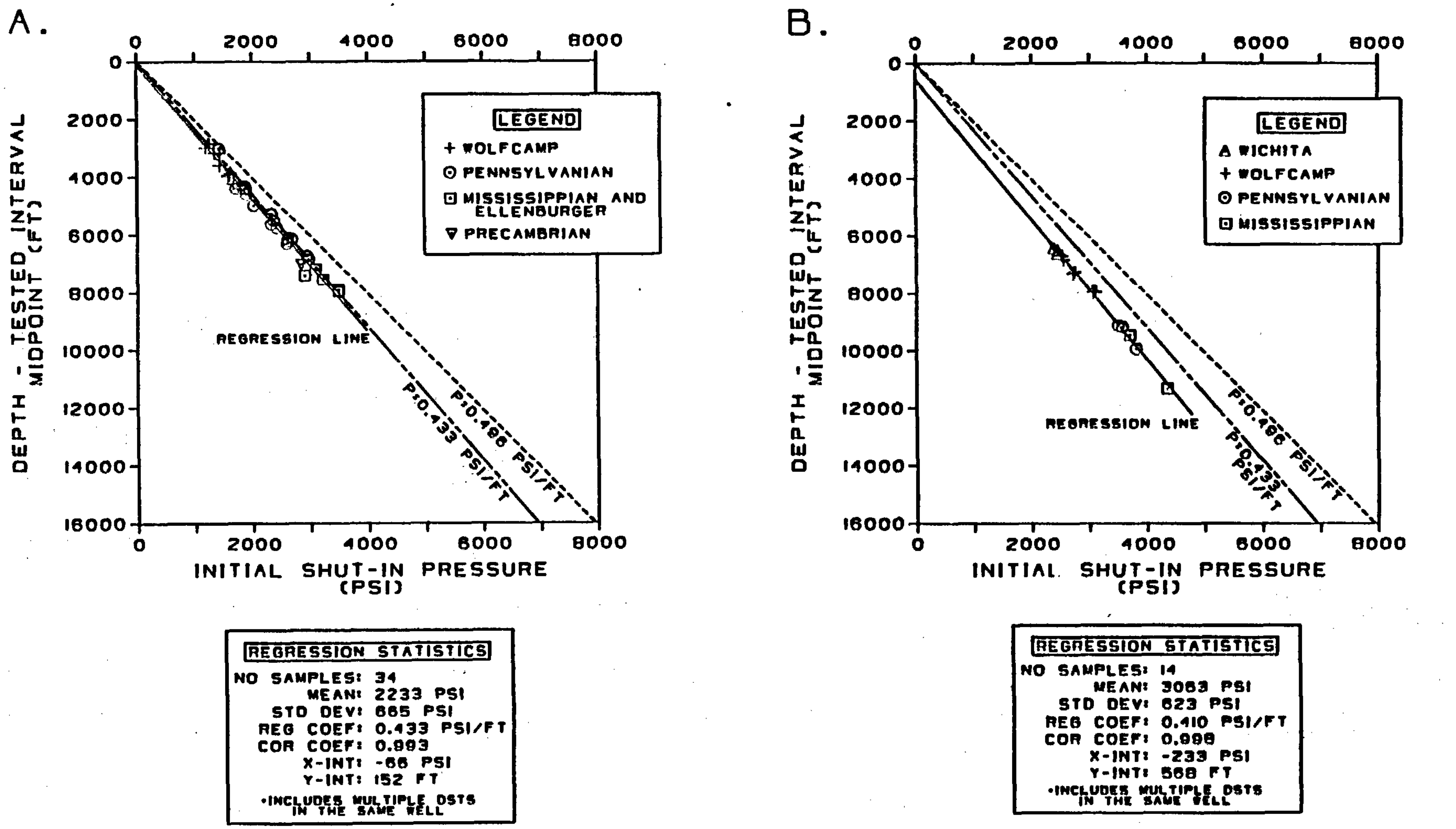


Figure 5-2. A. Pressure-Depth Diagram and Linear Regression of DST Data after Culling, Cottle County, Texas (Rolling Plains); B. Pressure-Depth Diagram and Linear Regression of DST Data after Culling, Hale County, Texas (High Plains).

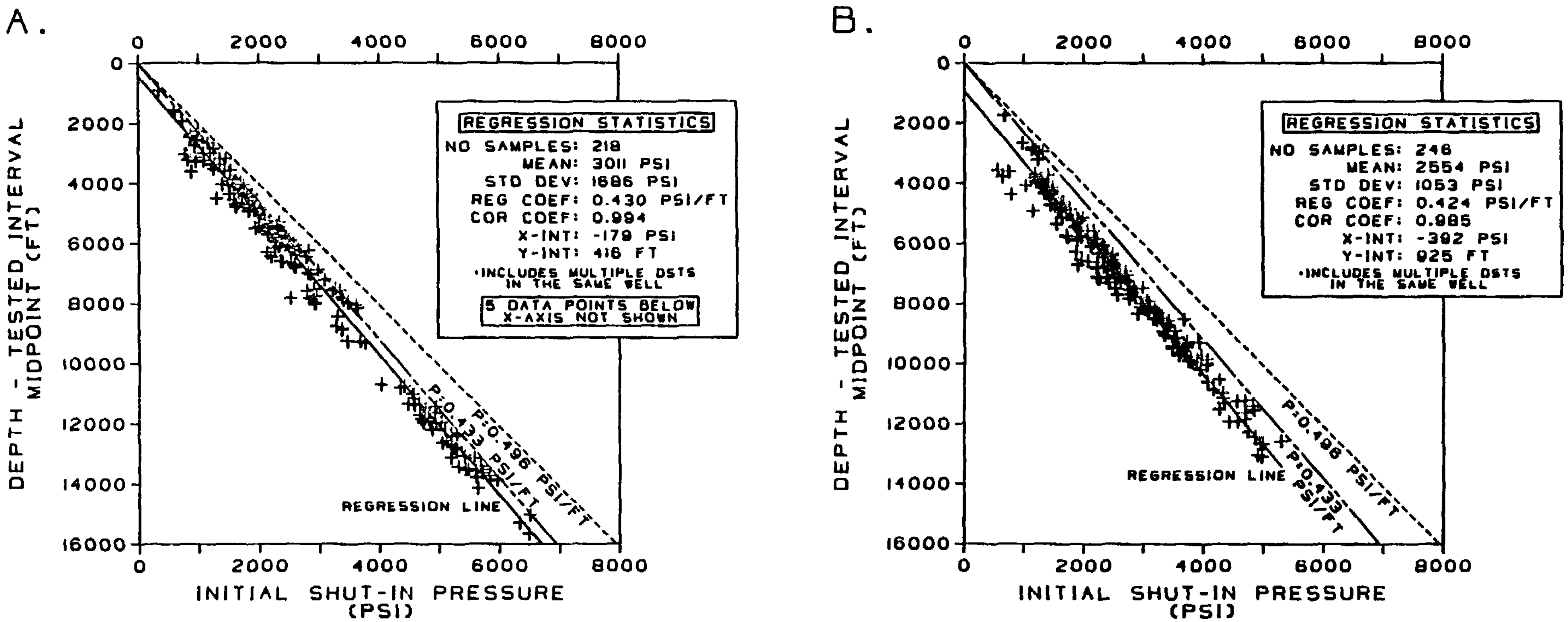


Figure 5-3. A. Pressure-Depth Diagram and Linear Regression of DST Data after Culling, from Wells Located on the Rolling Plains; B. Pressure-Depth Diagram and Linear Regression of DST Data after Culling, from Wells Located on the High Plains.

Table 5-1. Summary Regression Statistics of High Plains/Rolling Plains ISIP Data After Culling, Showing Changes Due to Separating Data Sets According to Topographic Setting

Topographic Setting	No. DSTs	Mean (psi)	Standard Deviation (psi)	Correlation Coefficient	Regression Coefficient (psi/ft)	X-Intercept (psi)	Y-Intercept (ft)
Rolling Plains	218	3011	1686	0.994	0.430	-179	416
High Plains	246	2554	1053	0.985	0.424	-392	925

Y-intercept value for Rolling Plains data reflects the lesser depth from the ground surface to potentiometric levels in the deep basin strata. Consequently, topographic variations (variations in the depth to potentiometric levels) appear to be a control on the location of the data along the Y-axis of a pressure-depth diagram.

5.2 PLANAR REGRESSION OF WOLFCAMP AND PENNSYLVANIAN ISIP DATA

5.2.1 General

Analysis of Wolfcamp and Pennsylvanian pressure-depth data, as described in Section 4.4, showed that after the data were culled an excellent correlation existed between pressure and depth. On further examination of these data and data from other geologic units, it was observed that better correlation was obtained by separating the data according to topographic setting, as described in Section 5.1. This analysis showed that pressure-depth data from the High Plains are far more underpressured than pressure-depth data from the Rolling Plains (see Figure 5-3), possibly due to topographic relief across the High Plains/Rolling Plains escarpment which dramatically changes the depth from the ground surface to potentiometric levels in the deep-basin strata. This lead to the hypothesis that a plane could be determined which would minimize the effect of measuring depth from variable elevations along the topographic surface as well as minimize the difference between the Y-intercepts of the High Plains and Rolling Plains regression lines.

A "best-fit" hypothetical plane was calculated for Wolfcamp data and for Pennsylvanian data. These planes were used to "normalize" the pressure-depth data to determine a best-fit plane for each aquifer which would minimize the effect of measuring depth from variable surface elevations and to minimize deviation from a linear pressure-depth relationship. It was assumed that these hypothetical planes were a linear function of longitude and latitude. It also was assumed that pressure was a linear function of depth below the hypothetical plane. Subtracting the elevation of the tested interval from the elevation of the hypothetical plane at the locations of DST wells produced an equation for pressure that depends on longitude, latitude, and the tested elevation of the DST.

A trend surface program (Esler and others, 1968) employing the method of least-mean squares was used to obtain a hypothetical plane for Wolfcamp ISIP data and separate hypothetical planes for Pennsylvanian ISIP data located north and south of the Amarillo Uplift. This was done because the uplift is a major barrier to ground-water flow in the Pennsylvanian System and pressure-depth data and head data on opposite sides of the uplift appear to be slightly different. Input to the program included ISIP as the dependent variable, and longitude, latitude, and elevation of the tested interval midpoint as independent variables. Output included coefficients for longitude, latitude, and elevation of the tested interval midpoint. These coefficients describe the orientation of the planes in a three-dimensional coordinate system. The coefficient for elevation of the tested interval midpoint is equal to the regression coefficient (psi/ft) of the pressure-depth data normalized to the hypothetical plane. Appendix D details the mathematical equations used to obtain the hypothetical planes.

5.2.2 Hypothetical Wolfcamp Plane

The hypothetical Wolfcamp plane is shown on Figure 5-4. The plane dips to the northeast and nowhere is higher than actual ground-surface elevation. When depths of Wolfcamp DSTs are measured from this plane, excellent correlation of pressure versus normalized depth is obtained. Figure 5-5 is a pressure-depth diagram plotting culled Wolfcamp data which have been normalized to the hypothetical plane. As shown on this figure, the regression line intercepts the Y-axis at a depth approximately equal to 0 feet, as expected. The correlation coefficient is 0.992, and the regression coefficient is 0.452 psi/ft.

5.2.3 Hypothetical Pennsylvanian Planes

The hypothetical Pennsylvanian planes are shown on Figure 5-6. The southern plane dips to the northeast at a gradient slightly less than the hypothetical Wolfcamp plane, whereas the northern plane dips very slightly to the northwest. The east-west dip reversal of the two planes across the Amarillo Uplift is not understood, but may be due to the limited study area

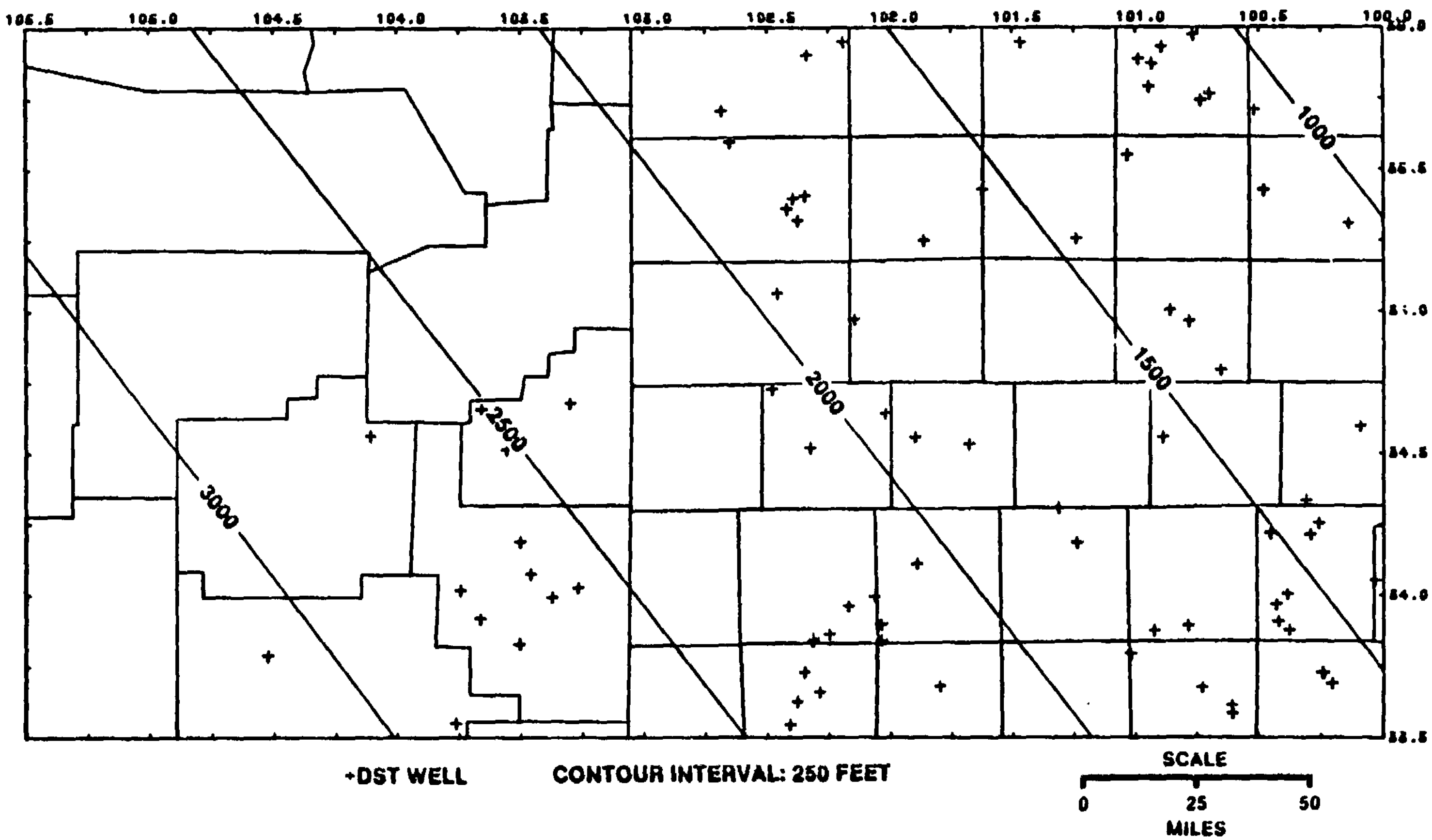


Figure 5-4. Hypothetical Plane that Maximizes Correlation of Wolfcamp ISIP Data after Culling.

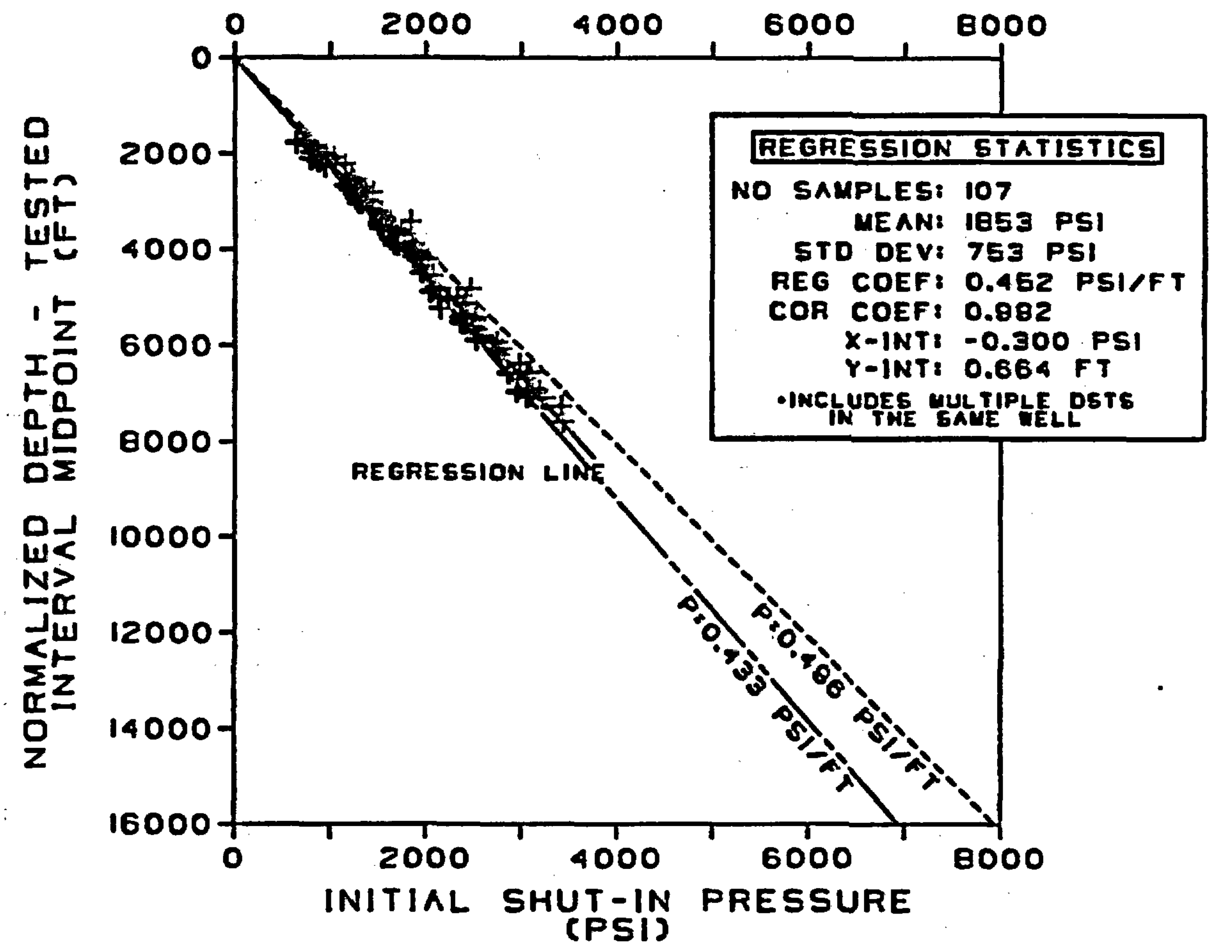


Figure 5-5. Pressure-Depth Diagram and Linear Regression of Wolfcamp DST Data after Culling, Normalized to a Hypothetical Plane.

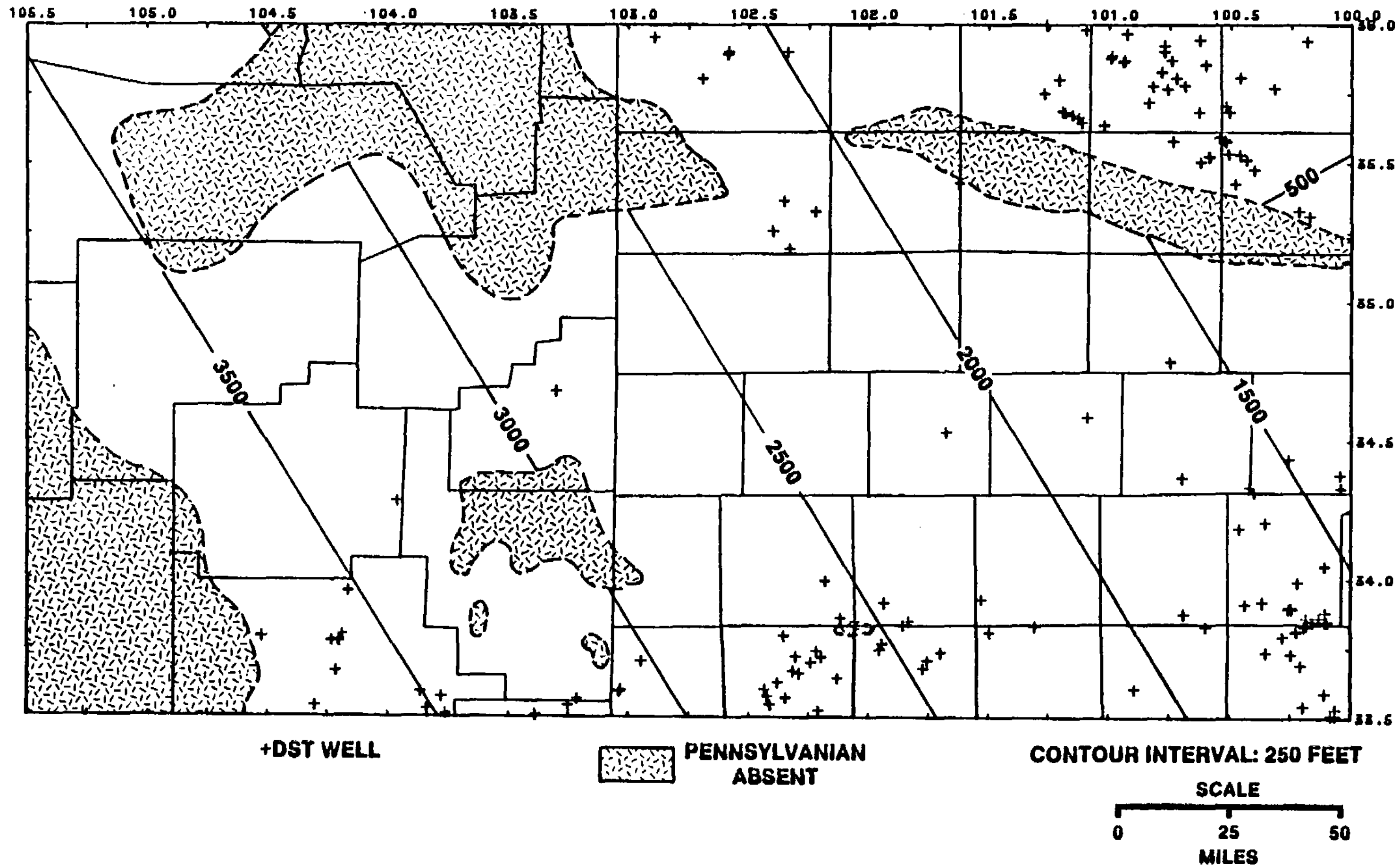


Figure 5-6. Hypothetical Planes that Maximize Correlation of Pennsylvanian ISIP Data after Culling.

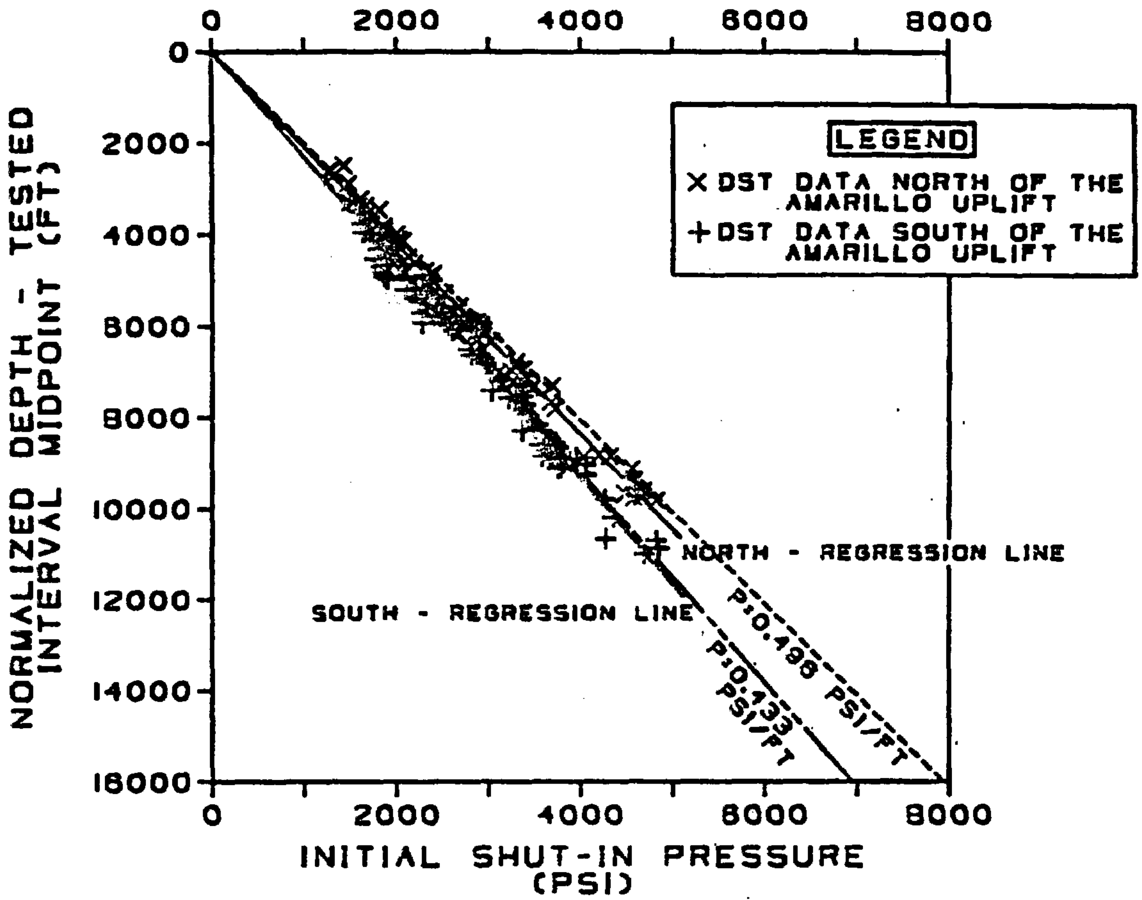
north of the uplift. Additional study incorporating DST data north and east of the current study area is planned.

The normalized pressure-depth diagram for Pennsylvanian data after culling is shown on Figure 5-7. The correlation coefficient is 0.993 and the regression coefficient is 0.429 psi/ft for the area south of the Amarillo Uplift. The correlation coefficient is 0.996 and the regression coefficient is 0.478 psi/ft for the area north of the Amarillo Uplift. Both regression lines intercept the Y-axis, at a depth appproximately equal to 0 feet.

5.2.4 Conclusions and Geologic Implications

Table 5-2 shows that correlation between pressure and depth for Wolfcamp data and Pennsylvanian data was further improved by normalizing the data to hypothetical topographic planes. This is shown graphically on Figures 5-8 and 5-9 where Wolfcamp data are plotted in nonnormalized and normalized form, respectively. Figures 5-10 and 5-11 show the same relationships for Pennsylvanian data. Note that normalizing exaggerates depressured, grossly underpressured, and grossly overpressured data, as shown on Figures 5-8B and 5-10B, by eliminating variance due to measuring depth from varying elevations along the existing topographic surface. This makes it easier to identify abnormally pressured DSTs. (It should be noted that the hypothetical planes which Figures 5-8B and 5-10B are based on are not shown and contain depressured, grossly underpressured, and grossly overpressured DSTs. Consequently, the normalized depths shown on these figures are significantly different than the normalized depths shown on Figures 5-9B and 5-11B which are based on the hypothetical planes shown on Figures 5-4 and 5-6, respectively, and which are based on culled data.)

Normalization of Wolfcamp and Pennsylvanian data, as shown on Figures 5-12 and 5-13, respectively, nearly eliminated the gap between the Rolling Plains and the High Plains regression lines and the difference between their Y-intercepts. The Y-intercept of the nonnormalized Wolfcamp regression line for High Plains data is 2,234 feet and the Y-intercept of the Rolling Plains regression line is 277 feet (Figure 5-12A). After normalization, the Y-intercept of the High Plains regression line is -40 feet and the Y-intercept of the Rolling Plains regression line is



REGRESSION STATISTICS

	NORTH OF AMARILLO UPLIFT	SOUTH OF AMARILLO UPLIFT
NO SAMPLES:	85	122
MEAN:	2853 PSI	2784 PSI
STD DEV:	1015 PSI	806 PSI
REG COEF:	0.478 PSI/FT	0.428 PSI/FT
COR COEF:	0.996	0.992
X-INT:	-0.016 PSI	-0.256 PSI
Y-INT:	0.033 FT	0.598 FT

•INCLUDES MULTIPLE DSTS IN THE SAME WELL

Figure 5-7. Pressure-Depth Diagram and Linear Regression of Pennsylvanian DST Data after Culling, Normalized to Two Hypothetical Planes.

Table 5-2. Summary Regression Statistics of Normalized Wolfcamp and Pennsylvanian ISIP Data Before and After Culling

Geologic Unit	No. DSTs*	Mean (psi)	Standard Deviation (psi)	Correlation Coefficient	Regression Coefficient (psi/ft)	X-Intercept (psi)	Y-Intercept (ft)
Wolfcamp Data							
Before Culling	150	1853	862	0.759	0.346	-142	410
Before Culling-Normalized	150	1853	862	0.908	0.477	-702	1472
After Culling	107	1853	753	0.932	0.413	-384	930
After Culling-Normalized	107	1853	753	0.992	0.452	-0.300	0.644
Pennsylvanian Data (South of Amarillo Uplift)							
Before Culling	236	2605	972	0.400	0.189	1094	-5788
Before Culling-Normalized	236	2605	972	0.402	0.176	-363	2063
After Culling	122	2783	806	0.954	0.382	50	-131
After Culling-Normalized	122	2783	806	0.992	0.428	-0.256	0.598

*Includes multiple DSTs in the same well.

Table 5-2. (Continued)

Geologic Unit	No. DSTs*	Mean (psi)	Standard Deviation (psi)	Correlation Coefficient	Regression Coefficient (psi/ft)	X-Intercept (psi)	Y-Intercept (ft)
Pennsylvanian Data (North of Amarillo Uplift)							
Before Culling	105	2998	1509	0.765	0.451	-884	1960
Before Culling-Normalized	105	2998	1509	0.760	0.483	-529	1095
After Culling	65	2853	1015	0.992	0.477	-879	1843
After Culling-Normalized	65	2853	1015	0.996	0.478	-0.016	0.033

*Includes multiple DSTs in the same well.

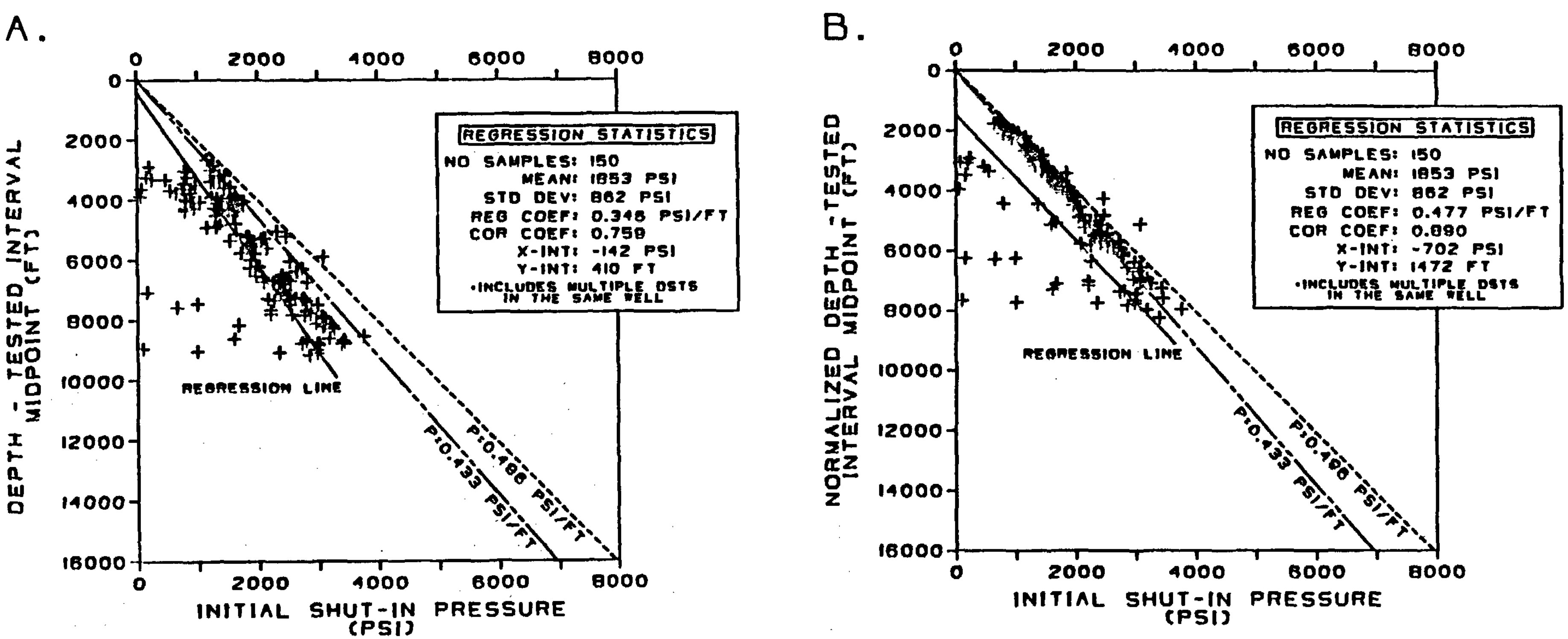


Figure 5-8. A. Pressure-Depth Diagram and Linear Regression of Wolfcamp ISIP Data; B. Pressure-Depth Diagram and Linear Regression of Normalized Wolfcamp ISIP Data.

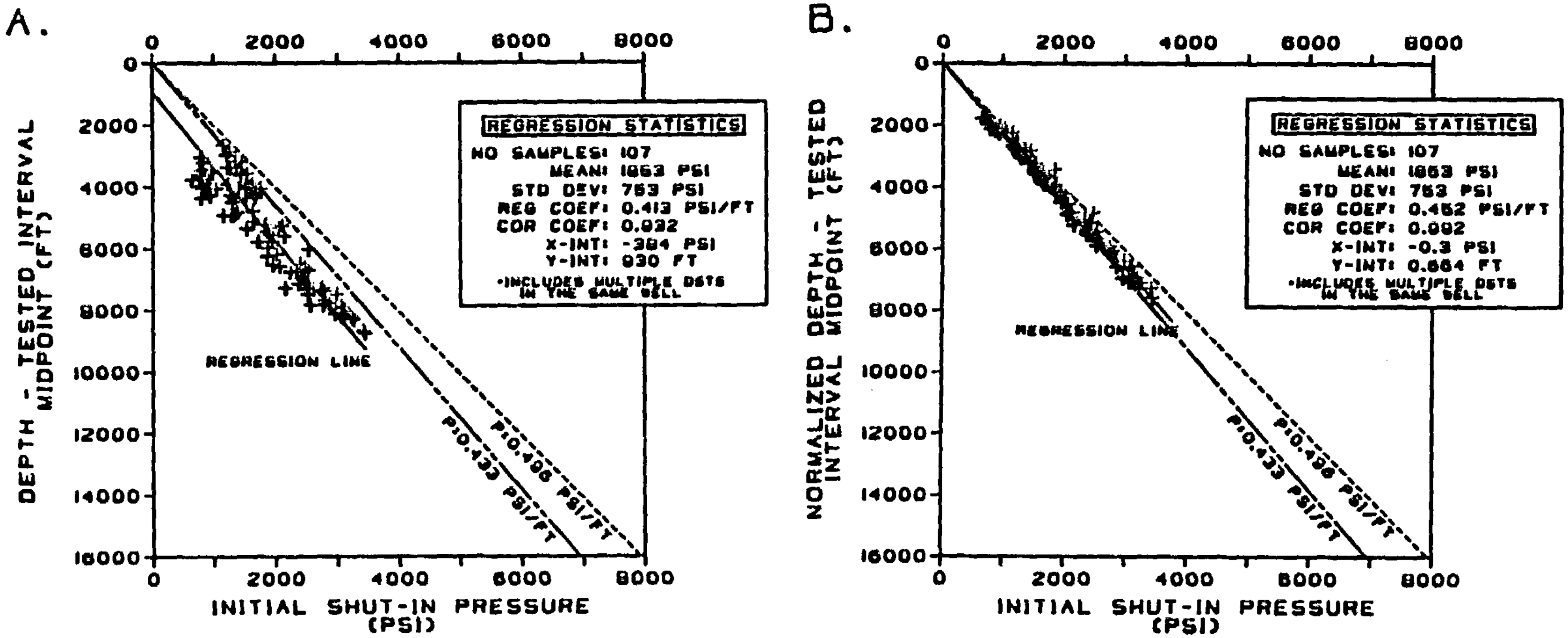


Figure 5-9. A. Pressure-Depth Diagram and Linear Regression of Wolfcamp ISIP after Culling; B. Pressure-Depth Diagram and Linear Regression of Normalized Wolfcamp ISIP Data after Culling.

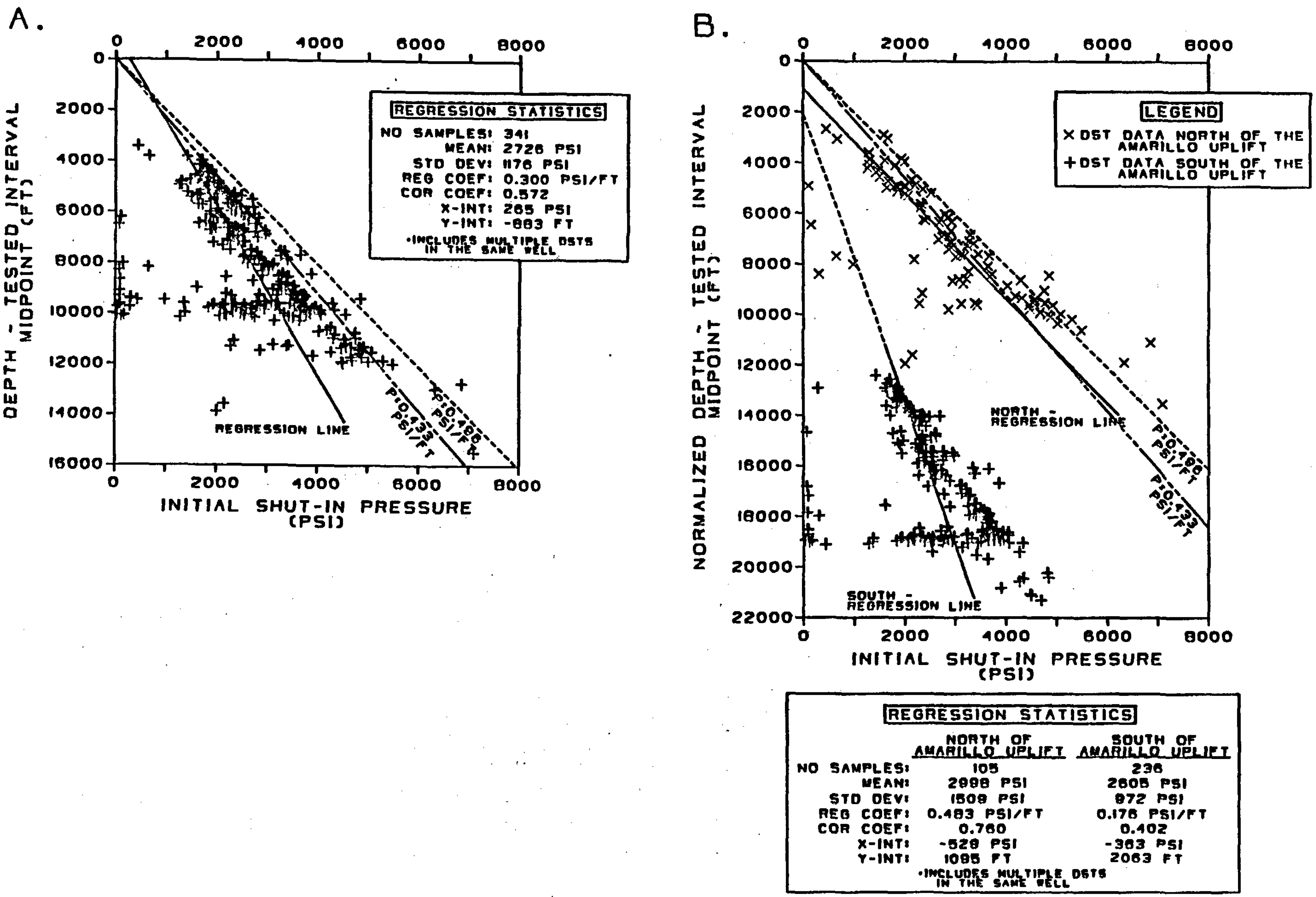
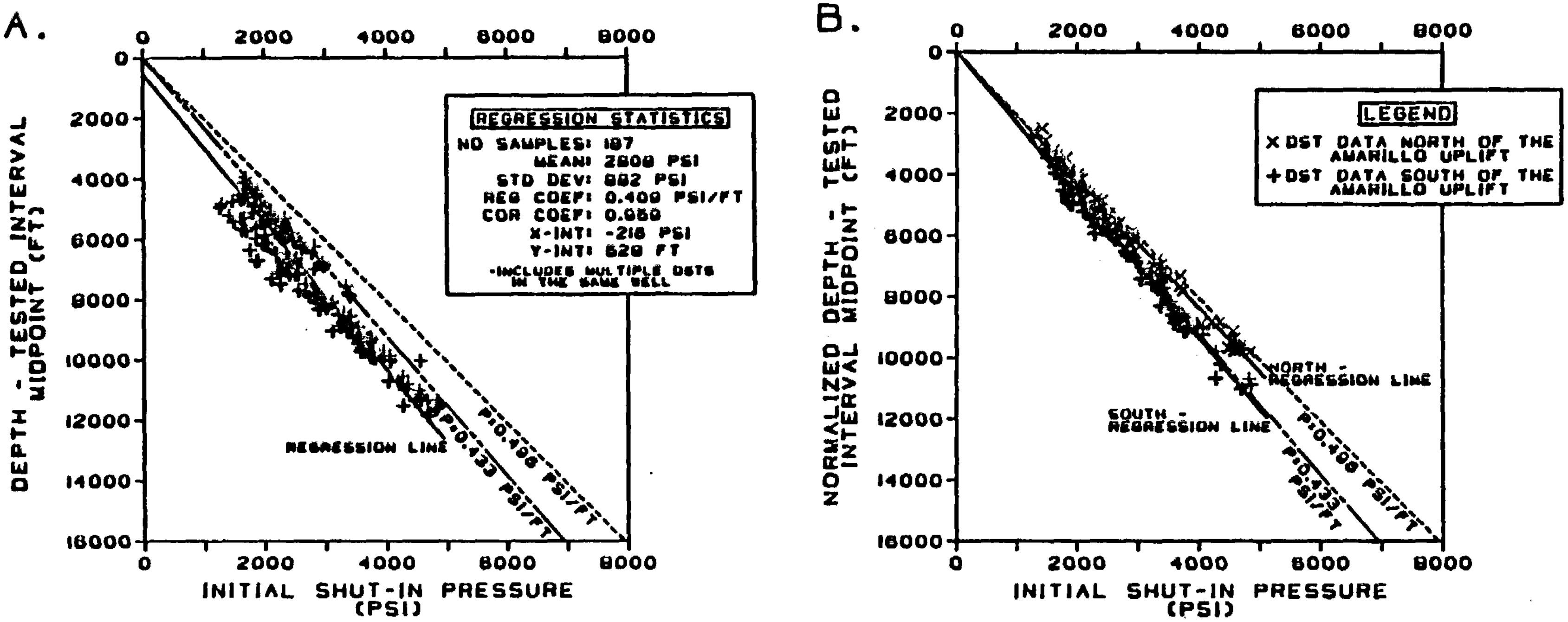


Figure 5-10. A. Pressure-Depth Diagram and Linear Regression of Pennsylvanian ISIP Data; B. Pressure-Depth Diagram and Linear Regression of Normalized Pennsylvanian ISIP Data.

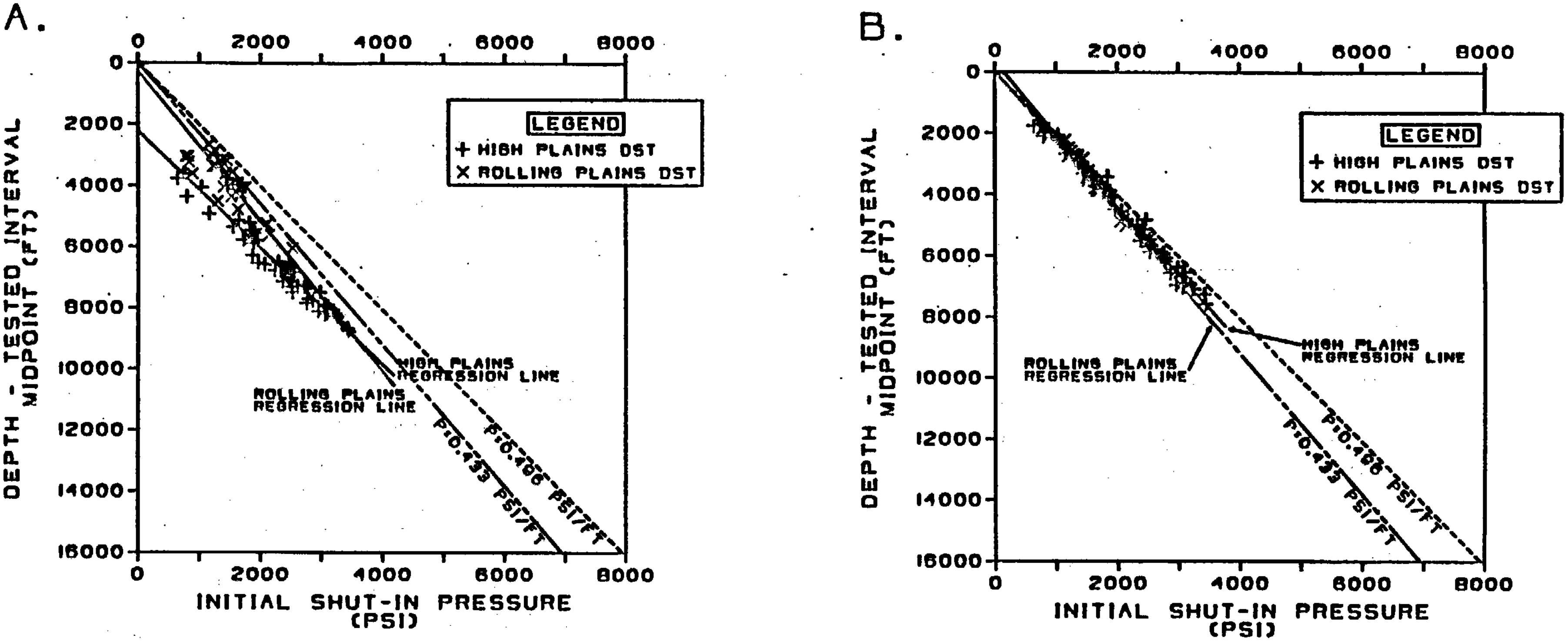


REGRESSION STATISTICS

	NORTH OF AMARILLO UPLIFT	SOUTH OF AMARILLO UPLIFT
NO SAMPLES:	65	122
MEAN:	2863 PSI	2783 PSI
STD DEV:	1016 PSI	806 PSI
REG COEF:	0.478 PSI/FT	0.429 PSI/FT
COR COEF:	0.996	0.992
X-INT:	-0.018 PSI	-0.256 PSI
Y-INT:	0.033 FT	0.598 FT

*INCLUDES MULTIPLE DSTS IN THE SAME WELL

Figure 5-11. A. Pressure-Depth Diagram and Linear Regression of Pennsylvanian ISIP Data after Culling; B. Pressure-Depth Diagram and Linear Regression of Normalized Pennsylvanian ISIP Data after Culling.



REGRESSION STATISTICS (A)

	HIGH PLAINS	ROLLING PLAINS
NO SAMPLES:	55	33
MEAN:	2308 PSI	1490 PSI
STD DEV:	716 PSI	384 PSI
REG COEF:	0.525 PSI/FT	0.408 PSI/FT
COR COEF:	0.978	0.856
X-INT:	-1173 PSI	-113 PSI
Y-INT:	2234 FT	277 FT

*INCLUDES MULTIPLE DSTS IN THE SAME WELL

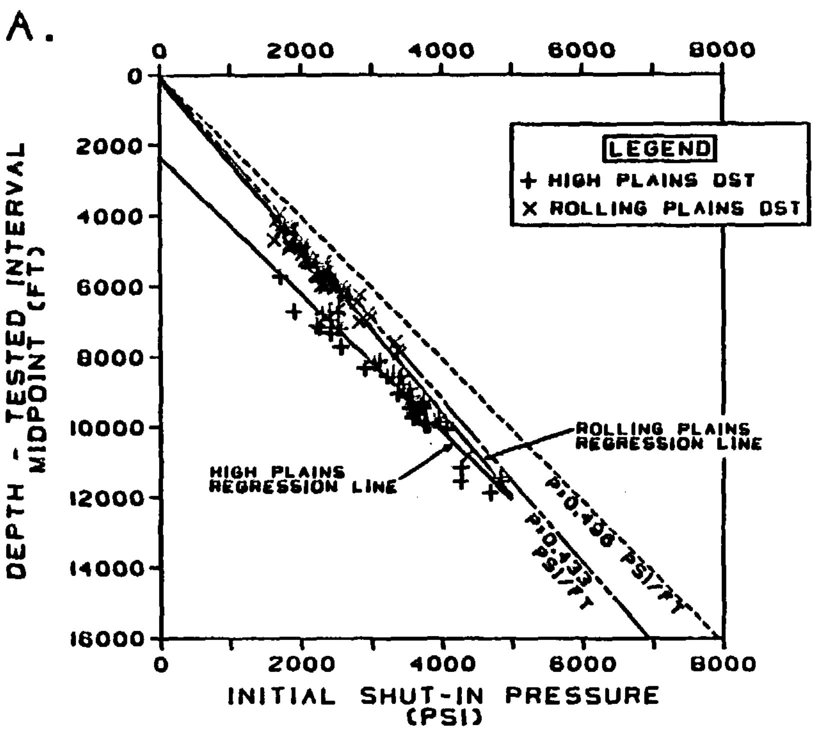
REGRESSION STATISTICS (B)

	HIGH PLAINS	ROLLING PLAINS
NO SAMPLES:	55	33
MEAN:	2308 PSI	1490 PSI
STD DEV:	716 PSI	384 PSI
REG COEF:	0.450 PSI/FT	0.415 PSI/FT
COR COEF:	0.991	0.978
X-INT:	18 PSI	122 PSI
Y-INT:	-40 FT	-294 FT

*INCLUDES MULTIPLE DSTS IN THE SAME WELL

Figure 5-12. A. Pressure-Depth Diagram and Linear Regression of Wolfcamp ISIP Data after Culling, from the Rolling Plains and High Plains; B. Pressure-Depth Diagram and Linear Regression of Normalized Wolfcamp ISIP Data after Culling, from the Rolling Plains and High Plains.

A.

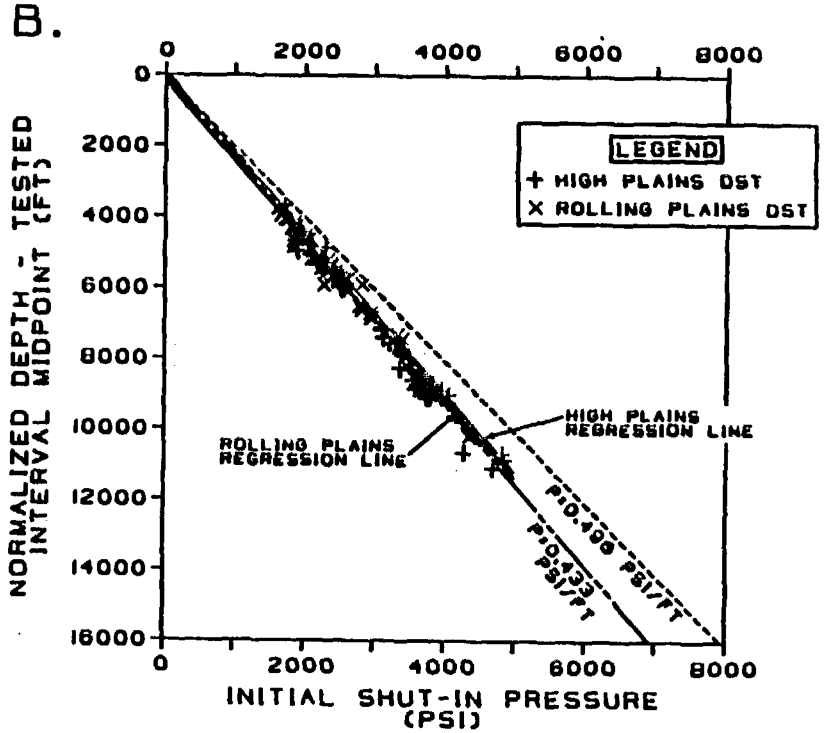


REGRESSION STATISTICS

	HIGH PLAINS	ROLLING PLAINS
NO SAMPLES:	54	61
MEAN:	3771 PSI	2342 PSI
STD DEV:	716 PSI	535 PSI
REG COEF:	0.513 PSI/FT	0.423 PSI/FT
COR COEF:	0.979	0.980
X-INT:	-1183 PSI	-55 PSI
Y-INT:	2306 FT	130 FT

*INCLUDES MULTIPLE DSTS IN THE SAME WELL

B.



REGRESSION STATISTICS

	HIGH PLAINS	ROLLING PLAINS
NO SAMPLES:	54	61
MEAN:	3771 PSI	2342 PSI
STD DEV:	716 PSI	535 PSI
REG COEF:	0.422 PSI/FT	0.447 PSI/FT
COR COEF:	0.988	0.987
X-INT:	46 PSI	-81 PSI
Y-INT:	-109 FT	181 FT

*INCLUDES MULTIPLE DSTS IN THE SAME WELL

Figure 5-13. A. Pressure-Depth Diagram and Linear Regression of Pennsylvanian ISIP Data Located South of the Amarillo Uplift after Culling, from the Rolling Plains and High Plains; B. Pressure-Depth Diagram and Linear Regression of Normalized Pennsylvanian ISIP Data Located South of the Amarillo Uplift after Culling, from the Rolling Plains and High Plains.

-294 feet (Figure 5-12B). Similarly, the Y-intercept of the nonnormalized Pennsylvanian regression line for High Plains data south of the Armarillo Uplift is 2,306 feet and the Y-intercept of the Rolling Plains regression line is 130 feet (Figure 5-13A). After normalization, the Y-intercept of the High Plains regression line is -109 feet and the Y-intercept of the Rolling Plains regression line is 181 feet.

The hypothetical planes represent surfaces which maximize correlation between pressure and depth regardless of current topographic elevations or settings. The geologic implications of these relationships are not fully understood, and these hypothetical planes have not been correlated with any historical geologic features or surfaces.

6 SUMMARY AND CONCLUSIONS

6.1 WOLFCAMP AND PENNSYLVANIAN POTENTIOMETRIC SURFACES

6.1.1 General

In accordance with the primary objective of the study, to produce regional potentiometric surfaces of the Wolfcamp Series and Pennsylvanian System, three sets of potentiometric-surface maps are presented based on three levels of data refinement. The maps were constructed using equivalent freshwater heads based on ISIP values obtained from Class 2 and 3 DSTs. Whenever possible, the few Class 1 DSTs were incorporated into the potentiometric surfaces by calculating equivalent freshwater heads from ISIP values obtained from DST charts or Horner plots. Potentiometric surfaces produced in this manner will be slightly lower than potentiometric surfaces based on extrapolated formation pressures. This procedure was necessitated by the inadequate number of Class 1 DSTs available to construct potentiometric surfaces. Use of this procedure was considered critical to the determination of horizontal hydraulic gradients in the Wolfcamp Series and Pennsylvanian System in the proposed repository site areas because heads based on extrapolated formation pressures when combined with heads based on ISIPs would produce fallacious gradients.

Figures 4-1 and 4-2 show the present configuration of the Wolfcamp and Pennsylvanian potentiometric surfaces, respectively, containing local temporal potentiometric data due to heads calculated from depressured DSTs and local aberrant potentiometric data due to heads calculated from grossly overpressured and grossly underpressured DSTs. The local temporal and local aberrant potentiometric data create the unrealistic local variations in hydraulic gradients and flow directions seen on these regional potentiometric surfaces. The Wolfcamp potentiometric surface is based on 118 head values whereas the Pennsylvanian potentiometric surface is based on 257 head values.

Figures 4-12 and 4-13 show the configuration of the Wolfcamp and Pennsylvanian potentiometric surfaces, respectively, after local temporal potentiometric data due to heads calculated from depressured DSTs were culled, but still containing local aberrant potentiometric data due to heads calculated from grossly overpressured and grossly underpressured DSTs. The depressured DSTs were performed in localized zones where oil and/or gas extraction reduced formation pressures and created temporal pressures that are not transmitted vertically to a great extent. DSTs performed in these zones record abnormally low ISIP and FSIP values which may be valid formation pressures but represent temporal pressures in local depressured zones within a regional flow system that is probably steady state. The depressured DSTs were culled according to the procedures described in Section 4.6.1. Twenty-three depressured DSTs were culled from the Wolfcamp data set, whereas 120 depressured DSTs were culled from the Pennsylvanian data set. Deletion of depressured DSTs produced potentiometric surfaces of the Wolfcamp and Pennsylvanian aquifers prior to oil and gas extraction, but still containing some local aberrant potentiometric data which, on a regional scale, produced unrealistic variations in flow directions and hydraulic gradients.

Figures 4-18 and 4-19 are the most refined representation of the regional Wolfcamp and Pennsylvanian potentiometric surfaces, respectively, after culling local temporal potentiometric data and local aberrant potentiometric data. The local aberrant potentiometric data were culled according to the procedures described in Section 4.7.1. Nine grossly overpressured and 11 grossly underpressured DSTs were culled from the Wolfcamp data set, whereas 24 grossly overpressured and 10 grossly underpressured DSTs were culled from the Pennsylvanian data set. Deletion of these data eliminated the local potentiometric mounds and depressions seen on Figures 4-12 and 4-13. The occurrence of local grossly overpressured and grossly underpressured Wolfcamp and Pennsylvanian DSTs did not appear to follow any discernible trends. Their distribution is similar to the distribution of all the DSTs. This may reflect the sampling bias that more DSTs are performed around the major oil and gas production areas, or it may reflect the greater geologic complexity of these areas. The potentiometric surfaces shown on Figures 4-18 and 4-19 represent the regional configuration of the Wolfcamp and Pennsylvanian potentiometric surfaces, respectively, prior to oil and gas production.

Statistical analysis of the culling procedures, based on linear regression analysis of pressure-depth data and statistical comparisons of original head values versus SURFACE II gridded head values, as described in

Section 4.8, showed that most of the refinement in the Wolfcamp and Pennsylvanian data sets was due to culling depressured DSTs. Some additional refinement was due to culling local grossly underpressured and grossly overpressured DSTs.

6.1.2 Wolfcamp Potentiometric Surface

The closed depression seen in the extreme northeast corner of Figure 4-18 is not an artifact of the computer contouring program. It may be real and represent a ground-water sink in the Wolfcamp potentiometric surface, or it may be the result of not having data in adjacent counties to the north and east of the current study area. Expansion of the study area to the east into Oklahoma should verify or negate the existence of this closed depression.

Depending on which DSTs are considered to be grossly overpressured or grossly underpressured, the direction of the hydraulic gradient in Hartley County, Texas (latitude 35.8 degrees, longitude 102.5 degrees), can vary from northwest to southeast or southeast to northwest. Because of this uncertainty, additional DST data from Dallam and Sherman Counties, Texas (located due north of Hartley and Moore Counties, Texas), and updated DST data from other counties in Texas from mid-1981 through early 1983 will be included in another topical report. The addition of these data should help clarify the direction of the hydraulic gradient in this area.

Preliminary interpretations indicate that the equipotential patterns shown on Figure 4-18 appear to be controlled by transmissivity variations corresponding to facies changes in the Wolfcampian strata, as described in Section 4.9. Topographic relief across the High Plains/Rolling Plains escarpment does not appear to influence equipotential patterns in the Wolfcamp aquifer. However, the general southwest-northeast flow direction in the Wolfcamp aquifer no doubt is influenced by the general west-east decrease in topographic elevation from its recharge area to the west, to its discharge area to the east.

6.1.3 Pennsylvanian Potentiometric Surface

The Pennsylvanian potentiometric surface, as shown on Figure 4-19, also needs refinement in the area of Hartley County, Texas, and in the area northeast of the Amarillo Uplift in the Anadarko Basin region where the identification of depressured, grossly underpressured, and grossly overpressured DST data was difficult.

Interpretation of the controlling factors influencing the equipotential patterns shown on Figure 4-19 is difficult because of the poor distribution of Pennsylvanian potentiometric data. The greater transmissivity of Pennsylvanian carbonates and granite wash and other coarse-grained clastic materials along the margins of the Oldham Nose and Amarillo Uplift is expected to greatly influence equipotential patterns in the Pennsylvanian aquifer. Topographic relief across the High Plains/Rolling Plains escarpment is not expected to influence local equipotential patterns in the Pennsylvanian aquifer. However, the general west-east flow direction shown on Figure 4-19 is probably influenced by the general west-east decrease in topographic elevation from its recharge area to the west, to its discharge area to the east.

6.2 PRESSURE-DEPTH ANALYSES

6.2.1 Wolfcamp and Pennsylvanian

Figures 4-4 and 4-5 show that almost all the Wolfcamp and Pennsylvanian DST data are underpressured with respect to the range of probable hydrostatic pressure gradients. The pressure-depth diagrams in Appendix C show that this relationship also applies to DST data from HSU B and to DST data from other geologic units in HSU C.

Evaluation of pressure-depth data, and oil and gas field location and production data, showed that many of the DSTs were performed in oil and gas production zones. The abnormally low formation pressures recorded in these DSTs represent temporal pressures in local depressured zones within a regional flow system that is probably steady state. Deletion of these local temporal pressures produced a data base that describes pressure-depth relationships throughout the deep-basin strata. However, this data base, still contained some local aberrant DST data (Figures 4-12 and 4-13).

Elimination of local aberrant DST data was based on comparison of ISIPs and heads at a similar depth in the same geologic unit in the same well and/or in adjacent wells. Deletion of local grossly overpressured and grossly underpressured data produced a data base that describes regional pressure-depth relationships throughout the deep-basin strata in the study area (Figures 4-20 and 4-21).

6.2.2 High Plains/Rolling Plains

Figures 5-2 and 5-3 show that pressure-depth data from DSTs performed in the deep-basin strata consist of two populations: one from the High Plains and one from the Rolling Plains. The figures show that DST data from wells located on the High Plains are far more underpressured than DST data from wells located on the Rolling Plains. This probably is due to the greater depth from the ground surface to potentiometric levels in the deep-basin strata beneath the High Plains compared to the Rolling Plains.

The effect of measuring depth from varying topographic elevations was minimized by normalizing the Wolfcamp and Pennsylvanian DST data to common hypothetical planes. Planar regression of these data produced correlation coefficients greater than 0.99 and integrated the separate populations from the High Plains and Rolling Plains (Figures 5-12 and 5-13). The geologic implications of these hypothetical planes are not fully understood.

6.3 ADDITIONAL STUDIES

Performance of additional studies has been mentioned in several sections of this report. Currently, the following additional studies are planned:

1. Extend the study area into north-central Texas and into the reported discharge area in south-central (Levorsen, 1967).
2. Further investigate topographic and geologic controls on equipotential patterns.

3. Investigate the role of brine density variations on pressure-depth relationships and determine areas and zones of vertical ground-water movement within the deep-basin strata.
4. Clarify the direction of hydraulic gradients in the area of Hartley County, Texas.
5. Update the Wolfcamp and Pennsylvanian potentiometric surfaces with additional DST data from mid-1981 through early 1983.
6. Evaluate the regional hydrodynamics of the deep-basin flow system.

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APPENDIX A

SURFACE II COMMANDS USED TO CONSTRUCT POTENTIOMETRIC-SURFACE MAPS

```
TITLE ____________________, POTENTIOMETRIC-SURFACE MAP
DEVICE  6, '____________________'
EXTREMES   -105.5010,-99.9990,33.4490,36.0010,0,0,0,0
ROUT  16,39, '(2F10.5)'
IDXY  __, 18,3,1,2,3,0,0,0,999, '(11X,F10.5,F13.5,F9.1)'
BOX  0.25,2,0.25,2,1-105.50,33.50,2,0.12
SIZC  1,15,7.8
POUT
GRID  0,100,50,1,4,0,0
NEAR  2,4,1.0,1.5
CINTERVAL  0,0,200,0,1,0.11,0,,5
MSMOOTH  1,1,2,4,4
CONTOUR  1,1,0.03,0,0,,2.0,0.07
POST  0,0,0.11,0.11,1
ECHO
PERFORM
```

APPENDIX B

Master File of Geologic, Hydrologic,
and Formation Pressure Data
(17 pages)

MASTER FILE LEGEND
GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS

```
       * = UNITED STATES DEPARTMENT OF ENERGY WELL
       $ = DRILL-STEM TEST PROVIDED BY THE TEXAS BUREAU OF
           ECONOMIC GEOLOGY
  SHECNO = STONE & WEBSTER WELL NUMBER
      TN = DRILL-STEM TEST NUMBER
      CL = CLASSIFICATION
                1 = FORMATION PRESSURE DETERMINED FROM HORNER PLOT
                2 = FSIP AGREES WITHIN 5 PERCENT OF ISIP, AND ISIT
                    AND FSIT ARE GREATER THAN OR EQUAL TO 60 MINUTES
                3 = FSIP AGREES WITHIN 5 PERCENT OF ISIP, AND ISIT
                    AND FSIT ARE GREATER THAN OR EQUAL TO 30 MINUTES
                    BUT LESS THAN 60 MINUTES
LATITUDE = LATITUDE (DEGREES AND DECIMAL DEGREES)
LONGITUD = LONGITUDE (DEGREES AND DECIMAL DEGREES)
    ELEV = ELEVATION OF GROUND SURFACE (FEET - RELATIVE TO MSL)
     TOP = DEPTH TO TOP OF TESTED INTERVAL (FEET BELOW GROUND SURFACE)
  BOTTOM = DEPTH TO BOTTOM OF TESTED INTERVAL (FEET BELOW GROUND SURFACE)
    MDPT = DEPTH TO MIDPOINT OF TESTED INTERVAL (FEET BELOW GROUND SURFACE)
   TELEV = ELEVATION OF DRILL-STEM TEST MIDPOINT (FEET - RELATIVE TO MSL)
    ISIP = INITIAL SHUT-IN PRESSURE (PSI) FOR CL=2 AND CL=3 DATA, AND
           EXTRAPOLATED FORMATION PRESSURE (PSI) FOR CL=1 DATA
    FSIP = FINAL SHUT-IN PRESSURE (PSI)
    EFWH = EQUIVALENT FRESHWATER HEAD (FEET - RELATIVE TO MSL)
    FORM = GEOLOGIC UNIT TESTED
             CAMB = CAMBRIAN SYSTEM
             DEAN = DEAN FORMATION (PERMIAN)
             ELLE = ELLENBURGER GROUP (ORDOVICIAN)
             FUSS = FUSSELMAN FORMATION (SILURIAN)
             GLOR = GLORIETA FORMATION (PERMIAN)
             HUNT = HUNTON GROUP (SILURIAN-DEVONIAN)
              LCF = LOWER CLEAR FORK FORMATION (PERMIAN)
              LSA = LOWER SAN ANDRES FORMATION (PERMIAN)
             LSA4 = LOWER SAN ANDRES UNIT #4 DOLOMITE (PERMIAN)
              LSR = LOWER SEVEN RIVERS FORMATION (PERMIAN)
             MISS = MISSISSIPPIAN SYSTEM
             PENN = PENNSYLVANIAN SYSTEM
             PREC = PRECAMBRIAN ERA
             QU/G = QUEEN/GRAYBURG FORMATION (PERMIAN)
             RDCV = RED CAVE FORMATION (PERMIAN)
             SILU = SILURIAN SYSTEM
             SIMP = SIMPSON GROUP (ORDOVICIAN)
             SPRA = SPRAYBERRY FORMATION (PERMIAN)
             SYLV = SYLVAN FORMATION (ORDOVICIAN)
             TUBB = TUBB FORMATION (PERMIAN)
              UCF = UPPER CLEAR FORK FORMATION (PERMIAN)
              USA = UPPER SAN ANDRES FORMATION (PERMIAN)
             VIOL = VIOLA GROUP (ORDOVICIAN)
             WICH = WICHITA GROUP (PERMIAN)
  STATUS = EVALUATION OF DRILL-STEM TEST DATA
             DEPR = DEPRESSURED DUE TO EXTRACTION OF OIL AND/OR
                    GAS IN ADJACENT AREAS IN THE SAME GEOLOGIC
                    UNIT AT A SIMILAR DEPTH
             MULT = MULTIPLE TESTS IN THE SAME GEOLOGIC UNIT IN THE
                    SAME WELL, NORMALLY PRESSURED WITH RESPECT TO
                    DATA IN ADJACENT AREAS AT A SIMILAR DEPTH
             OVER = GROSSLY OVERPRESSURED WITH RESPECT TO DATA
                    IN ADJACENT AREAS IN THE SAME GEOLOGIC UNIT
                    AT A SIMILAR DEPTH
             UNDE = GROSSLY UNDERPRESSURED WITH RESPECT TO DATA
                    IN ADJACENT AREAS IN THE SAME GEOLOGIC UNIT
                    AT A SIMILAR DEPTH BUT NOT ATTRIBUTABLE TO
                    OIL OR GAS EXTRACTION
             USED = NORMALLY PRESSURED WITH RESPECT TO DATA IN
                    ADJACENT AREAS IN THE SAME GEOLOGIC UNIT
                    AT A SIMILAR DEPTH
      YR = YEAR OF DRILL-STEM TEST
     HSU = HYDROSTRATIGRAPHIC UNIT OF THE TESTED INTERVAL
                B = SHALE AND EVAPORITE AQUITARD
                C = DEEP-BASIN FLOW SYSTEM
    TOPO = TOPOGRAPHIC SETTING OF WELL SITE
               CR = CANADIAN RIVER VALLEY
               HP = HIGH PLAINS
               RP = ROLLING PLAINS
```

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SHECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHW	FORM	STATUS	YR	MSU	TOPO
1	BRI-001	2	3	34.73282	101.45847	3254	6406	6520	6463	-3209	1922	1922	1226	PENN	UNDE	61	C	HP
2	BRI-011	1	3	34.53574	101.08630	2306	5970	6014	5992	-3686	2348	2348	1732	PENN	USED	67	C	RP
3	$BRI-021	2	1	34.34615	101.33902	3266	6344	6411	6378	-3112	2625		2946	WOLF	OVER	70	C	HP
4	BRI-021	2	2	34.34615	101.33902	3266	6340	6411	6375	-3109	2540	2522	2753	WOLF	OVER	70	C	HP
5	$CAR-038	1	1	35.25780	101.24310	3357	3601	3615	3608	-251	764		1512	WOLF	MULT	74	C	HP
6	CAR-038	1	2	35.25780	101.24310	3357	3601	3616	3608	-251	743	711	1464	WOLF	USED	74	C	HP
7	$CAS-001	1	1	34.72496	102.48157	3913	6909	7059	6984	-3071	2437	2435	2553	WOLF	USED	59	C	HP
8	$CAS-007	2	1	34.64046	102.02042	3711	5183	5228	5206	-1495	1633		2747	WOLF	MULT	66	C	HP
9	CAS-007	3	2	34.64046	102.02042	3711	5838	5940	5889	-2178	1879	1079	2158	WOLF	USED	66	C	HP
10	CAS-009	1	3	34.63043	102.15479	3731	5850	5918	5889	-2158	3080	3050	4950	WOLF	OVER	62	C	HP
11	$CAS-010	2	1	34.51755	102.32645	3855	6762	6792	6777	-2922	2230		2455	WOLF	MULT	70	C	HP
12	CAS-010	2	2	34.51755	102.32645	3855	6762	6782	6772	-2917	2234	2157	2238	WOLF	USED	70	C	HP
13	CHI-020	1	2	34.46519	100.32162	1879	5484	5502	5493	-3614	2392	2553	2598	PENN	OVER	75	C	RP
14	CHI-052	1	2	34.31683	100.39986	1888	4768	4863	4816	-2928	2015	2029	1723	PENN	USED	69	C	RP
15	CHI-053	1	2	34.33417	100.31236	1749	4030	4056	4043	-2294	1755	1745	1756	WOLF	USED	70	C	RP
16	CHI-057	1	3	34.31065	100.14163	1696	7997	8097	8047	-6351	3507	3607	1973	MISS	USED	66	C	RP
17	$CHI-076	1	1	34.59698	100.09479	1685	2633	2663	2648	-963	1155		1702	WOLF	USED	62	C	RP
18	CHI-092	2	2	34.43401	100.25723	1946	7840	7925	7883	-5937	3398	3390	1905	PENN	MULT	80	C	RP
19	CHI-092	3	2	34.43401	100.25723	1946	7635	7740	7688	-5742	3560	3503	2705	PENN	OVER	80	C	RP
20	CHI-092	5	2	34.43401	100.25723	1946	5016	5150	5083	-3137	2026	2029	1538	PENN	USED	80	C	RP
21	CHI-092	6	2	34.43401	100.25723	1946	4303	4408	4356	-2410	1639	1694	1442	WOLF	UNDE	80	C	RP
22	CHI-099	1	2	34.37791	100.04381	1668	7663	7930	7797	-6129	3376	3376	1552	PENN	USED	80	C	RP
23	CHI-099	2	2	34.37791	100.04381	1668	7530	7600	7565	-5897	3342	3342	1815	PENN	MULT	80	C	RP
24	CHI-108S	1	3	34.33119	100.04086	1673	5610	5655	5633	-3960	2302	2264	1353	PENN	USED	79	C	RP
25	COCH-055S	2	2	33.75793	102.89297	3839	4293	4466	4380	-541	1427	1414	2753	LSA	USED	79	B	HP
26	COCH-094S	1	2	33.59160	103.03520	3960	9442	9474	9458	-5498	3550	3535	2694	PENN	USED	62	C	HP
27	COCH-094S	2	3	33.59160	103.03520	3960	9518	9530	9524	-5564	3675	3675	2917	PENN	MULT	62	C	HP
28	COCH-X01	1	2	33.59720	103.02940	3958	11498	11542	11520	-7562	4273	4294	2299	PENN	USED	69	C	HP
29	COCH-X02	1	2	33.70320	102.86501	3832	10113	10261	10187	-6355	3944	3944	2747	MISS	USED	68	C	HP
30	COCH-X03	2	2	33.70200	102.94521	3900	4656	4756	4706	-806	1651	1623	3004	GLOR	USED	69	B	HP
31	COCH-X03	3	2	33.70200	102.94521	3900	9702	9742	9722	-5822	3586	3586	2453	PENN	USED	69	C	HP
32	COCH-X03	5	2	33.70200	102.94521	3900	9542	9670	9606	-5706	3612	3493	2329	PENN	MULT	69	C	HP
33	COCH-X04	1	3	33.59760	102.80080	3785	4830	4887	4859	-1074	1739	1605	2070	LSA	USED	66	B	HP
34	COCH-X05	1	3	33.67201	102.96841	3915	4770	4845	4808	-893	1520	1647	2045	LSA	USED	81	B	HP
35	COT-006	1	2	34.27431	100.14259	1732	7909	7934	7922	-6190	3475	3475	1830	ELLE	USED	64	C	RP
36	$COT-010	1	1	34.21820	100.45621	1865	3169	3178	3174	-1309	1445		2026	WOLF	MULT	69	C	RP
37	COT-010	1	3	34.21820	100.45621	1865	3169	3178	3174	-1309	1349	1349	1805	WOLF	USED	69	C	RP
38	COT-017	1	3	34.17600	100.27800	1779	7939	8011	7975	-6196	3480	3456	1836	ELLE	USED	67	C	RP
39	COT-029	3	3	34.05820	100.10460	1615	7180	7250	7215	-5600	3039	3045	1529	MISS	USED	68	C	RP
40	COT-029	4	3	34.05820	100.10460	1615	7480	7640	7560	-5945	3218	3218	1482	MISS	MULT	68	C	RP
41	COT-036	6	3	34.04520	100.30700	2007	7398	7451	7424	-5417	2910	2910	1299	ELLE	USED	60	C	RP
42	COT-043	2	3	33.97620	100.10600	1604	4725	4790	4758	-3154	1086	1085	1199	PENN	DEFR	68	C	RP
43	COT-043	3	3	33.97620	100.10600	1604	4790	4815	4803	-3199	1903	1901	1205	PENN	DEFR	68	C	RP
44	COT-045	1	3	33.95920	100.05580	1659	3815	3849	3832	-2173	1425	1423	1116	PENN	DEFR	65	C	RP
45	COT-051	1	3	33.96850	100.43150	2108	3950	3966	3958	-1850	1590	1590	1797	WOLF	USED	74	C	RP
46	COT-081	1	2	33.87790	100.37869	1952	3927	3980	3954	-2002	1610	1670	1714	WOLF	USED	62	C	RP
47	COT-081	2	2	33.87790	100.37869	1952	3880	3900	3890	-1938	1620	1600	1600	WOLF	MULT	62	C	RP
48	COT-089	1	3	33.89650	100.25650	1717	6728	6782	6755	-5038	2946	2906	1761	PENN	USED	54	C	RP
49	COT-091	1	2	33.89900	100.24850	1714	6838	6920	6879	-5165	2971	2930	1692	PENN	USED	64	C	RP
50	COT-099	1	3	33.83700	100.18280	1658	4410	4428	4419	-2761	1895	1895	1590	PENN	USED	67	C	RP
51	COT-112	1	3	33.88090	100.10470	1869	4430	4445	4438	-2569	1350	1350	1701	PENN	USED	62	C	RP
52	COT-150	1	3	34.21353	100.29476	1674	2974	3090	2982	-1308	1202	1205	1466	WOLF	USED	73	C	RP
53	COT-152	2	3	34.20720	100.35440	1748	4587	4625	4606	-2858	1899	1899	1525	PENN	USED	76	C	RP
54	COT-171	1	3	34.18419	100.46195	1926	4886	4900	4893	-2967	2035	2035	1730	PENN	USED	60	C	RP

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFWH	FORM	STATUS	YR	HSU	TOPO
55	COT-206	1	3	33.95000	100.36540	1864	6809	6835	6812	-4943	2540	2596	914	PENN	UNDE	69	C	RP
56	COT-275	1	3	33.83730	100.18240	1810	4412	4421	4416	-2606	1038	1058	1622	PENN	USED	71	C	RP
57	COT-X03	2	2	33.89470	100.24361	1720	6837	6920	6879	-5159	2975	2925	1706	PENN	USED	64	C	RP
58	COT-X04	1	2	33.90781	100.42239	2031	3589	3619	3604	-1573	1431	1402	1729	WOLF	USED	65	C	RP
59	COT-X07	1	2	33.99001	100.22000	1715	5274	5308	5291	-3576	2338	2309	1819	PENN	USED	69	C	RP
60	COT-X08	1	2	34.04990	100.10399	1810	5540	5631	5586	-3776	2374	2323	1702	PENN	USED	71	C	RP
61	COT-X09	1	2	33.84970	100.16440	1760	6135	6180	6158	-4398	2603	2603	1609	PENN	USED	73	C	RP
62	COT-X10	1	2	33.84660	100.15620	1755	4330	4390	4365	-2610	1378	1378	1724	PENN	USED	74	C	RP
63	COT-X10	2	2	33.84660	100.15620	1755	5635	5645	5640	-3885	2330	2306	1492	PENN	MULT	74	C	RP
64	COT-X11	2	2	33.91051	100.43719	2116	4385	4425	4405	-2289	1719	1719	1678	PENN	USED	74	C	RP
65	COT-X12	1	2	34.00410	100.38710	2022	6953	7092	7023	-5001	2851	2851	1579	PREC	USED	75	C	RP
66	COT-X12	2	2	34.00410	100.38710	2022	4230	4259	4245	-2223	1673	1673	1638	WOLF	USED	75	C	RP
67	COT-X13	1	2	34.25481	100.26109	1704	2844	2866	2855	-1151	1251	1251	1736	WOLF	USED	76	C	RP
68	COT-X13	2	2	34.25481	100.26109	1704	5704	5715	5710	-4006	2204	2215	1265	PENN	UNDE	76	C	RP
69	COT-X14	1	2	33.86040	100.13080	1759	4342	4350	4346	-2583	1632	1632	1640	PENN	USED	76	C	RP
70	COT-X15	1	2	33.84805	100.09547	1725	6127	6149	6138	-4413	2616	2525	1624	PENN	USED	77	C	RP
71	COT-X16	1	2	33.84839	100.10429	1865	6236	6408	6322	-4457	2626	2621	1557	PENN	USED	78	C	RP
72	COT-X17	1	2	33.85953	100.18353	1786	6220	6240	6230	-4444	2618	2618	1593	PENN	USED	78	C	RP
73	COT-X18	2	2	33.91960	100.36497	1875	5720	5810	5765	-3890	2421	2421	1697	PENN	USED	78	C	RP
74	COT-X19	1	2	34.00816	100.23773	1817	6779	6789	6784	-4967	2759	2734	1400	PENN	UNDE	79	C	RP
75	COT-X20	1	2	34.17502	100.46796	1918	4990	5020	5005	-3087	1836	1836	1150	PENN	DEFR	80	C	RP
76	CRO-002	1	3	33.80600	101.49541	3180	5983	6058	6021	-2841	2304	2304	2476	SPRA	USED	67	B	HP
77	CRO-002	4	3	33.80600	101.49541	3180	9430	9530	9480	-6300	3596	3539	1999	PENN	USED	67	C	HP
78	CRO-004	5	3	33.77510	101.10091	3012	5770	5786	5778	-2766	2060	1935	1988	LCF	USED	63	B	HP
79	CRO-013S	1	3	33.55560	101.27470	3022	9205	9223	9214	-6192	4010	4010	3032	MISS	OVER	62	C	HP
80	CRO-014	1	3	33.60249	101.31709	3081	5915	5909	5952	-2371	2226	2253	2266	LCF	USED	73	B	HP
81	CRO-019S	1	2	33.51140	101.18600	2701	5536	5630	5593	-2892	2314	2263	2448	SPRA	USED	77	B	RP
82	CRO-022S	1	3	33.50270	101.36610	3013	9229	9340	9285	-6272	3920	3310	2775	CANB	USED	60	C	HP
83	CRO-X01	2	2	33.67180	101.09891	2975	4569	4614	4591	-1616	2000	2000	2999	UCF	OVER	62	B	HP
84	CRO-X01	3	3	33.67180	101.09891	2975	5126	5158	5142	-2167	1913	1940	2259	UCF	USED	62	B	HP
85	CRO-X02	2	2	33.58749	101.13451	2615	4364	4439	4402	-1787	1725	1735	2194	GLOR	USED	61	B	RP
86	CRO-X03	1	2	33.50259	101.44460	3020	5054	5310	5182	-2162	1915	1915	2257	UCF	USED	69	B	HP
87	CRO-X04	1	2	33.62500	101.25790	3020	5205	5255	5230	-2210	1942	1942	2272	TUBB	USED	70	B	HP
88	CRO-X04	2	2	33.62500	101.25790	3020	5800	5858	5829	-2809	2209	2165	2269	LCF	USED	70	B	HP
89	CRO-X05	3	2	33.60561	101.42920	3031	8642	8696	8669	-5638	93	93	-5423	PENN	DIPR	71	C	HP
90	CRO-X06	1	2	33.82430	101.54410	3181	4102	4147	4125	-944	2094	2027	3389	GLOR	OVER	74	B	HP
91	CRO-X08	1	2	33.57230	101.42654	3070	6319	6346	6333	-3263	2242	2363	1911	SPRA	USED	79	B	HP
92	CRO-X09	1	3	33.57310	101.12531	2425	4890	4990	4940	-2515	2010	2010	2123	UCF	USED	62	B	RP
93	CRO-X10	1	3	33.52161	101.30980	3010	4846	4866	4856	-1846	1720	1720	2262	UCF	USED	62	B	HP
94	CRO-X11	2	3	33.49989	101.09660	2389	4634	4744	4689	-2300	1941	1941	1948	LCF	USED	61	B	RP
95	CRO-X12	1	3	33.57980	101.09500	2427	5687	5745	5716	-3289	2146	2183	1663	LCF	USED	61	B	RP
96	CRO-X17	1	3	33.55051	101.11060	2377	4009	4060	4035	-1658	1574	1493	1975	UCF	USED	71	B	RP
97	*DEA-032S	1	1	34.97330	102.21987	3808	2600	2710	2655	1153	975		3403	LSA4	USED	62	B	HP
98	*DEA-033S	2	1	34.93560	102.36510	3847	2749	2839	2794	1053	1150		3707	LSA4	USED	62	B	HP
99	*DEA-036S	6	1	35.06280	102.46000	4016	5630	5909	5770	-1754	1733		2245	WOLF	MULT	83	C	HP
100	*DEA-036S	6	3	35.06280	102.46000	4016	5630	5909	5770	-1754	1713	1697	2200	WOLF	USED	83	C	HP
101	DIC-001	1	3	33.79460	101.02161	3021	5125	5304	5215	-2194	1817	1672	1999	WOLF	USED	69	C	HP
102	DIC-003	1	3	33.62260	100.77760	2753	4005	4098	4052	-1299	1590	1530	2371	WICH	USED	63	B	RP
103	DIC-X01	2	3	33.67641	100.73199	2345	3265	3380	3323	-978	86	85	-779	RDCV	UNDE	66	B	RP
104	DIC-X01	3	3	33.67641	100.73199	2345	3880	3980	3930	-1585	1519	1519	1920	WOLF	MULT	66	C	RP
105	DIC-X01	4	3	33.67641	100.73199	2345	4010	4085	4048	-1703	1504	1534	1768	WOLF	MULT	66	C	RP
106	DIC-X01	7	2	33.67641	100.73199	2345	5585	5620	5603	-3258	2140	2140	1680	WOLF	USED	66	C	RP
107	DIC-X02	1	2	33.59420	100.60800	2212	5229	5290	5260	-3048	2103	2103	1806	WOLF	USED	67	C	RP
108	DIC-X03	1	2	33.61324	100.60817	2176	4337	4341	4339	-2163	1666	1625	1682	WOLF	USED	77	C	RP

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SHECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	MSJ	TOPO
109	DIC-X03	3	2	33.61324	100.60817	2176	5317	5325	5321	-3145	2048	2048	1591	WOLF	MULT	77	C	RP
110	DIC-X04	1	2	33.64326	100.71040	2192	5040	5050	5045	-2853	2308	2308	2473	WOLF	OVER	78	C	RP
111	DIC-X05	4	2	33.83057	100.59558	2309	5637	5658	5648	-3339	2202	2202	1743	PENN	USED	79	C	RP
112	DIC-X06	4	2	33.60442	100.89011	2447	6988	7000	6994	-4547	2814	2730	1947	PENN	USED	68	C	RP
113	DIC-X08	1	3	33.50929	100.70560	1990	4482	4510	4496	-2506	1572	1566	1168	WOLF	UNDE	70	C	RP
114	DIC-X09	1	3	33.50160	101.01350	2945	7580	7634	7607	-4662	2015	1933	-12	MISS	UNDE	71	C	RP
115	DON-027	1	3	34.96623	100.78648	2618	2863	2907	2885	-267	200	200	195	WOLF	UNDE	63	C	RP
116	DON-027	2	3	34.96623	100.78648	2618	3198	3242	3220	-602	827	827	1336	WOLF	USED	63	C	RP
117	$DON-031	1	1	34.79401	100.65601	2292	3350	3397	3374	-1082	1215		1722	WOLF	USED	64	C	RP
118	DON-036	1	3	34.78633	100.74779	2539	3196	3270	3233	-694	157	157	-332	WOLF	UNDE	69	C	RP
119	DON-036	3	3	34.78633	100.74779	2539	4670	4711	4691	-2152	1620	1641	1587	PENN	MULT	69	C	RP
120	DON-036	4	3	34.78633	100.74779	2539	6620	6675	6648	-4109	2520	2673	1707	PENN	USED	69	C	RP
121	DON-039	1	3	34.86856	100.80087	2717	3840	3920	3880	-1163	52	52	-1043	WOLF	UNDE	69	C	RP
122	*DON-076S	1	1	35.00500	100.85310	2590	2950	3123	3037	-447	815		1437	WOLF	MULT	81	C	RP
123	*DON-076S	1	2	35.00500	100.85310	2590	2950	3120	3035	-445	779	779	1353	WOLF	USED	81	C	RP
124	FLO-001	1	2	34.24600	101.24820	3187	4633	4706	4670	-1483	1302	1538	2214	WICH	USED	70	B	HP
125	FLO-004	1	3	34.16440	101.24210	3170	4675	4797	4736	-1566	1523	1462	1949	WICH	USED	64	B	HP
126	FLO-004	2	3	34.16440	101.24210	3170	5101	5153	5127	-1957	1640	1611	1828	WOLF	USED	64	C	HP
127	FLO-005	2	2	34.16420	101.24600	3191	9136	9158	9147	-5956	3515	3499	2156	MISS	USED	69	C	HP
128	FLO-009	1	2	34.12900	101.36380	3268	7609	7783	7696	-4428	2527	2527	1404	PENN	DEPR	69	C	HP
129	FLO-013	1	2	33.98199	101.32320	3158	8350	8524	8437	-5279	3877	3719	3668	PENN	OVER	69	C	HP
130	FLO-014	3	2	33.92641	101.53160	3224	8432	8616	8524	-5300	3220	3265	2131	PENN	USED	69	C	HP
131	FLO-023	5	3	33.90199	101.37740	3162	7924	8050	7987	-4825	2957	2794	1999	MISS	USED	76	C	HP
132	FLO-027	3	3	33.83670	101.30299	3111	6665	6710	6688	-3577	2400	2400	1962	PENN	USED	66	C	HP
133	FLO-028	2	3	33.87559	101.28371	3105	6856	6890	6878	-3773	2356	2356	1664	PENN	DEPR	65	C	HP
134	$FLO-038S	2	1	34.30643	101.31654	3258	5500	5581	5541	-2283	1907		2118	WOLF	MULT	77	C	HP
135	FLO-038S	2	2	34.30643	101.31654	3258	5500	5581	5541	-2283	1907	1907	2118	WOLF	USED	77	C	HP
136	FOA-001S	1	3	34.05399	100.03307	1750	3550	3570	3560	-1810	1532	1532	1725	WOLF	USED	63	C	RP
137	FOA-001S	3	3	34.05399	100.03307	1750	4554	4608	4581	-2831	1657	1640	993	PENN	DEPR	63	C	RP
138	FOA-001S	4	3	34.05399	100.03307	1750	4841	4851	4846	-3096	1785	1785	1023	PENN	DEPR	68	C	RP
139	FOA-001S	5	3	34.05399	100.03307	1750	4900	4938	4919	-3169	1839	1839	1075	PENN	MULT	68	C	RP
140	FOA-001S	7	3	34.05399	100.03307	1750	7470	7518	7494	-5744	3267	3267	1795	MISS	USED	65	C	RP
141	FOA-X02	2	3	34.16063	100.01044	1661	8115	8212	8164	-6503	3535	3705	1086	MISS	USED	64	C	RP
142	GRA-014	3	2	35.58154	100.73601	3108	10951	11101	10976	-7868	4318	4197	2097	PENN	USED	70	C	HP
143	GRA-014	4	2	35.58154	100.73601	3108	11101	11400	11251	-8143	4559	4559	2378	PENN	MULT	70	C	HP
144	GRA-021	4	2	35.60495	100.56848	3008	12434	12731	12533	-9525	5303	5171	2663	MISS	USED	65	C	HP
145	GRA-023	3	2	35.59541	100.54435	2943	7836	7865	7851	-4908	2878	2845	1734	PENN	USED	66	C	RP
146	GRA-024	14	2	35.53846	100.54326	2852	12650	12699	12675	-9823	5213	5213	2208	MISS	USED	66	C	RP
147	GRA-026	1	2	35.56937	100.56876	3004	11298	11332	11315	-8311	3394	3394	-479	PENN	DEPR	67	C	HP
148	GRA-028	5	2	35.52463	100.57120	2876	11700	11885	11793	-8917	4776	4776	2105	MISS	USED	67	C	RP
149	GRA-029	1	2	35.52744	100.58582	2892	7816	7839	7828	-4936	2835	2800	1607	PENN	MULT	67	C	RP
150	GRA-029	2	2	35.52744	100.58582	2892	7954	7990	7972	-5080	2919	2995	1656	PENN	MULT	67	C	RP
151	GRA-029	3	2	35.52744	100.58582	2892	8818	8863	8841	-5949	3379	3186	1849	PENN	MULT	67	C	RP
152	GRA-029	4	2	35.52744	100.58582	2892	9242	9266	9254	-6362	3455	3455	1634	PENN	USED	67	C	RP
153	GRA-029	8	2	35.52744	100.58582	2892	11449	11518	11484	-8592	4776	4776	2430	ELLE	USED	67	C	RP
154	GRA-029	9	2	35.52744	100.58582	2892	11520	11580	11550	-8658	4776	4776	2364	ELLE	USED	67	C	RP
155	GRA-029	10	2	35.52744	100.58582	2892	11582	11734	11658	-8766	4936	4918	2625	ELLE	USED	67	C	RP
156	GRA-029	11	2	35.52744	100.58582	2892	11762	11882	11822	-8930	4834	4760	2225	ELLE	USED	67	C	RP
157	GRA-029	12	2	35.52744	100.58582	2892	11883	11942	11913	-9021	4852	4834	2176	ELLE	USED	67	C	RP
158	GRA-029	13	2	35.52744	100.58582	2892	11942	12061	12002	-9110	4951	4957	2316	ELLE	USED	67	C	RP
159	GRA-033	5	2	35.53985	100.66367	3028	11550	11700	11625	-8597	4705	4705	2261	ELLE	USED	67	C	HP
160	GRA-037	2	2	35.54924	101.03651	3271	4050	4062	4056	-785	1036	1036	1606	WOLF	USED	70	C	HP
161	GRA-043	6	2	35.46124	100.66115	2705	11430	11451	11441	-8736	4943	4837	2663	SIMP	USED	66	C	RP
162	GRA-043	19	2	35.46124	100.66115	2705	12934	13203	13069	-10364	5404	5390	2153	ELLE	USED	66	C	RP

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	HSU	TOPO
163	GRA-045	2	2	35.50600	100.62402	2839	6409	6509	6459	-3620	2196	2183	1493	PENN	USED	72	C	RP
164	GRA-045	5	2	35.50600	100.62402	2839	11327	11457	11392	-8553	4595	4520	2053	MISS	USED	72	C	RP
165	GRA-045	7	2	35.50600	100.62402	2839	13041	13200	13121	-10282	5193	5354	1714	SIMP	USED	72	C	RP
166	GRA-045	9	2	35.50600	100.62402	2839	13534	13594	13564	-10725	5622	5433	2249	ELLE	USED	72	C	RP
167	GRA-046	4	2	35.47929	100.54825	2769	12549	12609	12579	-9810	5131	5131	2031	VIOL	USED	73	C	RP
168	GRA-047	2	2	35.46271	100.56097	2838	11445	11489	11468	-8630	2867	2997	-2013	PENN	UNDE	68	C	RP
169	GRA-047	3	2	35.46271	100.56097	2838	12400	12462	12431	-9593	5249	5156	2520	VIOL	USED	68	C	RP
170	GRA-047	6	2	35.46271	100.56908	2838	13098	13217	13158	-10320	5530	5543	2557	ELLE	USED	68	C	RP
171	GRA-047	8	2	35.46271	100.56908	2838	13410	13650	13530	-10692	5715	5603	2495	ELLE	USED	68	C	RP
172	GRA-047	9	2	35.46271	100.56908	2838	13604	13675	13640	-10802	5715	5603	2387	ELLE	USED	68	C	RP
173	GRA-091	1	2	35.52556	100.58914	2924	8000	8021	8011	-5087	2937	2974	1591	PENN	MULT	68	C	RP
174	GRA-091	2	2	35.52556	100.58914	2924	8735	8787	8761	-5837	3283	3210	1739	PENN	USED	68	C	RP
175	GRA-091	3	2	35.52556	100.58914	2924	8864	8890	8877	-5953	3374	3356	1833	PENN	MULT	68	C	RP
176	GRA-106	1	2	35.53701	100.62585	3046	12241	12643	12442	-9396	4075	4032	1854	VIOL	USED	79	C	RP
177	GRA-113	1	2	35.45804	100.66711	2764	10672	10855	10764	-8000	4424	4424	2210	VIOL	USED	79	C	RP
178	GRA-113	2	2	35.45804	100.66711	2764	12414	12715	12565	-9801	5127	4991	2031	ELLE	USED	79	C	RP
179	GRA-132	1	2	35.42702	100.59711	2719	12622	12655	12639	-9920	5056	5011	1798	VIOL	USED	77	C	RP
180	$HALE-006	1	1	34.11000	101.69300	3444	7864	8036	7950	-4506	3100		2649	WOLF	MULT	67	C	HP
181	HALE-006	1	3	34.11000	101.69300	3444	7864	8036	7950	-4506	3062	2979	2561	WOLF	USED	67	C	HP
182	HALE-014	1	3	33.99510	102.06630	3492	6400	6510	6455	-2963	2330	2350	2529	WICH	USED	61	B	HP
183	HALE-014	2	3	33.99510	102.06630	3492	7255	7301	7278	-3786	2750	2750	2530	WOLF	USED	61	C	HP
184	HALE-014	5	3	33.99510	102.06630	3492	9445	9473	9459	-5967	3695	3695	2560	MISS	USED	61	C	HP
185	HALE-033	1	3	33.84880	101.73599	3280	8282	8306	8294	-5014	72	72	-4843	PENN	DEPR	72	C	HP
186	HALE-034	4	2	33.89529	101.75050	3319	7992	8073	8033	-4714	2535	2605	1293	PENN	DEPR	62	C	HP
187	HALE-041	2	3	33.84599	101.83369	3343	6630	6685	6658	-3315	2440	2440	2316	WICH	USED	61	B	HP
188	HALE-041	3	3	33.84599	101.83369	3343	9128	9148	9138	-5795	3500	3450	2282	PENN	USED	61	C	HP
189	HALE-042	1	3	33.83270	101.85460	3344	6510	6535	6523	-3179	2440	2400	2452	WICH	USED	59	B	HP
190	HALE-042	4	3	33.83270	101.85460	3344	9166	9185	9176	-5832	3535	3535	2395	PENN	USED	59	C	HP
191	HALE-042	8	3	33.83270	101.85460	3344	11299	11345	11322	-7978	4345	4385	2075	MISS	USED	59	C	HP
192	HALE-049	1	2	33.84290	102.03880	3416	6690	6703	6697	-3281	2524	2598	2547	WOLF	USED	64	C	HP
193	HALE-050	1	2	33.89960	102.04111	3427	7290	7350	7320	-3893	2721	2637	2735	WOLF	USED	72	C	HP
194	HALE-071S	1	2	33.89760	102.03810	3336	6815	6844	6830	-3494	2554	2515	2400	WOLF	USED	76	C	HP
195	HALE-X02	6	2	33.91299	101.93300	3408	9903	9968	9936	-6528	3809	3733	2263	PENN	USED	70	C	HP
196	HALL-019	1	3	34.36894	100.69508	2081	5015	5030	5023	-2942	2054	2000	1799	PENN	USED	62	C	RP
197	HALL-041S	3	3	34.33302	100.41923	1695	4014	4032	4023	-2923	1934	1934	1535	PENN	USED	79	C	RP
198	$HALL-063S	1	1	34.55715	100.89093	2208	3365	3390	3378	-1170	1350		1969	WOLF	MULT	72	C	RP
199	HALL-063S	1	2	34.55715	100.89093	2208	3365	3390	3378	-1170	1263	1268	1757	WOLF	USED	72	C	RP
200	HART-010	1	2	35.98828	102.22638	3833	3495	3600	3548	285	570	570	1601	WICH	USED	74	B	HP
201	$HART-013	7	1	35.94876	102.19234	3832	4896	4940	4918	-1086	1156		1532	WOLF	USED	57	C	HP
202	$HART-016	1	1	35.96111	102.42262	3921	3916	3957	3937	-16	1313		3015	WOLF	OVER	56	C	HP
203	HART-020	1	3	35.95491	102.89333	4273	5678	5749	5714	-1441	1707	1684	2499	PENN	USED	68	C	HP
204	HART-026	1	2	35.90353	102.58322	3902	4218	4268	4243	-341	829	791	1572	WICH	USED	70	B	CR
205	HART-026	3	2	35.90353	102.58322	3902	6692	6712	6702	-2800	1850	1850	1492	PENN	MULT	70	C	CR
206	HART-026	4	2	35.90353	102.58322	3902	7472	7524	7498	-3596	2270	2226	1542	PENN	USED	70	C	CR
207	HART-029	1	2	35.90208	102.33865	3891	6478	6511	6495	-2604	65	65	-2454	PENN	UNDE	74	C	HP
208	HART-029	3	2	35.90208	102.33865	3891	6732	6808	6770	-2879	2302	2302	2453	PENN	USED	74	C	HP
209	HART-029	4	2	35.90208	102.33865	3891	4319	4391	4355	-464	792	760	1364	WOLF	USED	74	C	HP
210	HART-032S	1	2	35.89317	102.59932	3937	6298	6410	6354	-2417	1766	1756	1658	PENN	USED	80	C	CR
211	HART-034S	1	2	35.78799	102.40602	3830	7190	7218	7204	-3374	1934	1985	1039	PENN	UNDE	72	C	CR
212	HART-053S	1	2	35.80508	102.69313	3941	6700	6731	6716	-2775	1900	1872	1610	PENN	USED	80	C	HP
213	HART-056S	2	3	35.70642	102.68633	3897	3850	3894	3872	25	897	853	2095	WICH	OVER	65	B	CR
214	HART-056S	3	3	35.70642	102.68633	3897	4014	4044	4029	-132	809	809	1735	WOLF	USED	65	C	CR
215	HART-056S	4	3	35.70642	102.68633	3897	4060	4080	4070	-173	919	697	1948	WOLF	MULT	65	C	CR
216	HEM-043	3	2	35.92944	100.44853	2907	17852	18225	18039	-15132	7611	7554	2432	HUNT	USED	70	C	RP

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	FSU	TOPO
217	HEM-323	3	2	35.62505	100.51138	2962	14075	14225	14150	-11188	5642	5559	1832	HUNT	USED	72	C	RP
218	HEM-323	4	2	35.62505	100.51138	2962	15575	15732	15654	-12692	6483	6354	2281	ELLE	USED	72	C	RP
219	HEM-328	3	2	35.86411	100.22273	2275	17860	17973	17919	-15644	7378	7378	2536	HUNT	OVER	71	C	RP
220	HEM-329S	10	2	35.81020	100.46095	2681	11234	11372	11323	-8647	4675	4535	2143	PENN	USED	62	C	RP
221	HEM-329S	11	2	35.81020	100.46095	2681	10902	11050	10976	-8295	4770	4640	2713	PENN	OVER	62	C	RP
222	HEM-343S	1	2	35.70354	100.29559	2614	11227	11337	11307	-8693	4924	4924	2670	PENN	OVER	75	C	RP
223	HEM-X02	9	2	35.92023	100.22831	2300	16845	16929	16887	-14587	7961	7961	3555	MISS	OVER	70	C	RP
224	HEM-X03	4	2	35.69973	100.52106	2456	12965	12979	12972	-10516	6336	6336	4106	PENN	OVER	73	C	RP
225	HEM-X05	13	2	35.69405	100.52074	2555	13402	13446	13424	-10869	5319	5530	1436	MISS	USED	70	C	RP
226	HEM-X07	2	2	35.70782	100.52084	2869	4485	4515	4500	-1631	1303	1261	1376	WOLF	USED	72	C	RP
227	HEM-X07	3	2	35.70782	100.52084	2569	8255	8914	8590	-6021	3250	3198	1400	PENN	USED	72	C	RP
228	HEM-X09	1	2	35.94101	100.18481	2434	5448	5464	5456	-3022	2002	2005	1596	PENN	USED	72	C	RP
229	HEM-X10	1	2	35.77242	100.46272	2828	12000	12390	12195	-9367	4856	4771	1903	MISS	USED	72	C	RP
230	HEM-X11	4	2	35.89165	100.07533	2362	16820	17453	17137	-14775	7966	7831	3609	MISS	OVER	72	C	RP
231	HEM-X12	1	2	35.73938	100.29536	2520	7995	8050	8023	-5503	150	150	-5156	PENN	DEPR	74	C	RP
232	HEM-X13	2	2	35.69783	100.41943	2678	19169	19533	19351	-16673	8237	8237	2335	HUNT	USED	73	C	RP
233	HEM-X14	3	2	35.84074	100.07545	2183	9440	9523	9482	-7299	930	934	-5037	PENN	DEPR	74	C	RP
234	HEM-X16	1	2	35.64352	100.40431	2932	15255	16170	15713	-12781	6053	5973	1187	ELLE	UNDE	77	C	RP
235	HEM-X17	3	2	35.94458	100.14021	2533	12534	12998	12766	-10233	6860	6832	5598	PENN	OVER	78	C	RP
236	HEM-X17	4	2	35.94458	100.14021	2533	11114	11375	11245	-8712	3126	3155	-1493	PENN	DEPR	78	C	RP
237	HEM-X18	1	2	35.77255	100.32005	2625	10942	11095	11019	-8394	4530	4365	2176	PENN	USED	79	C	RP
238	HEM-X19	12	2	35.91895	100.09302	2440	11893	11896	11895	-9455	6300	6550	10161	PENN	OVER	64	C	RP
239	HEM-X20	6	2	35.68588	100.50658	2785	11137	11176	11157	-8372	4575	4352	2169	PENN	USED	65	C	RP
240	HEM-X20	7	2	35.68583	100.50658	2785	11518	11544	11531	-8746	5078	4966	2972	PENN	OVER	65	C	RP
241	HEM-X20	12	2	35.68588	100.50658	2785	14695	14795	14745	-11960	6431	6297	2996	VIOL	OVER	65	C	RP
242	HOC-004	1	2	33.74541	102.12000	3367	9782	10078	9930	-6563	4026	4026	2726	PENN	DEPR	68	C	HP
243	HOC-012	1	2	33.63499	102.26100	3460	6975	7062	7019	-3559	2570	2504	2372	LCF	USED	66	B	HP
244	HOC-012	2	2	33.63499	102.26100	3460	9772	9975	9874	-6414	3789	3767	2230	PENN	DEPR	65	C	HP
245	HOC-019	1	2	33.59399	102.23460	3433	9749	9757	9753	-6320	3540	3463	1649	PENN	DEPR	67	C	HP
246	HOC-019	3	2	33.59399	102.23460	3433	10060	10072	10066	-6633	2186	2199	-1538	PENN	DEPR	67	C	HP
247	HOC-021	1	2	33.55499	102.12421	3370	5969	6137	6053	-2683	2326	2237	2565	LCF	USED	67	B	HP
248	HOC-044S	1	2	33.80780	102.35240	3487	7090	7140	7115	-3628	2390	2530	2349	MICH	USED	77	B	HP
249	HOC-045S	2	2	33.77843	102.29764	3470	9064	9116	9090	-5620	3037	3153	1965	PENN	DEPR	60	C	HP
250	HOC-046S	2	2	33.80969	102.23940	3464	6890	7006	6948	-3484	2650	2695	3116	LCF	OVER	73	B	HP
251	HOC-091S	1	2	33.73933	102.21765	3430	7032	7072	7052	-3622	2541	2449	2242	MICH	USED	60	B	HP
252	HOC-091S	2	2	33.73933	102.21765	3430	9248	9304	9276	-5846	3659	3659	2595	PENN	USED	60	C	HP
253	HOC-121S	1	2	33.69780	102.23981	3411	9350	9375	9363	-5952	3722	3811	2538	PENN	USED	75	C	HP
254	HOC-121S	2	2	33.69780	102.23981	3411	9900	10070	9985	-6574	1376	1376	-3399	PENN	DEPR	75	C	HP
255	HOC-122S	1	2	33.72380	102.20917	3440	7235	7326	7281	-3841	65	65	-3691	LCF	DEPR	79	B	HP
256	HOC-131S	1	2	33.64900	102.27901	3483	6850	6933	6892	-3409	132	132	-3104	LCF	DEPR	77	B	HP
257	HOC-131S	2	2	33.64900	102.27901	3483	7030	7110	7070	-3587	2510	2403	2205	LCF	USED	77	B	HP
258	HOC-137S	1	2	33.62640	102.37830	3539	7005	7080	7043	-3504	52	52	-3304	LCF	DEPR	71	C	HP
259	HOC-137S	5	2	33.62640	102.37830	3539	8830	8991	8911	-5372	3535	3535	2786	PENN	USED	71	C	HP
260	HOC-137S	7	2	33.62640	102.37830	3539	10055	10083	10069	-6530	34	34	-6452	PENN	DEPR	71	C	HP
261	HOC-137S	10	2	33.62640	102.37830	3539	8715	8795	8755	-5216	3443	3443	2729	WOLF	USED	71	C	HP
262	HOC-139S	1	2	33.68735	102.44128	3587	4665	4774	4720	-1133	1449	1420	2209	LSA	USED	77	B	HP
263	HOC-152S	3	2	33.68449	102.22279	3430	9990	10038	10014	-6584	3330	3330	1101	PENN	DEPR	61	C	HP
264	HOC-155S	2	2	33.67261	102.14709	3391	9786	9806	9796	-6405	3946	3760	2701	PENN	DEPR	63	C	HP
265	HOC-160S	1	2	33.63229	102.57210	3654	11131	11162	11147	-7493	4332	4332	2504	MISS	USED	72	C	HP
266	HOC-182S	3	2	33.64726	102.27707	3470	9649	9664	9657	-6187	84	84	-5993	PENN	DEPR	79	C	HP
267	HOC-198S	1	2	33.57620	102.41960	3522	9424	9484	9454	-5932	3715	3535	2641	PENN	USED	62	C	HP
268	HOC-204S	1	2	33.56323	102.34200	3501	8130	8220	8175	-4674	3024	3024	2304	LCF	USED	78	B	HP
269	HOC-204S	2	2	33.56323	102.34200	3501	10075	10181	10128	-6627	113	109	-6366	PENN	DEPR	78	C	HP
270	HOC-238S	4	2	33.54491	102.40849	3519	8081	8319	8200	-4681	3227	3202	2766	WOLF	USED	72	C	HP

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFWH	FORM	STATUS	YR	HSU	TOPO
271	HOC-238S	5	2	33.54491	102.40849	3519	9169	9327	9248	-5729	3725	3726	2669	PENN	MULT	72	C	HP
272	HOC-238S	7	2	33.54491	102.40849	3519	9755	9830	9793	-6274	3779	3779	2447	PENN	USED	72	C	HP
273	HOC-248S	3	2	33.53380	102.37460	3493	7945	8045	7995	-4502	3009	2940	2442	LCF	USED	80	B	HP
274	HOC-256S	3	2	33.54543	102.31467	3490	6476	6525	6501	-3011	3317	3275	2644	LCF	USED	79	B	HP
275	HOC-259S	1	2	33.54810	102.26810	3452	6272	6315	6294	-2842	2341	2230	2551	UCF	USED	76	B	HP
276	HOC-259S	2	2	33.54810	102.26810	3452	6318	6384	6351	-2879	2392	2330	2661	UCF	MULT	76	B	HP
277	HOC-260S	1	2	33.56232	102.26877	3433	8088	8140	8114	-4676	3032	2966	2321	TUBB	USED	79	B	HP
278	HOC-262S	1	2	33.55386	102.22693	3450	6260	6553	6407	-2957	2470	2470	2744	UCF	USED	77	B	HP
279	HOC-271S	1	2	33.53720	102.12840	3349	6035	6150	6093	-2744	2240	2202	2426	UCF	USED	71	B	HP
280	HOC-271S	2	2	33.53720	102.12840	3349	7724	7808	7766	-4417	1510	1574	-932	DEAN	DEPR	71	B	HP
281	HOC-271S	3	2	33.53720	102.12840	3349	10057	10100	10054	-6735	2535	2535	-805	PENN	DEPR	71	C	HP
282	HOC-282S	1	2	33.50943	102.43745	3518	7582	7732	7657	-4139	2206	2228	952	WOLF	DEPR	77	C	HP
283	HOC-282S	2	2	33.50943	102.43745	3518	7729	7860	7795	-4277	2202	2193	805	WOLF	DEPR	77	C	HP
284	HOC-384S	5	2	33.71680	102.19580	3418	9295	9545	9420	-6002	3682	3580	2495	PENN	USED	71	C	HP
285	HOC-384S	6	2	33.71690	102.19530	3418	9965	10100	10033	-6615	2469	2469	-917	PENN	DEPR	71	C	HP
286	HOC-X04	3	2	33.52319	102.20830	3409	10141	10167	10154	-6745	2750	2750	-399	PENN	DEPR	63	C	HP
287	HOC-X04	3	2	33.52319	102.20330	3409	11495	11596	11545	-8137	4050	4050	3056	PENN	USED	65	C	HP
288	HOC-X06	1	2	33.50380	102.32539	3403	8725	8753	8739	-5336	3390	3252	2437	WOLF	DEPR	65	C	HP
289	HOC-X07	1	2	33.64261	102.24220	3442	9995	10052	10024	-6582	2555	2400	-695	PENN	DEPR	65	C	HP
290	HOC-X08	2	2	33.51660	102.25320	3425	8550	8584	8567	-5142	3826	3775	3637	LCF	OVER	67	B	HP
291	HOC-X08	4	2	33.51660	102.25320	3425	5943	6003	5973	-2548	2161	2060	2439	GLOR	USED	67	B	HP
292	HOC-X10	1	2	33.60779	102.27119	3464	8335	8433	8384	-4920	3635	3553	3515	LCF	OVER	67	B	HP
293	HOC-X11	1	2	33.72800	102.17760	3408	7871	7920	7896	-4488	3405	3435	3373	LCF	OVER	67	B	HP
294	HOC-X11	3	2	33.72800	102.17760	3408	9945	9980	9963	-6555	2313	2313	-1217	PENN	DEPR	67	C	HP
295	HOC-X12	1	2	33.66640	102.31380	3494	9354	9370	9362	-5870	3625	3625	2487	PENN	USED	67	C	HP
296	HOC-X13	1	2	33.66760	102.24200	3444	6920	6935	6928	-3484	2567	2491	2440	UCF	USED	67	B	HP
297	HOC-X13	3	2	33.66760	102.24200	3444	10030	10060	10045	-6601	2100	2167	-1570	PENN	DEPR	67	C	HP
298	HOC-X13	4	2	33.66760	102.24200	3444	10064	10069	10067	-6623	2143	2143	-1677	PENN	DEPR	67	C	HP
299	HOC-X14	1	2	33.65360	102.25140	3462	6908	6930	6919	-3457	2695	2605	2762	UCF	USED	68	B	HP
300	HOC-X14	2	2	33.66360	102.25140	3462	8010	8130	8070	-4608	3520	3520	3515	TUBB	OVER	69	B	HP
301	HOC-X15	1	2	33.72900	102.53819	3634	4688	4723	4706	-1072	1697	1545	2822	LSA	DEPR	68	B	HP
302	HOC-X16	1	2	33.72900	102.34940	3487	8032	8120	8101	-4614	3165	3059	2736	WOLF	USED	69	C	HP
303	HOC-X17	1	2	33.75500	102.23621	3418	6830	6891	6861	-3443	2591	2462	2537	UCF	USED	69	B	HP
304	HOC-X18	1	2	33.65900	102.28860	3482	7422	7459	7441	-3959	2816	2802	2540	LCF	USED	69	B	HP
305	HOC-X18	2	2	33.65900	102.28860	3482	8090	8121	8106	-4624	2955	2955	2196	WOLF	MULT	69	C	HP
306	HOC-X18	3	2	33.65900	102.28860	3482	8175	8205	8190	-4708	3094	3094	2432	WOLF	USED	69	C	HP
307	HOC-X18	4	2	33.65900	102.28860	3482	8205	8225	8215	-4733	3064	3064	2338	WOLF	MULT	69	C	HP
308	HOC-X18	5	2	33.65900	102.28860	3482	9038	9048	9043	-5561	3361	3477	2195	PENN	USED	69	C	HP
309	HOC-X18	8	2	33.65900	102.28860	3482	10081	10160	10121	-6639	2057	2057	-1092	PENN	DEPR	69	C	HP
310	HOC-X19	1	2	33.58000	102.25160	3456	10089	10095	10092	-6636	2187	2149	-1579	PENN	DEPR	69	C	HP
311	HOC-X20	1	2	33.57060	102.34360	3502	9564	9578	9571	-6069	3670	3670	2490	PENN	USED	70	C	HP
312	HOC-X21	1	2	33.60159	102.43159	3564	8546	8626	8586	-5022	3378	3357	2773	PENN	USED	71	C	HP
313	HOC-X27	2	2	33.54649	102.35651	3502	10158	10178	10168	-6666	1230	1255	-3712	PENN	DEPR	72	C	HP
314	HOC-X28	3	2	33.59620	102.27960	3464	9800	9850	9825	-6361	3661	3711	2087	PENN	DEPR	74	C	HP
315	HOC-X28	4	2	33.59620	102.27960	3464	10070	10104	10087	-6623	2694	2530	-406	PENN	DEPR	74	C	HP
316	HOC-X29	1	2	33.59171	102.28799	3455	8445	8642	8594	-5089	3752	3752	3570	WOLF	OVER	73	C	HP
317	HOC-X30	2	2	33.72090	102.30310	3464	10465	10604	10535	-7071	4265	4273	2772	PENN	USED	74	C	HP
318	HOC-X31	2	2	33.58560	102.35609	3499	7480	7600	7540	-4041	2742	2558	2207	LCF	USED	75	B	HP
319	HOC-X31	3	2	33.58560	102.35609	3499	7595	7650	7623	-4124	2825	2721	2396	LCF	MULT	75	B	HP
320	HOC-X33	1	2	33.73680	102.25121	3430	6834	6925	6880	-3450	1951	1865	1076	LCF	DEPR	76	B	HP
321	HOC-X40	1	2	33.54498	102.18040	3398	10022	10300	10161	-6763	3509	3509	1335	PENN	DEPR	77	C	HP
322	HOC-X43	2	2	33.59418	102.25008	3441	6312	6360	6336	-2895	2475	2353	2817	UCF	USED	78	B	HP
323	HOC-X43	3	2	33.59418	102.25008	3441	9750	9770	9760	-6319	3671	3671	2153	PENN	DEPR	78	C	HP
324	HOC-X43	4	2	33.59418	102.25008	3441	10055	10083	10069	-6628	3656	3676	1809	PENN	DEPR	78	C	HP

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	HSU	TOPO
325	HOC-X45	1	2	33.57442	102.34209	3510	10029	10135	10082	-6572	168	168	-6184	PENN	DEFR	79	C	HP
326	HOC-X47	1	2	33.79391	102.35266	3465	8096	8250	8173	-4708	3032	3075	2296	PENN	USED	79	C	HP
327	HOC-X50	4	2	33.51903	102.34703	3489	8596	8620	8608	-5119	3173	3115	2215	WOLF	DEFR	80	C	HP
328	HOC-X50	5	2	33.51903	102.34703	3489	10226	10350	10288	-6799	3144	3123	456	PENN	DEFR	80	C	HP
329	HOC-X51	1	2	33.50293	102.40446	3499	5020	5254	5137	-1638	1982	1962	2935	LSA	USED	80	B	HP
330	HOC-X52	1	2	33.63573	102.24564	3425	9728	9745	9737	-6312	3645	3591	2100	PENN	DEFR	81	C	HP
331	HOC-X52	2	2	33.63573	102.24564	3425	10027	10080	10054	-6629	3767	3727	2065	PENN	DEFR	81	C	HP
332	HOC-X53	2	2	33.64117	102.12801	3383	11315	11530	11423	-8040	4821	4745	3026	PENN	USED	81	C	HP
333	HUT-023	1	2	35.93967	101.43996	3343	3640	3727	3684	-341	542	542	910	WOLF	DEFR	72	C	HP
334	HUT-031	1	2	35.93558	101.10135	2701	8022	8355	8189	-5488	655	645	-3976	PENN	UNDE	74	C	CR
335	HUT-048	2	3	35.65050	101.30714	3076	3295	3343	3319	-243	460	459	837	WOLF	UNDE	69	C	CR
336	HUT-048	4	3	35.65050	101.30714	3076	3412	3430	3421	-345	456	469	707	PENN	DEFR	69	C	CR
337	HUT-048	5	3	35.65050	101.30714	3076	3300	3330	3815	-739	671	685	809	PENN	DEFR	69	C	CR
338	HUT-048	6	3	35.65050	101.30714	3076	5012	5080	5046	-1970	1526	1539	1552	ELLE	USED	69	C	CR
339	HUT-048	7	3	35.65050	101.30714	3076	4740	4780	4760	-1684	1446	1459	1653	VIOL	USED	69	C	CR
340	HUT-128	1	2	35.66576	101.12592	2984	6154	6240	6197	-3213	2057	2067	1557	PENN	USED	73	C	CR
341	HUT-146S	1	2	35.90041	101.21147	2918	9225	9452	9339	-6421	3630	3530	1957	ELLE	USED	68	C	CR
342	HUT-147S	7	3	35.68958	101.19276	3049	5222	5235	5229	-2180	1430	1430	1121	PENN	USED	60	C	CR
343	HUT-148S	1	2	35.94795	101.46632	3320	3760	3791	3776	-456	641	619	1024	WOLF	USED	73	C	HP
344	HUT-X05	1	2	35.64778	101.11283	3260	7975	8032	8004	-4744	2739	2739	1577	MISS	USED	78	C	CR
345	HUT-X05	2	3	35.64778	101.11288	3006	4795	4845	4820	-1814	1304	1304	1195	PENN	USED	59	C	CR
346	HUT-X06	1	3	35.80241	101.20595	2727	4725	4766	4746	-2019	1475	1435	1305	PENN	USED	61	C	CR
347	HUT-X10	2	3	35.68703	101.18256	3039	5410	5435	5423	-2384	1500	1500	1078	PENN	USED	68	C	CR
348	HUT-X12	1	3	35.98103	101.09531	2798	5278	5314	5296	-2498	1670	1679	1356	PENN	USED	64	C	CR
349	HUT-X12	3	3	35.98103	101.09531	2798	8255	8296	8276	-5478	3021	2914	1494	PENN	MULT	64	C	CR
350	HUT-X13	5	3	35.75259	101.26900	2939	6838	6931	6885	-3946	2405	2400	1605	PENN	USED	53	C	CR
351	HUT-X14	4	3	35.99069	101.25893	3201	4922	4932	4952	-1751	1270	1237	1160	PENN	USED	67	C	CR
352	HUT-X15	1	3	35.67603	101.15234	3007	4930	4978	4954	-1947	1311	1311	1076	PENN	DEFR	67	C	CR
353	HUT-X15	2	3	35.67603	101.15234	3007	5962	5991	5977	-2970	1865	1900	1334	PENN	USED	67	C	CR
354	KIN-004S	1	2	33.71600	100.10640	1835	6095	6110	6103	-4268	2500	2440	1501	MISS	USED	74	C	RP
355	KIN-031S	1	2	33.58690	100.10640	1684	4802	4817	4810	-3126	1850	1850	1143	PENN	USED	75	C	RP
356	KIN-037S	2	2	33.56540	100.08980	1735	5400	5428	5414	-3679	2200	2200	1398	MISS	DEFR	72	C	RP
357	KIN-038S	1	2	33.81200	100.22500	1812	3945	3952	3949	-2137	1702	1702	1791	PENN	USED	76	C	RP
358	KIN-042S	1	2	33.79359	100.28180	1881	4220	4267	4243	-2362	1747	1747	1670	PENN	USED	74	C	RP
359	KIN-043S	2	2	33.78380	100.01760	1626	5900	5990	5945	-4319	2511	2365	1476	MISS	USED	68	C	RP
360	KIN-X01	1	2	33.74319	100.02759	1740	5666	5695	5681	-3941	2405	2375	1609	MISS	USED	59	C	RP
361	KIN-X02	1	2	33.83141	100.19160	1840	4454	4460	4457	-2617	1830	1800	1606	PENN	USED	68	C	RP
362	KIN-X04	3	2	33.56540	100.19040	1810	5455	5465	5460	-3650	2120	2120	1242	MISS	DEFR	70	C	RP
363	KIN-X05	2	2	33.53740	100.19160	1810	5256	5293	5275	-3465	2149	2149	1494	MISS	DEFR	69	C	RP
364	KIN-X06	3	2	33.53329	100.16930	1810	5440	5458	5449	-3639	2164	2075	1401	MISS	DEFR	71	C	RP
365	KIN-X07	1	2	33.54250	100.19620	1825	5230	5238	5234	-3409	2170	2160	1599	PENN	USED	70	C	RP
366	KIN-X07	3	2	33.54250	100.19620	1825	5328	5348	5338	-3513	2190	2150	1541	MISS	DEFR	70	C	RP
367	KIN-X08	1	2	33.50861	100.06320	1705	5177	5198	5188	-3483	2075	2040	1352	PENN	MULT	71	C	RP
368	KIN-X08	3	2	33.50861	100.06320	1705	5388	5401	5395	-3690	2300	2260	1618	PENN	MULT	71	C	RP
369	KIN-X08	4	2	33.50861	100.06320	1705	5416	5426	5421	-3716	2295	2205	1580	PENN	USED	71	C	RP
370	KIN-X08	5	2	33.50861	100.06320	1705	5433	5440	5437	-3732	2340	2270	1668	PENN	MULT	71	C	RP
371	KIN-X09	2	2	33.53481	100.17500	1870	5425	5450	5438	-3568	2019	2019	1091	MISS	DEFR	71	C	RP
372	KIN-X09	3	2	33.53481	100.17500	1870	5450	5460	5455	-3585	1828	1855	633	MISS	DEFR	71	C	RP
373	KIN-X10	1	2	33.59261	100.18480	1750	5246	5262	5254	-3504	2180	2180	1527	MISS	USED	71	C	RP
374	KIN-X12	1	2	33.72970	100.24699	1795	4069	4099	4084	-2289	1690	1690	1611	WOLF	USED	72	C	RP
375	KIN-X12	2	2	33.72990	100.24699	1795	4379	4398	4389	-2594	1858	1858	1694	PENN	USED	72	C	RP
376	KIN-X13	1	2	33.72960	100.24040	1775	4053	4075	4064	-2289	1663	1663	1548	WOLF	USED	72	C	RP
377	KIN-X15	2	2	33.83470	100.14030	1713	6088	6150	6119	-4406	2626	2646	1654	MISS	DEFR	74	C	RP
378	KIN-X17	3	2	33.59320	100.11050	1652	5786	5796	5791	-4139	2200	2200	938	MISS	UNDE	75	C	RP

MASTER FILE

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OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFWH	FORM	STATUS	YR	MSU	TOPO
379	KIN-X20	4	2	33.50920	100.08000	1823	5296	5320	5308	-3485	2158	2158	1995	PENN	USED	76	C	RP
380	KIN-X21	1	2	33.57103	100.13245	1855	5468	5476	5472	-3617	2105	2105	1241	MISS	UNDE	77	C	RP
381	KIN-X21	2	2	33.57103	100.13245	1855	5516	5524	5520	-3665	2230	2230	1431	MISS	USED	77	C	RP
382	KIN-X22	1	2	33.53200	100.06456	1685	4288	4310	4299	-2614	1801	1801	1542	PENN	USED	78	C	RP
383	KIN-X23	3	2	33.54070	100.18733	1833	5449	5465	5457	-3624	705	773	-1810	MISS	DEPR	79	C	RP
384	KIN-X24	1	2	33.51431	100.05388	1805	5179	5193	5186	-3381	2066	2056	1307	PENN	DEPR	78	C	RP
385	KIN-X25	1	2	33.60204	100.25946	1677	5336	5343	5340	-3663	2094	2094	1170	MISS	DEPR	80	C	RP
386	KIN-X26	1	2	33.73759	100.35098	1945	4120	4140	4130	-2185	1655	1655	1634	PENN	USED	80	C	RP
387	KIN-X27	1	2	33.69110	100.20697	1730	4000	4134	4067	-2337	1702	1704	1591	WOLF	USED	80	C	RP
388	KIN-X27	3	2	33.69110	100.20697	1730	5325	5397	5361	-3631	2430	2430	2092	PENN	OVER	80	C	RP
389	KIN-X27	4	2	33.69110	100.20697	1730	5509	5591	5550	-3820	2349	2349	1601	PENN	USED	80	C	RP
390	LAM-001	1	2	34.25360	102.57680	3741	8420	8587	8504	-4763	3168	3163	2548	MISS	USED	71	C	HP
391	LAM-024	1	3	33.99210	102.18140	3530	6265	6350	6309	-2778	2297	2260	2528	WICH	USED	65	B	HP
392	LAM-024	2	3	33.99210	102.18140	3530	8105	8150	8128	-4598	3103	3083	2563	PENN	USED	65	C	HP
393	LAM-027	2	3	34.03999	102.23840	3583	3780	3850	3815	-232	1271	1195	2701	LSA	USED	67	B	HP
394	LAM-098	1	2	33.83659	102.30540	3486	6691	6762	6727	-3241	2001	2773	3223	WOLF	OVER	65	C	HP
395	LAM-105	1	2	33.86230	102.24899	3453	6705	6770	6738	-3285	2394	2369	2240	WOLF	MULT	71	C	HP
396	LAM-105	2	3	33.86230	102.24899	3453	8260	8335	8298	-4845	3253	3253	2662	WOLF	MULT	71	C	HP
397	LAM-105	3	3	33.86230	102.24899	3453	8090	8122	8106	-4653	3117	3117	2540	WOLF	USED	71	C	HP
398	LAM-116	2	2	33.85800	102.11510	3452	6250	6315	6283	-2831	2730	2636	3470	WOLF	OVER	[illegible]	C	HP
399	LAM-116	3	2	33.85800	102.11510	3452	8070	8100	8085	-4633	3111	3111	2575	PENN	USED	70	C	HP
400	LAM-116	4	2	33.85800	102.11510	3452	8385	8522	8454	-5002	3300	3300	2514	PENN	MULT	70	C	HP
401	LAM-116	5	2	33.85800	102.11510	3452	8730	8845	8788	-5336	3412	3346	2533	PENN	MULT	70	C	HP
402	LAM-134S	1	2	33.84642	102.31546	3465	6685	6743	6714	-3249	2427	2437	2352	WOLF	USED	80	C	HP
403	LAM-143S	1	2	33.83701	102.31520	3481	6680	6747	6714	-3233	2363	2301	2232	WOLF	MULT	77	C	HP
404	LAM-143S	2	2	33.83701	102.31520	3481	7352	7404	7378	-3897	2784	2784	2528	WOLF	USED	77	C	HP
405	LAM-143S	3	2	33.83701	102.31520	3481	7743	7800	7774	-4293	2857	2859	2305	WOLF	MULT	77	C	HP
406	LAM-143S	4	2	33.83701	102.31520	3481	7795	7950	7873	-4392	3054	3054	2656	WOLF	MULT	77	C	HP
407	LAM-155S	1	2	33.96222	102.17224	3535	6456	6522	6489	-2954	2396	2343	2575	WOLF	USED	80	C	HP
408	LUB-004S	2	2	33.76500	101.94200	3313	10038	10062	10050	-6737	4053	4079	2628	PENN	USED	76	C	HP
409	LUB-005S	2	2	33.75937	101.93387	3344	7128	7313	7221	-3877	2742	2742	2451	SPRA	USED	77	B	HP
410	LUB-005S	5	2	33.75937	101.93387	3344	6293	6350	6322	-2978	1954	1925	1532	LCF	DEPR	77	B	HP
411	LUB-007S	2	2	33.75000	101.75940	3285	9280	9325	9303	-6018	80	80	-5333	PENN	DEPR	73	C	HP
412	LUB-007S	3	2	33.75000	101.75940	3285	9260	9600	9430	-6145	309	322	-5432	PENN	DEPR	73	C	HP
413	LUB-008S	1	2	33.74020	101.70461	3249	6490	6578	6534	-3285	2390	2442	2230	SPRA	USED	77	B	HP
414	LUB-009S	1	3	33.73480	101.69960	3237	9296	9314	9305	-6068	3624	3647	2295	PENN	USED	72	C	HP
415	LUB-016S	1	3	33.66950	102.05950	3358	4368	4475	4421	-1063	105	105	-820	LSA	UNDE	58	B	HP
416	LUB-026S	1	2	33.54030	101.70239	3118	5780	5810	5795	-2677	2225	2137	2453	LCF	USED	65	B	HP
417	LUB-X01	1	2	33.74425	101.95341	3338	7103	7185	7144	-3806	2634	2652	2272	SPRA	USED	78	B	HP
418	LUB-X01	2	2	33.74425	101.95341	3338	9894	9926	9910	-6572	3753	3804	2089	PENN	USED	78	C	HP
419	LUB-X02	1	2	33.68744	101.94060	3319	7029	7074	7052	-3733	2722	2643	2549	SPRA	USED	73	B	HP
420	LUB-X03	2	2	33.71442	101.74454	3239	6570	6690	6630	-3391	2514	2471	2411	SPRA	USED	79	B	HP
421	LUB-X04	1	2	33.62344	101.65224	3140	5369	5550	5460	-2320	2061	2008	2437	UCF	USED	80	B	HP
422	LUB-X05	3	2	33.72986	101.70850	3239	9255	9320	9288	-6049	3490	3424	2005	PENN	DEPR	77	C	HP
423	LUB-X06	1	2	33.63820	102.02380	3295	9895	9942	9919	-6624	3833	3491	2221	PENN	DEPR	66	C	HP
424	LUB-X07	2	2	33.70540	101.75459	3250	9276	9311	9294	-6044	3673	3724	2433	PENN	USED	67	C	HP
425	LUB-X08	3	2	33.73462	101.95801	3318	7510	7556	7533	-4215	2833	2053	2369	DEAN	USED	80	B	HP
426	LUB-X09	1	2	33.56441	102.06740	3321	9995	10047	10021	-6700	3848	3809	2181	PENN	DEPR	65	C	HP
427	LUB-X10	2	2	33.67000	102.02921	3320	6412	6657	6535	-3215	2484	2434	2518	LCF	USED	69	B	HP
428	LUB-X10	3	2	33.67000	102.02921	3320	5661	5836	5749	-2429	2061	1976	2327	LCF	USED	69	B	HP
429	LUB-X11	1	2	33.72060	101.73000	3246	5550	5586	5568	-2322	2166	2090	2676	UCF	USED	69	B	HP
430	LUB-X12	1	2	33.53540	102.07660	3319	6035	6150	6093	-2774	2347	2319	2642	LCF	USED	68	B	HP
431	LUB-X13	1	2	33.61920	102.07060	3337	5808	5894	5851	-2514	2114	2045	2391	UCF	USED	67	B	HP
432	LUB-X14	1	3	33.79630	101.92020	3356	6230	6350	6290	-2934	2207	2099	2160	LCF	DEPR	75	B	HP

MASTER FILE

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OBS	SHECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFWH	FORM	STATUS	YR	HSU	TOPO
433	LUB-X15	1	3	33.82200	101.86700	3340	6287	6320	6303	-2963	2935	2935	3812	LCF	OVER	69	B	HP
434	LUB-X15	3	3	33.82200	101.86700	3340	8963	9003	8983	-5643	1611	1661	-1925	PENN	DEFR	69	C	HP
435	LUB-X15	4	3	33.82200	101.86700	3340	11222	11242	11232	-7892	4697	4590	2947	MISS	USED	69	C	HP
436	LUB-X16	1	3	33.65160	101.85850	3231	5070	5140	5105	-1874	80	80	-1689	CLCR	DEFR	57	B	HP
437	LUB-X17	2	3	33.72580	101.82020	3295	6050	6163	6106	-2811	2255	2255	2162	LCF	USED	59	B	HP
438	LUB-X18	2	3	33.67670	101.77170	3230	9328	9368	9348	-6118	3652	3652	2310	PENN	USED	62	C	HP
439	LUB-X18	4	3	33.67670	101.77170	3230	9975	10020	9997	-6767	4052	4052	2584	PENN	MULT	62	C	HP
440	LUB-X19	1	3	33.68050	101.79760	3260	7456	7526	7491	-4231	2920	2692	2645	WOLF	USED	63	C	HP
441	LUB-X20	1	3	33.54820	101.61170	3106	4524	4622	4573	-1467	1671	1502	2389	GLCR	DEFR	67	B	HP
442	LUB-X21	2	3	33.54960	102.06760	3300	6008	6119	6058	-2758	2394	2327	2767	UCF	DEFR	67	B	HP
443	MOO-042	1	3	35.68931	101.83229	3451	3246	3406	3326	125	293	293	685	WOLF	DEFR	69	C	CR
444	MOT-001	1	3	34.23810	100.91769	2301	8014	8094	8054	-5753	3130	3120	1470	PENN	UNDE	57	C	RP
445	MOT-039	1	3	33.87570	100.92550	2757	4770	4790	4780	-2023	1630	1630	1739	WOLF	USED	61	C	RP
446	MOT-048	1	2	33.87421	100.68761	2237	5274	5356	5315	-3078	2106	2106	1732	PENN	USED	73	C	RP
447	MOT-048	2	2	33.87421	100.68761	2237	5248	5274	5261	-3024	2071	2044	1755	PENN	MULT	73	C	RP
448	MOT-089S	1	3	33.59349	100.78900	2529	4248	4295	4272	-1743	790	790	81	WOLF	DEFR	62	C	RP
449	MOT-089S	3	3	33.69349	100.78900	2529	4345	4380	4363	-1834	1520	1520	1674	WOLF	USED	62	C	RP
450	MOT-094S	1	3	33.69561	100.78900	2535	4281	4331	4305	-1770	1364	1402	1373	WOLF	DEFR	70	C	RP
451	$OLD-004	1	1	35.59621	102.65120	3553	3446	3471	3459	94	783		1991	WOLF	MULT	61	C	CR
452	OLD-004	1	3	35.59621	102.65120	3553	3446	3471	3459	94	770	725	1845	WOLF	USED	61	C	CR
453	$OLD-048	1	1	35.40704	102.34653	3600	5340	5367	5354	-1754	1540		1801	WOLF	USED	69	C	CR
454	OLD-063	1	2	35.32053	102.37709	3905	7272	7312	7292	-3387	2152	2086	1579	WOLF	USED	69	C	CR
455	OLD-103S	2	2	35.36581	102.35529	3709	6714	6735	6725	-3016	2218	2283	2255	PENN	USED	80	C	CR
456	OLD-111S	2	2	35.25681	102.40025	3949	7120	7210	7165	-3216	2411	2411	2348	PENN	USED	80	C	HP
457	OLD-111S	3	2	35.25681	102.40025	3949	8314	8348	8331	-4382	2899	2772	2303	PENN	MULT	80	C	HP
458	OLD-111S	4	2	35.25681	102.40025	3949	7646	7770	7708	-3759	2562	2502	2153	PENN	MULT	80	C	HP
459	OLD-111S	5	2	35.25681	102.40025	3949	7090	7202	7146	-3197	2267	2267	2035	PENN	MULT	80	C	HP
460	OLD-112S	1	2	35.19295	102.33081	3966	7318	7334	7326	-3360	2419	2419	2222	PENN	USED	80	C	HP
461	OLD-112S	2	2	35.19295	102.33081	3966	7036	7145	7091	-3125	2217	2083	1992	PENN	MULT	80	C	HP
462	OLD-116S	2	2	35.36060	102.42160	3830	6172	6227	6200	-2370	2016	2016	2203	WOLF	USED	81	C	CR
463	OLD-117S	1	2	35.33220	102.44275	3884	6630	6660	6645	-2761	1970	1895	1725	PENN	DEFR	81	C	CR
464	OLD-118S	1	2	35.32747	102.22202	3544	7000	7028	7014	-3470	2354	2394	1982	PENN	MULT	81	C	CR
465	OLD-118S	2	2	35.32747	102.22202	3544	7125	7175	7150	-3606	2554	2516	2288	PENN	USED	81	C	CR
466	*OLD-121S	1	1	35.39750	102.39630	3687	4800	4996	4898	-1211	1322		1840	WOLF	MULT	82	C	CR
467	*OLD-121S	1	2	35.39750	102.39630	3687	4800	4996	4898	-1211	1292	1298	1771	WOLF	USED	82	C	CR
468	*OLD-121S	6	2	35.39750	102.39630	3687	6612	6640	6626	-2939	2216	2219	2175	PENN	DEFR	82	C	CR
469	*OLD-121S	7	2	35.39750	102.39630	3687	4812	4840	4826	-1139	1376	1361	2037	WOLF	MULT	82	C	CR
470	POT-026	1	3	35.42839	101.62508	3540	3600	3646	3623	-83	71	71	81	WOLF	DEFR	64	C	CR
471	POT-026	2	3	35.42839	101.62508	3540	3907	4050	3979	-439	800	800	1498	WOLF	USED	64	C	CR
472	POT-026	3	3	35.42839	101.62508	3540	5652	5710	5681	-2141	1634	1612	1530	PENN	USED	64	C	CR
473	POT-039	2	3	35.24370	101.86406	3577	4047	4077	4062	-485	872	872	1527	WOLF	USED	64	C	CR
474	*RAN-048S	1	1	34.77700	101.65700	3624	1718	1764	1741	1883	683		3459	QU/G	MULT	83	B	HP
475	*RAN-048S	1	3	34.77700	101.65700	3624	1718	1764	1741	1883	657	673	3420	QU/G	USED	83	B	HP
476	RAN-X01	1	3	34.97224	102.14690	3777	5340	5361	5351	-1574	1530	1550	2003	WOLF	USED	61	C	HP
477	ROB-034	1	2	35.77917	100.81905	2862	7459	7524	7492	-4630	2683	2683	1552	PENN	USED	63	C	CR
478	ROB-105S	3	2	35.85722	100.60190	2840	6985	7055	7020	-4180	2330	2365	1197	PENN	USED	72	C	CR
479	ROB-105S	5	2	35.85722	100.60190	2840	11943	12043	11993	-9153	5493	5397	3523	PENN	OVER	72	C	CR
480	ROB-127	2	2	35.95889	100.65256	2537	9355	9462	9409	-6872	4256	4524	4335	PENN	OVER	68	C	CR
481	ROB-127	3	2	35.95889	100.65256	2537	9583	9587	9585	-7048	4294	4272	2861	PENN	OVER	68	C	CR
482	ROB-158	1	2	35.88884	100.98886	2675	3400	3622	3511	-836	963	963	1325	WOLF	USED	72	C	CR
483	ROB-158	2	2	35.88884	100.98886	2675	5570	5626	5598	-2923	1865	1887	1331	PENN	USED	72	C	CR
484	ROB-158	3	2	35.88884	100.98886	2675	6888	6907	6898	-4223	2364	2364	1233	PENN	MULT	72	C	CR
485	ROB-158	6	2	35.88884	100.98886	2675	7958	8030	7994	-5319	2936	2809	1455	PENN	MULT	72	C	CR
486	ROB-158	8	2	35.88884	100.98886	2675	10590	10660	10625	-7950	4475	4209	2377	MISS	USED	72	C	CR

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	HSU	TOPO
487	ROB-158	9	2	35.88884	100.98886	2675	10912	11119	11016	-8341	4475	4475	1986	HUNT	USED	72	C	CR
488	ROB-158	11	2	35.88884	100.98886	2675	11348	11575	11462	-8787	4587	4587	1799	VIOL	USED	72	C	CR
489	ROB-158	12	2	35.88884	100.98886	2675	11778	12040	11909	-9234	4059	4059	1979	ELLE	USED	72	C	CR
490	ROB-158	13	2	35.88884	100.98886	2675	11135	11205	11170	-8495	4311	4204	1453	SYLV	USED	72	C	CR
491	ROB-195	1	2	35.63303	100.78278	2897	7989	8119	8054	-5157	2659	2764	1454	PENN	USED	76	C	CR
492	ROB-207	1	2	35.79111	100.94926	2974	3877	3895	3886	-912	867	854	1069	WOLF	USED	72	C	CR
493	ROB-288	1	2	35.68736	100.62923	2782	13665	14176	13921	-11139	5504	5526	1973	ELLE	USED	74	C	CR
494	ROB-288	2	2	35.68736	100.62923	2782	10613	10695	10654	-7872	4192	4305	1802	PENN	USED	74	C	CR
495	ROB-288	3	2	35.68736	100.62923	2782	14110	14552	14331	-11549	5210	5095	2039	ELLE	USED	74	C	CR
496	ROB-296	1	2	35.63859	101.02202	3145	4746	4890	4818	-1673	1298	1278	1322	PENN	MULT	70	C	CR
497	ROB-296	2	2	35.63859	101.02202	3145	6976	7014	6995	-3850	2317	2240	1497	PENN	USED	70	C	CR
498	ROB-X01	3	2	35.95763	100.59830	2492	10017	10017	10017	-7525	4400	4230	2627	MISS	OVER	62	C	CR
499	ROB-X02	1	2	35.72098	100.63739	3103	9430	9491	9461	-6358	3652	3310	2070	PENN	USED	62	C	HP
500	ROB-X03	2	2	35.83091	100.65179	2832	11000	11066	11033	-8201	5023	5023	3391	MISS	OVER	73	C	CR
501	ROB-X04	2	2	35.97356	100.76892	2466	3903	3920	3912	-1446	1226	1229	1334	WOLF	USED	69	C	CR
502	ROB-X04	3	2	35.97356	100.76892	2466	11612	12140	11876	-9410	4911	4911	1923	MISS	USED	67	C	CR
503	ROB-X05	1	2	35.95131	100.72549	2548	9494	9556	9525	-6977	2946	2959	-179	PENN	DEPR	70	C	CR
504	ROB-X07	1	2	35.92477	100.77206	2710	6165	6228	6197	-3487	2005	1936	1139	PENN	USED	71	C	CR
505	ROB-X08	1	2	35.76906	100.75844	3045	8060	8120	8090	-5045	2913	2915	1682	PENN	USED	70	C	CR
506	ROB-X08	2	2	35.76906	100.75844	3045	10845	10905	10875	-7830	4335	4244	2174	MISS	USED	70	C	CR
507	ROB-X08	3	2	35.76906	100.75844	3045	12750	13000	12875	-9830	5457	5401	2763	SYLV	OVER	70	C	CR
508	ROB-X08	4	2	35.76906	100.75844	3045	5313	5350	5332	-2287	1607	1607	1422	PENN	MULT	70	C	CR
509	ROB-X09	3	2	35.90337	100.77220	2679	5867	5898	5883	-3204	2017	2017	1451	PENN	USED	72	C	CR
510	ROB-X09	5	2	35.90337	100.77220	2679	6094	6108	6101	-3422	1862	1832	815	PENN	DEPR	72	C	CR
511	ROB-X10	3	2	35.90668	100.60910	2627	12011	12140	12076	-9449	5597	5652	3468	MISS	OVER	72	C	CR
512	ROB-X13	1	2	35.87206	100.74158	2877	6125	6186	6156	-3279	1981	1981	1293	PENN	USED	72	C	CR
513	ROB-X14	3	2	35.71185	100.73759	3020	6432	6466	6449	-3429	1643	1620	353	PENN	DEPR	72	C	CR
514	ROB-X15	1	2	35.74036	100.56653	2635	4081	4095	4088	-1453	1123	1123	1139	WICH	DEPR	75	B	CR
515	ROB-X15	2	2	35.74036	100.56653	2635	6181	6235	6208	-3573	104	102	-3333	PENN	DEPR	75	C	CR
516	ROB-X17	2	2	35.74315	100.73807	3129	6428	6472	6450	-3321	1849	1772	944	PENN	DEPR	75	C	CR
517	ROB-X17	3	2	35.74315	100.73807	3129	4268	4283	4276	-1147	943	955	1030	WOLF	USED	75	C	CR
518	ROB-X18	2	2	35.76607	100.70032	3013	4004	4090	4047	-1034	1258	1259	1092	WOLF	USED	75	C	CR
519	ROB-X19	1	2	35.94345	100.68839	2498	9631	9662	9647	-7149	3162	3199	148	PENN	DEPR	75	C	CR
520	ROB-X21	2	2	35.80820	100.72243	2976	8991	9095	9043	-6067	3113	2967	1117	PENN	USED	75	C	CR
521	ROB-X22	1	2	35.74333	100.76569	3057	6270	6500	6385	-3328	1777	1799	773	PENN	DEPR	77	C	HP
522	ROB-X23	3	2	35.88347	100.73007	2690	9598	9636	9617	-6927	3222	3195	508	PENN	DEPR	78	C	CR
523	ROB-X24	1	2	35.78105	100.68777	2984	9712	9963	9838	-6854	3727	3772	1747	PENN	USED	75	C	CR
524	ROB-X25	1	2	35.94574	100.62715	2560	5088	5138	5113	-2553	1917	1774	1640	PENN	USED	73	C	CR
525	ROB-X26	1	2	35.65013	100.93552	3211	9219	9239	9229	-6018	2187	2167	-971	PENN	USED	78	C	HP
526	ROB-X27	1	2	35.96790	100.92705	2538	8830	8892	8861	-6323	3267	3092	1216	PENN	USED	60	C	CR
527	ROB-X28	1	2	35.88043	100.99301	2733	7664	7830	7747	-5014	2676	2781	1161	PENN	MULT	60	C	CR
528	ROB-X28	2	2	35.88043	100.99301	2733	8105	8136	8121	-5388	2374	2308	1245	PENN	USED	60	C	CR
529	ROB-X29	2	2	35.86687	100.94113	2900	7870	7897	7884	-4984	2742	2770	1394	PENN	USED	60	C	CR
530	ROB-X29	3	2	35.86687	100.94113	2900	8069	8108	8089	-5189	2942	2954	1600	PENN	MULT	60	C	CR
531	ROB-X30	1	2	35.87158	100.93640	2874	8040	8112	8076	-5202	2902	2928	1495	PENN	USED	62	C	CR
532	ROB-X30	3	2	35.87158	100.93640	2874	3745	3775	3760	-886	887	850	1161	WOLF	USED	60	C	CR
533	ROB-X32	1	2	35.93207	100.89613	2660	4325	4355	4340	-1680	1341	1323	1415	WOLF	USED	66	C	CR
534	ROB-X34	2	2	35.92056	100.72594	2663	9280	9505	9393	-6730	305	305	-6026	PENN	DEPR	68	C	CR
535	ROB-X34	3	2	35.92056	100.72594	2663	9540	9656	9598	-6935	3034	3119	102	PENN	DEPR	69	C	CR
536	$SHI-008	1	1	34.55617	101.90129	3591	5765	5796	5781	-2190	1945		2300	WOLF	USED	61	C	HP
537	*SHI-025S	5	1	34.53120	101.68000	3405	2927	2972	2950	455	1253		3340	LSA4	MULT	62	B	HP
538	*SHI-025S	5	2	34.53120	101.68000	3405	2927	2972	2950	455	1260	1189	3363	LSA4	USED	62	B	HP
539	*SHI-025S	6	1	34.53120	101.68000	3405	5365	5542	5453	-2048	1875		2279	WOLF	MULT	62	C	HP
540	*SHI-025S	6	3	34.53120	101.68000	3405	5365	5542	5453	-2048	1057	1041	2238	WOLF	USED	62	C	HP

MASTER FILE

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OBS	SHECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	HSU	TOPO
541	*SHI-025S	7	1	34.53120	101.68000	3405	7146	7225	7186	-3781	2539		2124	PENN	MULT	82	C	HP
542	*SHI-025S	7	2	34.53120	101.68000	3405	7146	7225	7186	-3781	2516	2492	2026	PENN	USED	82	C	HP
543	*SHI-026S	1	1	34.65000	101.80900	3525	2840	2906	2873	652	1203		3428	LSA4	MULT	82	B	HP
544	*SHI-026S	1	2	34.65000	101.80900	3525	2840	2906	2873	652	1142	1127	3280	LSA4	USED	82	B	HP
545	*SHI-026S	2	1	34.65000	101.80900	3525	2830	3050	2940	585	1315		3620	LSA4	MULT	82	B	HP
546	*SHI-026S	2	2	34.65000	101.80900	3525	2830	3050	2940	585	1254	1220	3479	LSA4	MULT	82	B	HP
547	WHE-008	1	2	35.59551	100.11754	2546	11026	11139	11082	-8536	2349	2317	-3115	PENN	DEPR	72	C	RP
548	WHE-008	3	2	35.59551	100.11754	2546	13805	13918	13862	-11316	2025	1951	-6609	PENN	DEPR	72	C	RP
549	WHE-023	5	2	35.57947	100.51733	2816	10694	10710	10702	-7886	4032	4070	1419	PENN	MULT	72	C	RP
550	WHE-023	6	2	35.57947	100.51733	2816	11254	11280	11267	-8451	3439	3653	-515	PENN	DEPR	72	C	RP
551	WHE-023	7	2	35.57947	100.51733	2816	11690	11758	11724	-8908	4379	4531	2351	PENN	OVER	72	C	RP
552	WHE-023	9	2	35.57947	100.51733	2816	12175	12250	12212	-9396	5102	5102	2378	MISS	USED	72	C	RP
553	WHE-023	10	2	35.57947	100.51733	2816	13428	13592	13510	-10694	5432	5138	1241	ELLE	USED	72	C	RP
554	WHE-023	11	2	35.57947	100.51733	2816	13592	13864	13728	-10912	5336	5407	2555	ELLE	USED	72	C	RP
555	WHE-023	12	2	35.57947	100.51733	2816	6295	6330	6312	-3496	2134	2097	1429	PENN	USED	72	C	RP
556	WHE-026	2	2	35.53531	100.50892	2694	6580	6621	6601	-3907	2352	2352	1522	PENN	MULT	77	C	RP
557	WHE-026	4	2	35.53531	100.50892	2694	7580	7602	7591	-4897	2795	2795	1555	PENN	MULT	77	C	RP
558	WHE-026	6	2	35.53531	100.50892	2694	11337	11366	11352	-8658	4479	4457	1679	PENN	USED	77	C	RP
559	WHE-026	8	2	35.53531	100.50892	2694	11894	11914	11904	-9210	5017	5017	2368	PENN	OVER	77	C	RP
560	WHE-026	10	2	35.53531	100.50892	2694	12301	12376	12339	-9645	5207	5165	2371	MISS	USED	77	C	RP
561	WHE-031	3	2	35.51397	100.43633	2618	9148	9375	9261	-6643	3601	3601	1352	PENN	USED	66	C	RP
562	WHE-031	4	2	35.51397	100.43633	2618	10985	11057	11021	-8403	4557	4453	2113	PENN	MULT	66	C	RP
563	WHE-031	6	2	35.51397	100.43633	2618	11795	11893	11844	-9226	5303	5303	3012	MISS	OVER	66	C	RP
564	WHE-031	7	2	35.51397	100.43633	2618	11500	11991	11745	-9127	5293	5293	3068	MISS	OVER	66	C	RP
565	WHE-069	1	2	35.32969	100.21597	2251	4514	4579	4546	-2295	1536	1603	1345	PENN	USED	71	C	RP
566	WHE-069	3	2	35.32969	100.21597	2251	5482	5492	5487	-3236	1930	1874	1236	PENN	MULT	71	C	RP
567	WHE-127S	2	2	35.48495	100.34745	2595	12975	13025	13000	-10405	4955	5046	1030	MISS	UNDE	71	C	RP
568	WHE-127S	5	2	35.48495	100.34745	2595	13387	13468	13428	-10833	5603	5743	2293	MISS	USED	71	C	RP
569	WHE-X01	3	2	35.53262	100.46143	2673	6425	8465	8445	-5772	3303	3331	1650	PENN	USED	62	C	RP
570	WHE-X01	12	2	35.53262	100.46143	2673	12604	12914	12759	-10086	5225	5205	2110	MISS	USED	62	C	RP
571	WHE-X04	2	2	35.43512	100.34637	2590	13765	13986	13876	-11286	5753	5718	2484	MISS	USED	70	C	RP
572	WHE-X05	1	2	35.47086	100.33160	2563	13556	13597	13577	-11014	5594	5625	1896	MISS	USED	70	C	RP
573	WHE-X06	2	2	35.56960	100.35445	2656	15250	15345	15298	-12642	6332	6112	1971	SYLV	USED	73	C	RP
574	WHE-X07	8	2	35.50414	100.39673	2603	12535	12800	12693	-10090	5198	5198	1906	MISS	USED	67	C	RP
575	WHE-X08	2	2	35.59685	100.44012	2766	14990	15060	15025	-12259	6506	6505	2755	VIOL	USED	71	C	RP
576	WHE-X12	1	2	35.36797	100.07846	2155	21037	21195	21116	-18961	9874	9825	3825	ELLE	USED	72	C	RP
577	WHE-X13	2	2	35.42747	100.48090	2613	3600	3634	3617	-1004	895	885	1035	WOLF	USED	72	C	RP
578	WHE-X13	3	2	35.42747	100.48090	2613	11315	11342	11329	-8716	4573	4577	1349	PENN	USED	72	C	RP
579	WHE-X13	8	2	35.42747	100.48090	2613	12325	12345	12335	-9722	5297	5297	2502	SYLV	USED	72	C	RP
580	WHE-X14	1	2	35.59444	100.10442	2569	13424	13726	13575	-11006	2153	2025	-6038	PENN	DEPR	73	C	RP
581	WHE-X14	2	2	35.59444	100.10442	2569	15350	15516	15433	-12914	7073	6709	3454	PENN	OVER	73	C	RP
582	WHE-X15	1	2	35.30981	100.13992	2148	4012	4063	4038	-1890	1396	1319	1332	WOLF	USED	73	C	RP
583	WHE-X16	2	2	35.39693	100.18665	2483	15166	15199	15183	-12700	7643	7643	4950	HUNT	OVER	74	C	RP
584	WHE-X17	1	2	35.45497	100.26651	2462	16640	16690	16665	-14203	7401	7401	2376	MISS	USED	74	C	RP
585	WHE-X18	1	2	35.32327	100.00600	2050	12430	12552	12491	-10441	4764	4673	533	MISS	UNDE	76	C	RP
586	WHE-X19	2	2	35.46242	100.23116	2445	11275	11355	11315	-8870	2269	2314	-3593	PENN	DEPR	76	C	RP
587	WHE-X20	1	2	35.53726	100.28415	2568	13939	14016	13978	-11410	9042	9042	9472	MISS	OVER	76	C	RP
588	WHE-X20	4	2	35.53726	100.28415	2568	18032	18450	18241	-15673	5374	5356	-2118	MISS	UNDE	76	C	RP
589	WHE-X21	2	2	35.55492	100.24645	2582	14585	14752	14669	-12087	9904	9938	10769	MISS	OVER	76	C	RP
590	WHE-X23	4	2	35.52150	100.50870	2748	13270	13500	13385	-10637	4004	4595	449	SIMP	UNDE	77	C	RP
591	WHE-X24	2	2	35.61787	100.53796	2995	11828	11880	11854	-8859	4708	4600	2006	MISS	USED	77	C	RP
592	WHE-X24	3	2	35.61787	100.53796	2995	11892	12037	11965	-8970	4745	4745	1930	MISS	USED	77	C	RP
593	WHE-X25	1	2	35.58630	100.52435	2795	11558	11662	11610	-8815	4822	4822	2313	PENN	USED	78	C	RP
594	WHE-X26	2	2	35.43626	100.50969	2755	11910	12001	11956	-9201	5040	5038	2430	HUNT	USED	77	C	RP

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	HOU	TOPO
595	WHE-X27	3	2	35.44241	100.42941	2595	12750	12800	12775	-10180	5233	5233	1896	MISS	USED	73	C	RP
596	WHE-X28	2	2	35.41853	100.01788	2245	16689	19200	17945	-15700	11183	11723	10113	MISS	OVER	79	C	RP
597	WHE-X29	1	2	35.31149	100.17123	2149	4640	4459	4550	-2501	1664	1664	1340	PENN	USED	79	C	RP
598	WHE-X30	1	2	35.39166	100.33508	2433	13345	13557	13451	-11018	5774	5774	2307	ELLE	USED	79	C	RP
599	WHE-X30	2	2	35.39166	100.33508	2433	9280	9310	9295	-6862	3190	3215	500	PENN	OTHR	79	C	RP
600	WHE-X31	1	2	35.49629	100.15791	2333	10682	10845	10764	-8431	4757	4737	2347	PENN	OVER	80	C	RP
601	WHE-X32	2	2	35.56996	100.53238	2935	13435	13600	13518	-10583	5454	5354	2073	ELLE	USED	80	C	RP
602	WHE-X32	3	2	35.56996	100.53238	2935	13586	14000	13793	-10858	5611	5548	2090	ELLE	USED	80	C	RP
603	WHE-X33	1	2	35.47087	100.41722	2666	12800	12879	12840	-10174	5261	5275	2013	MISS	USED	80	C	RP
604	WHE-X34	3	2	35.59586	100.53806	2976	11702	11730	11716	-8740	4574	4574	2045	PENN	USED	76	C	RP
605	WHE-X35	4	2	35.59537	100.39046	2686	11860	11863	11862	-9176	5300	5300	3455	PENN	OVER	66	C	RP
606	WHE-X35	8	2	35.59537	100.39046	2686	13709	13825	13767	-11081	6271	6271	3371	MISS	OVER	66	C	RP
607	WHE-X35	11	2	35.59537	100.39046	2686	16002	16081	16042	-13356	6969	6941	2727	VIOL	USED	66	C	RP
608	WHE-X36	1	2	35.47711	100.40294	2577	6787	6860	6824	-4247	2520	2571	1559	PENN	USED	66	C	RP
609	CHA-001S	2	2	33.62416	103.65916	4434	9800	9856	9828	-5454	3277	3141	2039	PENN	DEPR	80	C	HP
610	CHA-001S	3	2	33.62416	103.65916	4434	11020	11050	11040	-6606	4091	4091	2335	MISS	UNDE	80	C	HP
611	CHA-005S	1	2	33.97841	103.96169	4212	7290	7320	7305	-3093	2553	2426	2759	MISS	DEPR	80	C	HP
612	CHA-008S	2	2	33.95320	104.16310	3853	6060	6126	6093	-2240	2611	2736	3735	PENN	USED	73	C	RP
613	CHA-008S	3	2	33.95320	104.16310	3853	6200	6272	6236	-2383	2824	2747	4134	PENN	MULT	73	C	RP
614	CHA-011S	2	2	33.85471	104.25160	3755	5793	5843	5818	-2063	2714	2693	4200	PENN	OVER	73	C	RP
615	CHA-018S	1	2	33.77139	103.94600	4151	5235	5328	5282	-1131	627	640	316	TUBB	DEPR	73	B	RP
616	CHA-023S	5	2	33.76370	104.23180	3840	6030	6093	6062	-2222	2608	2560	3796	MISS	MULT	72	C	RP
617	CHA-023S	6	2	33.76370	104.23180	3840	6075	6210	6143	-2303	2592	2515	3553	MISS	USED	72	C	RP
618	CHA-024S	2	2	33.66479	104.21330	4029	2450	2530	2490	1539	1149	1149	4191	GLOR	OVER	74	B	RP
619	CHA-024S	3	2	33.66479	104.21330	4029	6000	6064	6032	-2003	2470	2470	3697	PENN	USED	74	C	RP
620	CHA-024S	8	2	33.66479	104.21330	4029	6700	6723	6712	-2683	2575	2575	3260	MISS	USED	74	C	RP
621	CHA-024S	9	2	33.66479	104.21330	4029	6725	6765	6745	-2716	2575	2575	3225	MISS	MULT	74	C	RP
622	CHA-031S	3	2	33.66920	103.87080	4099	7475	7600	7538	-3439	3261	3261	4037	PENN	OVER	69	C	RP
623	CHA-038S	1	2	33.59030	103.86211	4176	9072	9173	9125	-4949	3219	3109	2477	PENN	DEPR	75	C	RP
624	CHA-038S	3	2	33.59030	103.86211	4176	9125	9520	9323	-5147	3759	3697	3528	PENN	USED	75	C	RP
625	CHA-038S	4	2	33.59030	103.86211	4176	9060	9100	9080	-4904	3248	3234	2591	PENN	DEPR	75	C	RP
626	CHA-038S	6	2	33.59030	103.86211	4176	6360	6440	6400	-2224	256	241	-1633	LCF	DEPR	75	B	RP
627	CHA-053S	1	2	33.51305	103.89729	4075	7302	7380	7341	-3266	2259	2215	1947	WOLF	DEPR	79	C	RP
628	CHA-054S	1	2	33.55759	103.76181	4278	3860	3909	3935	393	1263	1221	3308	LSA	USED	77	B	HP
629	CHA-055S	2	2	33.55099	103.76199	4294	8444	8705	8575	-4301	3419	3625	3510	WOLF	USED	77	C	HP
630	CHA-055S	4	2	33.55099	103.76199	4294	10060	10160	10120	-5826	3420	3289	2066	PENN	DEPR	77	C	HP
631	CHA-055S	5	2	33.55099	103.76199	4294	10225	10320	10273	-5979	3642	3419	2425	PENN	DEPR	77	C	HP
632	CHA-058S	1	2	33.67360	104.05341	4070	2487	2592	2540	1530	980	933	3792	LSA	USED	73	B	RP
633	CHA-058S	2	2	33.67360	104.05341	4070	6708	6750	6729	-2659	2083	2196	2143	WOLF	UNDE	73	C	RP
634	CHA-058S	4	2	33.67360	104.05341	4070	6708	6795	6752	-2682	2245	2284	2499	WOLF	UNDE	73	C	RP
635	CHA-059S	1	2	33.73080	104.14799	4049	2532	2637	2585	1464	963	953	3697	LSA	USED	77	B	RP
636	CHA-059S	5	2	33.73080	104.14799	4049	6607	6692	6650	-2601	2409	2422	2959	WOLF	UNDE	77	C	RP
637	CHA-X02	3	2	33.79240	104.20061	4050	6210	6236	6223	-2173	2648	2504	3938	MISS	USED	71	C	RP
638	CHA-X03	1	2	33.79620	104.18781	4110	5874	5952	5913	-1808	2376	2257	3675	PENN	USED	71	C	RP
639	CHA-X03	3	2	33.79620	104.18781	4110	6374	6480	6427	-2317	2931	2852	4285	MISS	OVER	71	C	RP
640	CHA-X04	1	2	33.77409	104.23100	3870	5641	5765	5703	-1833	2235	2168	3325	PENN	MULT	74	C	RP
641	CHA-X04	3	2	33.77409	104.23100	3870	5979	6007	5993	-2123	2566	2483	3799	PENN	USED	74	C	RP
642	CHA-X04	4	2	33.77409	104.23100	3870	6043	6123	6083	-2213	2746	2743	4129	PENN	OVER	74	C	RP
643	CHA-X05	2	2	33.77800	104.20050	4150	5880	5959	5920	-1770	2390	2309	3745	PENN	USED	70	C	RP
644	CHA-X06	4	2	33.76340	104.20061	3932	6150	6224	6187	-2255	3026	3026	4728	MISS	OVER	71	C	RP
645	CHA-X07	1	2	33.77060	104.20061	4048	5730	5850	5790	-1742	2366	2366	3718	PENN	USED	71	C	RP
646	CHA-X09	3	2	33.76041	103.92799	4166	7990	8055	8023	-3857	2995	2992	3054	MISS	DEPR	66	C	RP
647	CHA-X10	1	2	33.77216	104.01302	4147	2700	2777	2739	1408	949	949	3599	USA	USED	80	B	RP
648	CHA-X11	1	2	33.77640	103.71899	4532	4050	4100	4075	457	1374	1395	3628	GLOR	USED	67	B	HP

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SHECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFIH	FORM	STATUS	YR	QDU	TOPO
649	CHA-X12	1	2	33.67261	104.15179	3955	6780	6812	6796	-2841	2597	2524	3152	MISS	USED	78	C	RP
650	CHA-X13	1	2	33.67174	104.22153	4039	1835	1972	1929	2110	730	695	3735	LSA	USED	73	B	RP
651	CHA-X13	2	2	33.67174	104.22153	4039	6515	6678	6597	-2558	2309	2300	2335	MISS	USED	78	C	RP
652	CHA-X15	3	2	33.73116	103.87093	4235	3650	3765	3713	522	1405	1320	3765	LSA	USED	77	B	HP
653	CHA-X16	1	2	33.68060	103.90540	4148	3235	3310	3273	875	959	942	3033	LSA	USED	67	B	RP
654	CHA-X18	1	2	33.65540	104.36440	3613	856	976	921	2692	347	347	3493	LSA	USED	65	B	RP
655	CHA-X19	1	2	33.61870	104.28210	3850	1533	1650	1607	2253	615	587	3672	USA	USED	65	B	RP
656	CHA-X20	2	2	33.57480	104.11320	3955	2352	2451	2402	1553	677	645	3577	LSA	USED	67	B	RP
657	CHA-X20	3	2	33.57480	104.11320	3955	2432	2495	2464	1491	659	638	3425	LSA	MULT	67	B	RP
658	CHA-X21	1	2	33.59589	103.95859	3981	1828	1934	1851	2100	42	42	2197	LSA	DEPR	73	B	RP
659	CHA-X21	2	2	33.59589	103.95859	3981	2965	3039	3002	979	1030	1076	3439	LSA	USED	73	B	RP
660	CHA-X22	1	2	33.65581	103.73260	4380	3960	4125	4043	337	1345	1345	3444	USA	USED	76	B	HP
661	CHA-X22	4	2	33.65581	103.73260	4380	10484	10647	10636	-6236	3973	3787	2652	MISS	UNDS	76	C	HP
662	CHA-X23	1	2	33.64160	103.73920	4234	4020	4082	4051	233	1235	1229	3129	LSA	DEPR	77	B	HP
663	CHA-X24	1	2	33.61639	103.72000	4405	4000	4085	4043	362	1276	1276	3307	LSA	DEPR	68	B	HP
664	CHA-X25	2	2	33.61594	103.73656	4278	4027	4070	4049	229	1133	1107	2844	LSA	DEPR	77	B	HP
665	CHA-X26	2	2	33.62656	103.74969	4328	3954	3992	3978	350	1253	1253	3253	USA	USED	79	B	HP
666	CHA-X27	1	2	33.60430	103.74541	4305	3878	3943	3923	382	1216	1196	3193	USA	USED	64	B	HP
667	CHA-X28	1	2	33.60380	103.72000	4399	4000	4102	4051	348	1339	1334	3369	LSA	USED	67	B	HP
668	CHA-X29	1	2	33.59720	103.81760	4209	3650	3730	3690	519	1195	1195	3277	LSA	USED	64	B	HP
669	CHA-X30	1	2	33.57320	103.77521	4280	3800	3910	3835	425	1310	1203	3448	USA	USED	68	B	HP
670	CHA-X30	2	2	33.57320	103.77521	4280	8510	8571	8541	-4261	3411	3277	3611	PENN	USED	68	C	HP
671	CHA-X30	5	2	33.57320	103.77521	4280	9068	9145	9107	-4327	92	92	-4615	PENN	DEPR	68	C	HP
672	CHA-X30	6	2	33.57320	103.77521	4280	10592	10612	10602	-6322	4068	4111	3056	MISS	USED	68	C	HP
673	CHA-X31	1	2	33.57961	103.74921	4320	3870	3936	3928	392	1273	1261	3276	USA	USED	69	B	HP
674	CHA-X32	1	2	33.65581	103.61639	4450	4082	4235	4159	291	192	161	734	LSA	DEPR	66	B	HP
675	CHA-X32	2	2	33.65581	103.61639	4450	4242	4365	4304	146	1331	1295	3218	LSA	DEPR	66	B	HP
676	CHA-X33	5	2	33.64180	103.66360	4490	10844	10885	10865	-6375	4167	4167	3241	MISS	USED	69	C	HP
677	CHA-X35	1	2	33.60201	103.68021	4344	4050	4085	4069	276	1156	1123	3013	USA	DEPR	66	B	HP
678	CHA-X36	2	2	33.59601	103.61690	4395	8924	8995	8990	-4595	2975	2875	2270	WOLF	DEPR	65	C	HP
679	CHA-X37	1	2	33.57260	103.62000	4406	9065	9135	9101	-4695	2978	2847	2177	WOLF	DEPR	69	C	HP
680	CHA-X38	2	2	33.64661	103.55119	4385	8780	8910	8845	-4460	3013	2925	2493	WOLF	DEPR	67	C	HP
681	CHA-X39	1	2	33.57610	103.60320	4387	9070	9250	9160	-4773	2852	2830	1009	WOLF	DEPR	75	C	HP
682	CHA-X40	1	2	33.53900	104.30080	3765	1498	1598	1548	2217	610	610	3625	LSA	USED	69	B	RP
683	CHA-X40	3	2	33.53900	104.30080	3765	5913	6000	5957	-2192	2279	2373	3057	PENN	USED	69	C	RP
684	CHA-X41	3	2	33.55341	104.04920	3944	7026	7123	7077	-3133	153	155	-2753	WOLF	DEPR	71	C	RP
685	CHA-X42	1	2	33.56740	103.94119	4010	3105	3160	3133	877	948	943	3235	USA	USED	67	B	RP
686	CHA-X43	2	2	33.54601	103.94600	4015	7672	7795	7734	-3719	3252	3252	3809	PENN	OVER	77	C	RP
687	CHA-X43	5	2	33.54601	103.94600	4015	8674	8745	8710	-4695	2713	2718	1573	PENN	DEPR	77	C	RP
688	CHA-X43	6	2	33.54601	103.94600	4015	8744	8772	8758	-4743	3149	3149	2524	MISS	DEPR	77	C	RP
689	CHA-X43	7	2	33.54601	103.94600	4015	9536	9609	9573	-5558	3440	3340	2843	SILU	DEPR	77	C	RP
690	CHA-X44	2	2	33.52820	103.83560	4130	9411	9561	9486	-5356	435	435	-4352	PENN	DEPR	68	C	RP
691	CHA-X44	3	2	33.52820	103.83560	4130	10710	10920	10815	-6685	4353	4353	3360	PENN	USED	66	C	RP
692	CHA-X45	1	2	33.50999	103.85339	4093	3480	3555	3518	575	1255	1271	3471	LSA	USED	66	B	RP
693	CHA-X46	1	2	33.55780	103.80960	4202	3630	3770	3715	487	893	883	2559	USA	UNDS	69	B	HP
694	CHA-X47	1	2	33.54300	103.79260	4203	3780	3840	3810	393	1262	1270	3352	USA	USED	68	B	HP
695	CHA-X49	2	2	33.51041	103.75780	4232	3970	4120	4045	187	1412	1376	3446	LSA	USED	68	B	HP
696	CHA-X50	1	2	33.51140	103.75940	4232	11828	11871	11850	-7618	4692	4692	3210	PENN	USED	68	C	HP
697	CHA-X51	2	2	33.78970	104.52450	3696	2230	2321	2275	1421	996	946	3726	LSA	USED	73	B	RP
698	CHA-X51	3	2	33.78970	104.52450	3696	5965	6104	6035	-2339	2526	2526	3490	WOLF	USED	73	C	RP
699	CHA-X51	4	2	33.78970	104.52450	3696	6432	6480	6456	-2760	2779	2779	3553	PENN	USED	73	C	RP
700	CHA-X53	1	2	33.66126	104.14549	3939	5565	5590	5578	-1639	1726	1643	2344	RDCV	DEPR	81	B	RP
701	CHA-X53	3	2	33.66126	104.14549	3939	6713	6742	6728	-2789	2469	2490	2939	PENN	DEPR	81	C	RP
702	CHA-X54	1	3	33.60830	103.91678	4055	3150	3330	3240	815	1089	1038	3328	LSA	USED	82	B	RP

MASTER FILE

----- GEOLOGIC, HYDROLOGIC, AND FORMATION PRESSURE DATA FROM DRILL-STEM TESTS -----

OBS	SWECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	HSU	TOPO
703	CHA-X56	2	2	33.53382	104.34245	3812	6055	6140	6098	-2286	2325	2325	3079	MISS	USED	62	C	RP
704	CHA-X56	3	2	33.53382	104.34245	3812	6155	6191	6173	-2361	2253	2265	2850	MISS	MULT	62	C	RP
705	CHA-X56	4	2	33.53382	104.34245	3812	6350	6385	6368	-2556	40	40	-2463	MISS	UNDE	62	C	RP
706	CUR-013S	3	3	34.67816	103.29985	4411	6552	6612	6582	-2171	2065	2045	2594	WOLF	USED	75	C	HP
707	CUR-013S	4	2	34.67816	103.29985	4411	6875	7049	6962	-2551	2409	2449	3009	PENN	USED	75	C	HP
708	CUR-014S	2	3	34.65427	103.65927	4623	2800	3049	2925	1698	1139	1139	4327	LSA	USED	73	B	HP
709	CUR-014S	3	3	34.65427	103.65927	4623	6259	6300	6279	-1655	1836	1863	2650	WOLF	USED	73	C	HP
710	CUR-022S	1	2	34.51180	103.55771	4553	3115	3300	3203	1345	1240	1101	4207	LSA	USED	64	B	HP
711	CUR-022S	2	2	34.51180	103.55771	4553	6508	6546	6527	-1974	1953	1922	2533	WOLF	USED	64	C	HP
712	DEB-006S	2	2	34.56232	104.10957	4480	6580	6639	6609	-2129	2470	2392	3571	WOLF	USED	74	C	HP
713	DEB-011S	4	2	34.28214	103.95999	4475	6459	6493	6476	-2001	2751	2619	4347	PENN	OVER	74	C	HP
714	DEB-011S	5	2	34.28214	103.95999	4475	6702	6774	6738	-2263	2514	2472	3539	PENN	USED	74	C	HP
715	GUA-007S	4	3	35.17097	104.25966	4917	1617	1636	1627	3290	522	522	4495	GLOR	USED	63	B	CR
716	GUA-X01	1	3	34.64732	104.48241	4560	1274	1354	1314	3246	439	460	4259	LSA	USED	73	B	CR
717	HAR-X01	2	2	35.90227	103.52859	4770	1837	2100	1969	2801	441	441	3819	GLOR	USED	71	B	CR
718	LEA-046S	1	2	33.51880	103.63341	4335	5807	5845	5826	-1491	3162	3183	5836	GLOR	OVER	66	B	HP
719	LEA-047S	1	2	33.55980	103.53030	4340	4540	4650	4595	-255	1637	1595	3523	USA	USED	72	B	HP
720	LEA-047S	2	2	33.55980	103.53030	4340	9540	9580	9560	-5220	2133	2163	-102	PENN	DEPR	72	C	HP
721	LEA-049S	1	2	33.55920	103.36940	4185	9760	9820	9790	-5605	2521	2521	212	PENN	DEPR	69	C	HP
722	LEA-050S	1	2	33.53419	103.20081	4022	11640	11694	11667	-7645	3912	3826	1333	PENN	DEPR	77	C	HP
723	LEA-051S	2	2	33.51500	103.08760	3947	11905	11927	11916	-7969	4573	4484	2504	FUSS	USED	65	C	HP
724	LEA-051S	3	2	33.51500	103.08760	3947	11908	11930	11934	-7987	4529	4528	2452	FUSS	MULT	65	C	HP
725	LEA-X02	1	2	33.56500	103.63341	4430	4289	4374	4332	96	1393	1374	3313	LSA	USED	68	B	HP
726	LEA-X04	1	2	33.55141	103.64220	4445	4298	4364	4331	114	1353	1323	3235	LSA	USED	65	B	HP
727	LEA-X05	1	2	33.52470	103.63361	4331	8935	8953	8944	-4613	93	93	-4393	WOLF	DEPR	74	C	HP
728	LEA-X06	1	2	33.51460	103.62100	4385	9049	9120	9084	-4699	2350	2338	724	WOLF	DEPR	67	C	HP
729	LEA-X07	1	2	33.51100	103.62500	4350	4220	4285	4253	97	1495	1409	3549	USA	USED	69	B	HP
730	LEA-X07	2	2	33.51100	103.62500	4350	9021	9046	9034	-4684	997	997	-2333	WOLF	DEFR	69	C	HP
731	LEA-X09	2	2	33.54440	103.57260	4385	4435	4520	4478	-93	1450	1437	3254	USA	USED	71	B	HP
732	LEA-X09	3	2	33.54440	103.57260	4385	8593	8654	8624	-4239	1601	1627	-544	WOLF	DEPR	71	C	HP
733	LEA-X09	4	2	33.54440	103.57260	4385	9315	9350	9333	-4948	2290	2302	337	PENN	DEFR	71	C	HP
734	LEA-X11	2	2	33.52940	103.52400	4337	9648	9662	9655	-5318	2540	2520	543	PENN	DEPR	69	C	HP
735	LEA-X12	1	2	33.53259	103.58180	4390	9239	9285	9262	-4872	2830	2827	1705	PENN	DEFR	65	C	HP
736	LEA-X13	1	2	33.51520	103.55240	4366	9645	9654	9650	-5284	2930	2920	1593	PENN	DEPR	63	C	HP
737	LEA-X14	1	2	33.52589	103.52049	4325	9652	9675	9664	-5339	2296	2296	-41	PENN	DEPR	70	C	HP
738	LEA-X15	1	2	33.50760	103.52499	4312	9640	9700	9670	-5353	2121	2121	-463	PENN	DEPR	69	C	HP
739	LEA-X16	1	2	33.50060	103.52960	4303	9650	9750	9700	-5397	2170	2170	-389	PENN	DEPR	69	C	HP
740	LEA-X17	1	2	33.50819	103.53349	4317	9635	9685	9660	-5343	1941	1941	-864	PENN	DEPR	70	C	HP
741	LEA-X18	1	2	33.55420	103.46899	4273	9535	9640	9638	-5365	2357	2408	74	PENN	DEPR	69	C	HP
742	LEA-X18	2	2	33.55920	103.46899	4273	9685	9720	9703	-5430	1911	1910	-1020	PENN	DEPR	69	C	HP
743	LEA-X19	1	2	33.54460	103.47321	4275	9678	9740	9709	-5434	2836	2806	1041	PENN	DEPR	68	C	HP
744	LEA-X20	1	2	33.54100	103.40770	4200	9749	9820	9785	-5585	1836	1836	-1340	PENN	DEPR	70	C	HP
745	LEA-X21	1	2	33.53740	103.45580	4250	9715	9775	9745	-5495	2862	2842	1110	PENN	DEFR	68	C	HP
746	LEA-X22	2	2	33.52960	103.54900	4312	9615	9675	9645	-5333	2336	2336	58	PENN	DEPR	71	C	HP
747	LEA-X23	1	2	33.51950	103.46330	4187	9804	9814	9809	-5622	3450	3444	2340	PENN	DEPR	63	C	HP
748	LEA-X24	2	2	33.51900	103.44780	4225	9789	9847	9818	-5593	1361	1361	-2452	PENN	DEPR	69	C	HP
749	LEA-X25	1	2	33.55920	103.34801	4170	9760	9830	9795	-5625	2582	2532	334	PENN	DEPR	69	C	HP
750	LEA-X26	4	2	33.56880	103.36960	4190	9745	9770	9758	-5568	2779	2779	845	PENN	DEFR	66	C	HP
751	LEA-X28	1	2	33.54800	103.40401	4203	9770	9856	9813	-5610	2507	2493	175	PENN	DEPR	69	C	HP
752	LEA-X27	1	2	33.51190	103.45100	4230	4729	4795	4762	-532	1630	1601	3330	LSA	USED	67	B	HP
753	LEA-X27	5	2	33.51190	103.45100	4230	9842	9859	9851	-5621	2537	2533	233	PENN	DEPR	67	C	HP
754	LEA-X29	1	2	33.55540	103.37840	4190	9804	9867	9836	-5646	2700	2700	595	PENN	DEPR	68	C	HP
755	LEA-X30	1	2	33.54920	103.38580	4190	9760	9835	9798	-5608	2553	2537	284	PENN	DEFR	69	C	HP
756	LEA-X31	1	2	33.53500	103.31641	4112	9522	9578	9550	-5438	2804	2761	1033	PENN	DEPR	65	C	HP

MASTER FILE

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OBS	SHECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFHH	FORM	STATUS	YR	REG	TOPO
757	LEA-X31	2	2	33.53500	103.31641	4112	11902	11913	11908	-7796	4465	4414	2554	PENN	DEPR	65	C	HP
758	LEA-X31	3	2	33.53500	103.31641	4112	11940	11991	11966	-7854	4508	4503	2549	PENN	DEPR	65	C	HP
759	LEA-X32	1	2	33.53380	103.35201	4153	9754	9816	9735	-5632	2035	2000	-867	PENN	DEPR	69	C	HP
760	LEA-X33	1	2	33.54080	103.36940	4175	9780	9850	9815	-5640	2660	2612	498	PENN	DEPR	69	C	HP
761	LEA-X34	1	2	33.52892	103.37347	4165	4722	4819	4771	-606	804	793	1253	LSA	DEPR	31	B	HP
762	LEA-X34	2	2	33.52892	103.37347	4165	9722	9744	9733	-5568	44	44	-5466	PENN	DEPR	61	C	HP
763	LEA-X34	3	2	33.52892	103.37347	4165	12608	12625	12617	-8452	44	44	-8350	MISS	DEPR	61	C	HP
764	LEA-X34	4	2	33.52892	103.37347	4165	12615	12639	12627	-8462	4728	4708	2537	MISS	DEPR	61	C	HP
765	LEA-X35	3	2	33.52316	103.36903	4158	9715	9770	9743	-5585	288	283	-4920	PENN	DEPR	73	C	HP
766	LEA-X35	4	2	33.52316	103.36903	4158	12655	12690	12673	-8515	4950	4950	2909	MISS	USED	78	C	HP
767	LEA-X35	5	2	33.52316	103.36903	4158	12652	12674	12663	-8505	5000	4955	3033	MISS	MULT	78	C	HP
768	LEA-X36	1	2	33.52650	103.34781	4148	4790	4901	4846	-698	1600	1588	2994	LSA	USED	70	B	HP
769	LEA-X37	1	2	33.50571	103.35139	4128	4811	4874	4843	-715	1574	1305	2917	LSA	USED	63	B	HP
770	LEA-X37	3	2	33.50570	103.35139	4128	9831	9870	9851	-5723	4333	4319	4275	PENN	OVER	63	C	HP
771	LEA-X38	1	2	33.50819	103.38640	4162	9706	9764	9735	-5573	3936	3944	3536	PENN	USED	67	C	HP
772	LEA-X39	2	2	33.56560	103.21001	4047	9790	9836	9813	-5766	3837	3837	3204	PENN	USED	76	C	HP
773	LEA-X40	1	2	33.56000	103.27080	4085	4800	4913	4857	-772	1711	1711	3176	LSA	USED	67	B	HP
774	LEA-X41	1	2	33.56281	103.27480	4095	9778	9840	9809	-5714	2325	2417	-210	PENN	DEPR	63	C	HP
775	LEA-X43	1	2	33.54100	103.24800	4057	4800	4950	4875	-818	1731	1724	3292	LSA	USED	69	B	HP
776	LEA-X43	2	2	33.54100	103.24800	4057	9825	9910	9868	-5811	4058	4019	3553	PENN	USED	69	C	HP
777	LEA-X44	5	2	33.51221	103.20950	4012	12244	12284	12264	-8252	4748	4725	2704	MISS	USED	61	C	HP
778	QUA-001	1	2	35.67107	103.10875	4261	1140	1260	1200	3061	135	135	3373	LSA	USED	71	B	CR
779	QUA-017S	1	2	34.97958	103.77466	4193	5094	5323	5209	-1016	2430	2430	4651	WOLF	OVER	74	C	CR
780	ROO-006	2	2	34.16840	103.50240	4085	7255	7326	7291	-3206	2607	2536	2811	WOLF	USED	72	C	HP
781	ROO-011	1	2	34.11880	103.30760	3993	6584	6712	6648	-2655	2233	2233	2498	MICH	USED	72	B	HP
782	ROO-012	1	2	34.02756	103.26869	4160	7127	7170	7149	-2989	2477	2406	2728	WOLF	USED	77	C	HP
783	ROO-014	2	2	34.01691	103.74600	4376	7628	7770	7699	-3323	2799	2641	3136	WOLF	USED	73	C	HP
784	ROO-028	1	2	33.67000	103.53931	4383	8671	8695	8683	-4300	2799	2711	2157	WOLF	DEPR	71	C	HP
785	ROO-028	3	2	33.67000	103.53931	4383	8737	8810	8774	-4391	2997	3000	2526	WOLF	DEPR	71	C	HP
786	ROO-028	5	2	33.67000	103.53931	4383	9580	9660	9620	-5237	92	92	-5025	PENN	DEPR	71	C	HP
787	ROO-028	6	2	33.67000	103.53931	4383	9684	9800	9742	-5359	2554	2665	535	PENN	DEPR	71	C	HP
788	ROO-034S	1	2	34.22760	103.69940	4314	6462	6772	6617	-2303	2213	2179	2604	MICH	USED	72	B	HP
789	ROO-037S	2	2	34.01260	103.51630	4301	7400	7510	7455	-3154	994	1019	-858	WOLF	UNDE	74	C	HP
790	ROO-041S	1	2	33.99350	103.37370	4220	7390	7598	7494	-3274	2525	2386	2553	WOLF	USED	72	C	HP
791	ROO-044S	3	2	33.85609	103.79120	4485	4122	4155	4139	346	1972	1972	4897	GLOR	OVER	72	B	HP
792	ROO-046S	2	2	33.87759	103.59821	4444	8150	8249	8200	-3756	2397	2354	1776	MISS	DEPR	76	C	HP
793	ROO-057S	1	2	33.76199	103.32410	4205	4317	4397	4357	-152	1477	1427	3256	LSA	USED	71	B	HP
794	ROO-062S	3	2	33.79120	103.52499	4355	7539	7607	7573	-3218	656	689	-1704	WOLF	DEPR	69	C	HP
795	ROO-071S	3	2	33.73180	103.54810	4379	9380	9437	9409	-5030	3477	3477	2994	FUSS	USED	65	B	HP
796	ROO-073S	1	2	33.69540	103.54810	4388	8497	8544	8521	-4133	2903	2903	2567	PENN	DEPR	63	C	HP
797	ROO-077S	1	2	33.74319	103.22380	4127	8843	9012	8928	-4801	3334	3371	2893	MISS	USED	71	C	HP
798	ROO-094S	1	2	33.77277	103.06757	3954	4223	4287	4255	-301	1410	1410	2953	LSA	USED	78	B	HP
799	ROO-X02	1	2	34.02950	103.53365	4323	6820	6868	6844	-2521	2217	2196	2595	MICH	USED	79	B	HP
800	ROO-X04	1	2	34.07494	103.45969	4294	7254	7350	7302	-3008	2516	2462	2798	WOLF	USED	80	C	HP
801	ROO-X05	1	2	33.91740	103.66460	4362	7075	7200	7138	-2776	2369	2369	2691	WOLF	USED	76	C	HP
802	ROO-X06	2	2	33.91060	103.26421	4235	4209	4450	4330	-95	1478	1047	3316	LSA	USED	67	B	HP
803	ROO-X07	1	2	33.92470	103.18970	4190	4100	4190	4145	45	1397	1397	3269	LSA	USED	70	B	HP
804	ROO-X08	1	2	33.88519	103.74760	4555	3635	3750	3693	862	93	93	1077	LSA	UNDE	67	B	HP
805	ROO-X08	2	2	33.88519	103.74760	4555	4101	4132	4117	438	1481	1441	3856	GLOR	USED	67	B	HP
806	ROO-X10	1	2	33.87720	103.61760	4480	3778	3820	3799	681	1136	1123	3418	LSA	USED	69	B	HP
807	ROO-X11	1	2	33.75752	103.64127	4446	4230	4330	4280	166	1390	1311	3374	GLOR	USED	80	B	HP
808	ROO-X12	3	2	33.79840	103.53860	4387	3895	4010	3953	434	1207	1186	3219	LSA	USED	67	B	HP
809	ROO-X13	2	2	33.76981	103.44060	4293	4225	4400	4313	-20	1413	1407	3241	LSA	USED	70	B	HP
810	ROO-X14	3	2	33.75037	103.44905	4311	4342	4397	4370	-59	1749	1692	3978	LSA	OVER	78	B	HP

MASTER FILE

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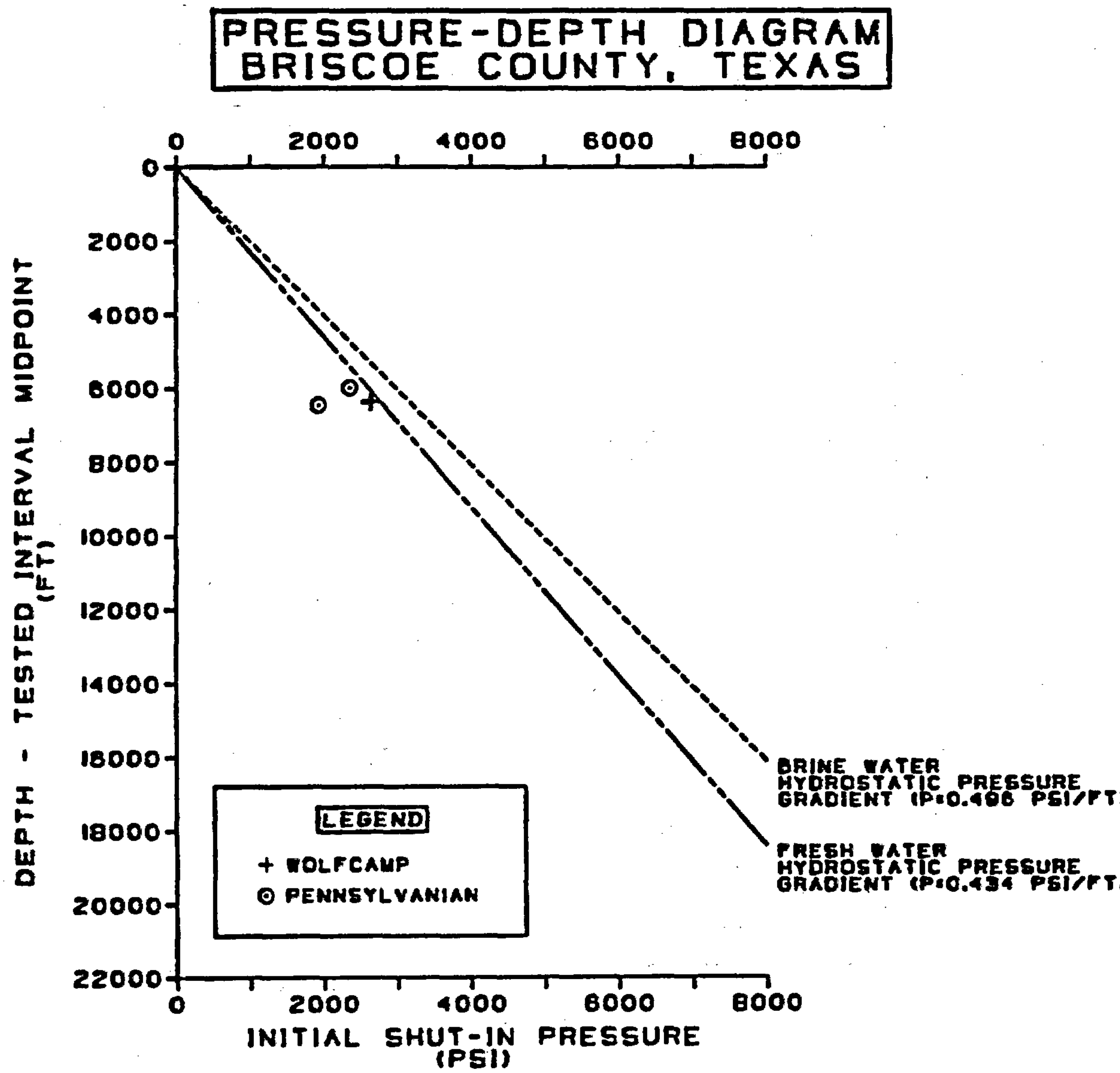
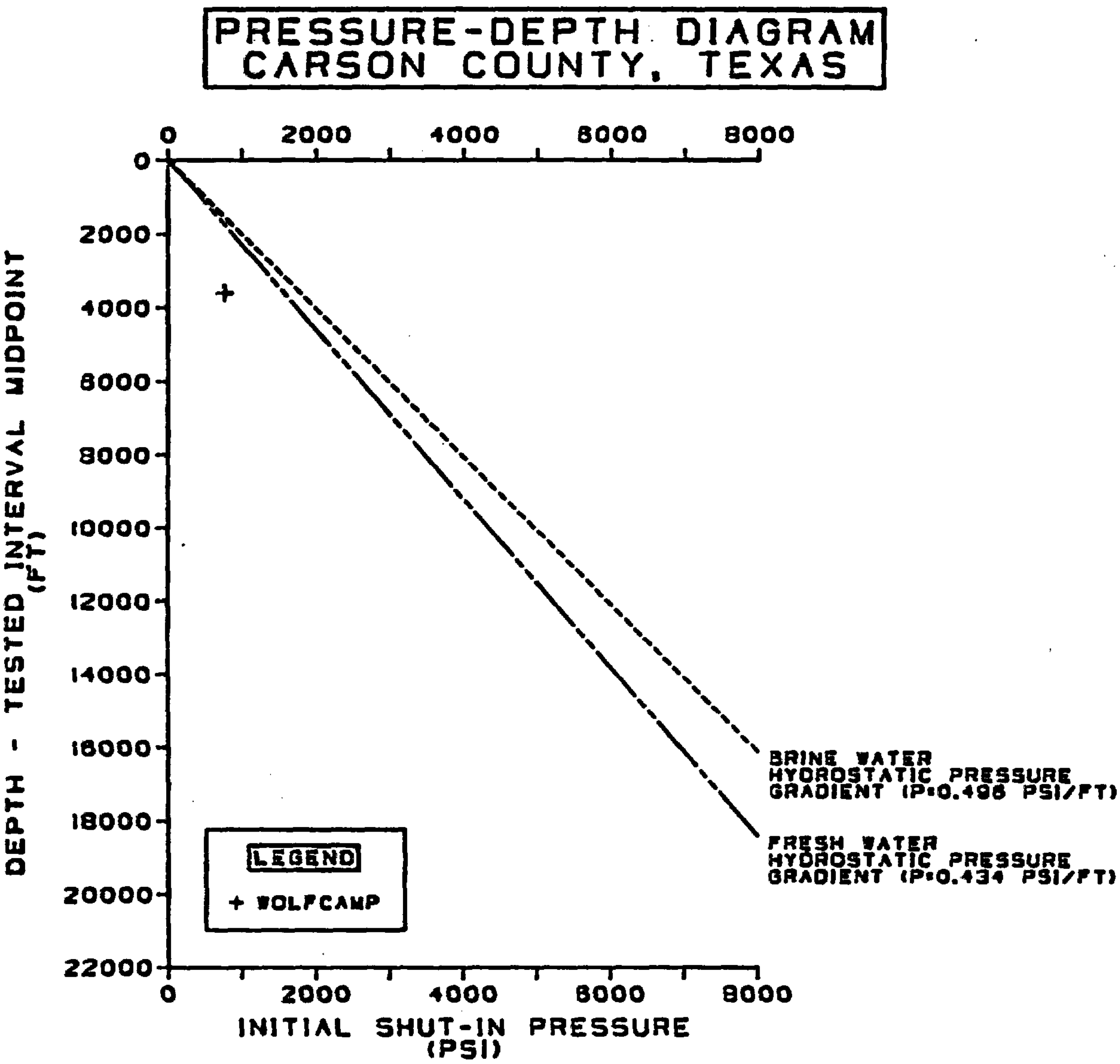
OBS	SHECNO	TN	CL	LATITUDE	LONGITUD	ELEV	TOP	BOTTOM	MDPT	TELEV	ISIP	FSIP	EFIH	FORM	STATUS	YR	HSU	TOPO
811	ROO-X16	1	2	33.80190	103.05200	3930	4185	4230	4208	-273	1967	1397	3107	LSA	USED	73	B	HP
812	ROO-X18	1	2	33.68500	103.60520	4469	4230	4275	4253	216	1225	1175	3043	LSA	DEPR	66	B	HP
813	ROO-X19	1	2	33.67400	103.70216	4437	4065	4133	4099	338	132	135	643	LSA	DEPR	77	B	HP
814	ROO-X20	2	2	33.66721	103.64560	4480	8705	8857	8781	-4301	2726	2730	1990	WOLF	UNDE	65	C	HP
815	ROO-X21	1	2	33.50420	103.29610	4114	9796	9806	9801	-5687	2930	2930	1075	PREC	UNDE	62	C	HP
816	ROO-X23	3	2	33.68829	103.53940	4350	9425	9525	9475	-5125	3472	3472	2837	FUSS	USED	62	B	HP
817	ROO-X24	2	2	33.66650	103.58240	4424	4298	4350	4324	100	1330	1318	3238	LSA	USED	65	B	HP
818	ROO-X25	5	2	33.82599	103.52264	4414	7820	7850	7835	-3421	2759	2202	2936	WOLF	USED	78	C	HP
819	ROO-X26	3	2	33.69600	103.10260	4027	4732	4795	4764	-737	1639	1633	3160	LSA	USED	66	B	HP
820	ROO-X27	1	2	33.67551	103.15430	4060	4500	4670	4585	-525	1670	1575	3329	LSA	USED	75	B	HP
821	ROO-X27	2	2	33.67551	103.15430	4060	8112	8223	8168	-4108	1670	1575	-254	WOLF	DEFR	75	C	HP
822	ROO-X28	2	2	33.58730	103.43331	4245	4576	4695	4646	-401	1538	1523	3264	USA	USED	63	B	HP
823	ROO-X29	2	2	33.57300	103.40900	4215	5090	5178	5134	-910	1893	1793	3427	LSA	USED	69	B	HP
824	ROO-X30	1	2	33.63161	103.30600	4150	4892	4950	4921	-771	1675	1613	3094	GLOR	DEFR	67	B	HP
825	ROO-X31	1	2	33.57280	103.30920	4129	9819	9850	9835	-5706	2981	3051	1031	PENN	DEFR	61	C	HP
826	ROO-X32	2	2	33.64600	103.23199	4095	4856	4900	4878	-783	1622	1622	2950	LSA	DEFR	65	B	HP
827	ROO-X33	3	2	33.63901	103.25780	4105	13040	13065	13053	-8948	4901	4901	2362	PREC	USED	66	C	HP
828	ROO-X34	1	2	33.62440	103.26241	4104	4770	4878	4824	-720	150	150	-373	LSA	DEFR	69	B	HP
829	ROO-X34	5	2	33.62430	103.26241	4104	13083	13138	13111	-9007	4969	4969	2469	PREC	USED	69	C	HP
830	ROO-X37	1	2	33.57680	103.28799	4110	9805	9880	9843	-5733	2386	2386	-227	PENN	DEFR	68	C	HP
831	ROO-X38	2	2	33.59540	103.21300	4045	4936	4966	4951	-906	1790	1745	3110	LSA	DEPR	67	B	HP
832	ROO-X39	1	2	33.58771	103.05360	3965	9527	9547	9537	-5572	3979	3979	3610	PREC	OVER	72	C	HP
833	ROO-X39	2	2	33.58771	103.05360	3965	4766	4932	4849	-884	1611	1544	2834	LSA	DEPR	72	B	HP
834	ROO-X40	7	2	33.58411	103.07201	3970	11344	11379	11362	-7392	4738	4738	3542	MISS	OVER	64	C	HP
835	ROO-X40	9	2	33.58411	103.07201	3970	11407	11449	11428	-7433	4406	4375	2709	MISS	DEFR	64	C	HP
836	SAN-002S	1	3	35.66637	105.19528	6631	4657	4781	4724	1907	1758	1706	5934	PREC	USED	68	C	CR
837	SAN-006S	2	3	35.64655	104.14369	4965	1616	1637	1627	3338	115	115	3603	GLOR	USED	67	B	CR
838	SAN-010S	3	3	35.56931	104.34196	4650	1049	1396	1223	3427	481	484	4544	GLOR	USED	67	B	CR
839	SAN-010S	4	3	35.56931	104.34196	4650	1538	1558	1548	3102	15	15	3137	UCF	UNDE	67	B	CR
840	SAN-010S	7	3	35.56931	104.34196	4650	1785	1850	1818	2832	745	743	4552	TUBB	USED	67	B	CR
841	SAN-010S	8	3	35.56931	104.34196	4650	1850	2252	2051	2599	782	782	4404	PREC	USED	67	C	CR

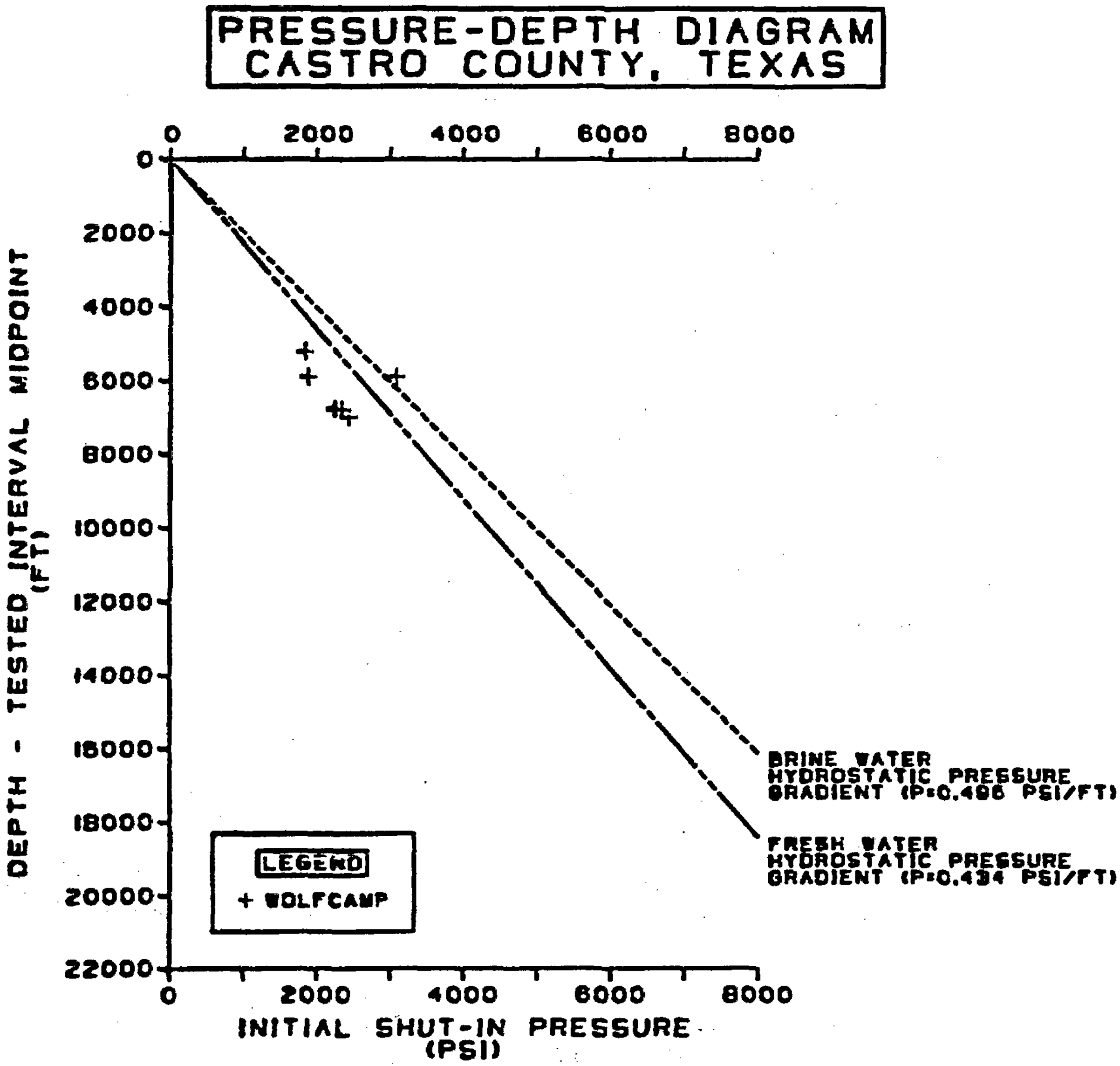
APPENDIX C

Pressure-Depth Diagrams Constructed From Class 1, 2, and 3 DST Data From Selected Counties in the Study Area

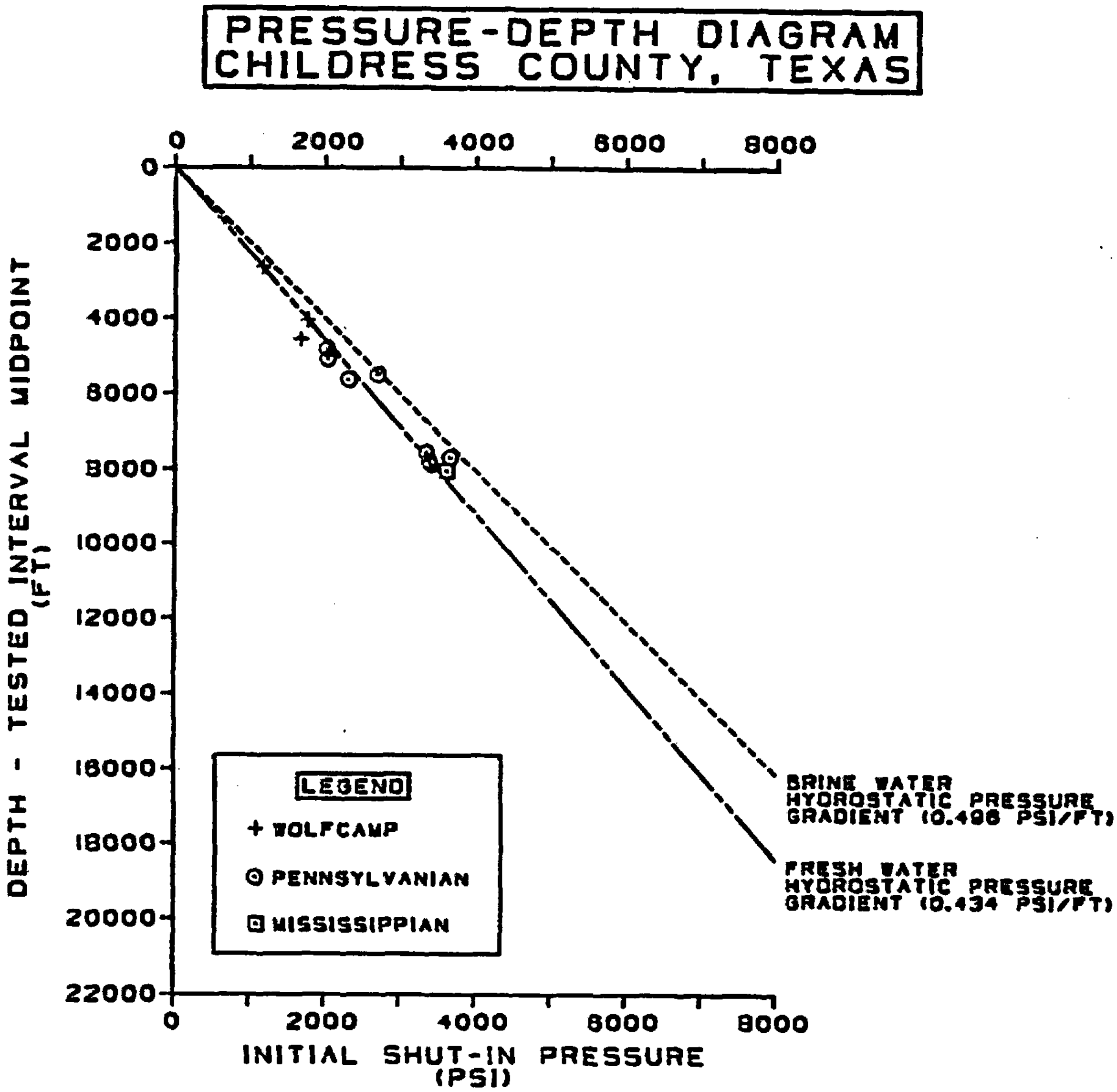
(39 pages)


PRESSURE-DEPTH DIAGRAM
BRISCOE COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
18000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (P=0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (P=0.434 PSI/FT)
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN

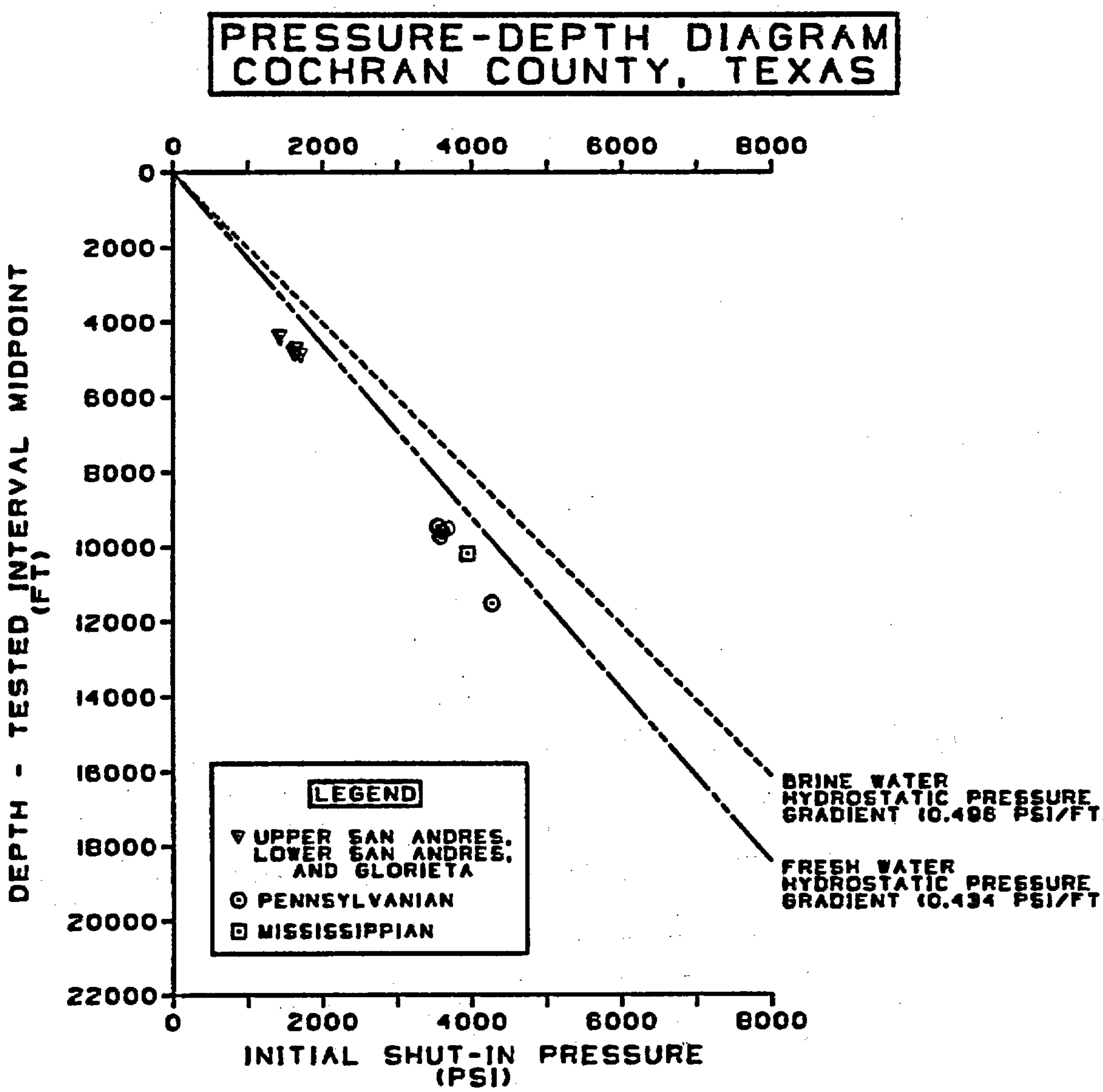

PRESSURE-DEPTH DIAGRAM
CARSON COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (P=0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (P=0.434 PSI/FT)
LEGEND
+ WOLFCAMP
INITIAL SHUT-IN PRESSURE (PSI)

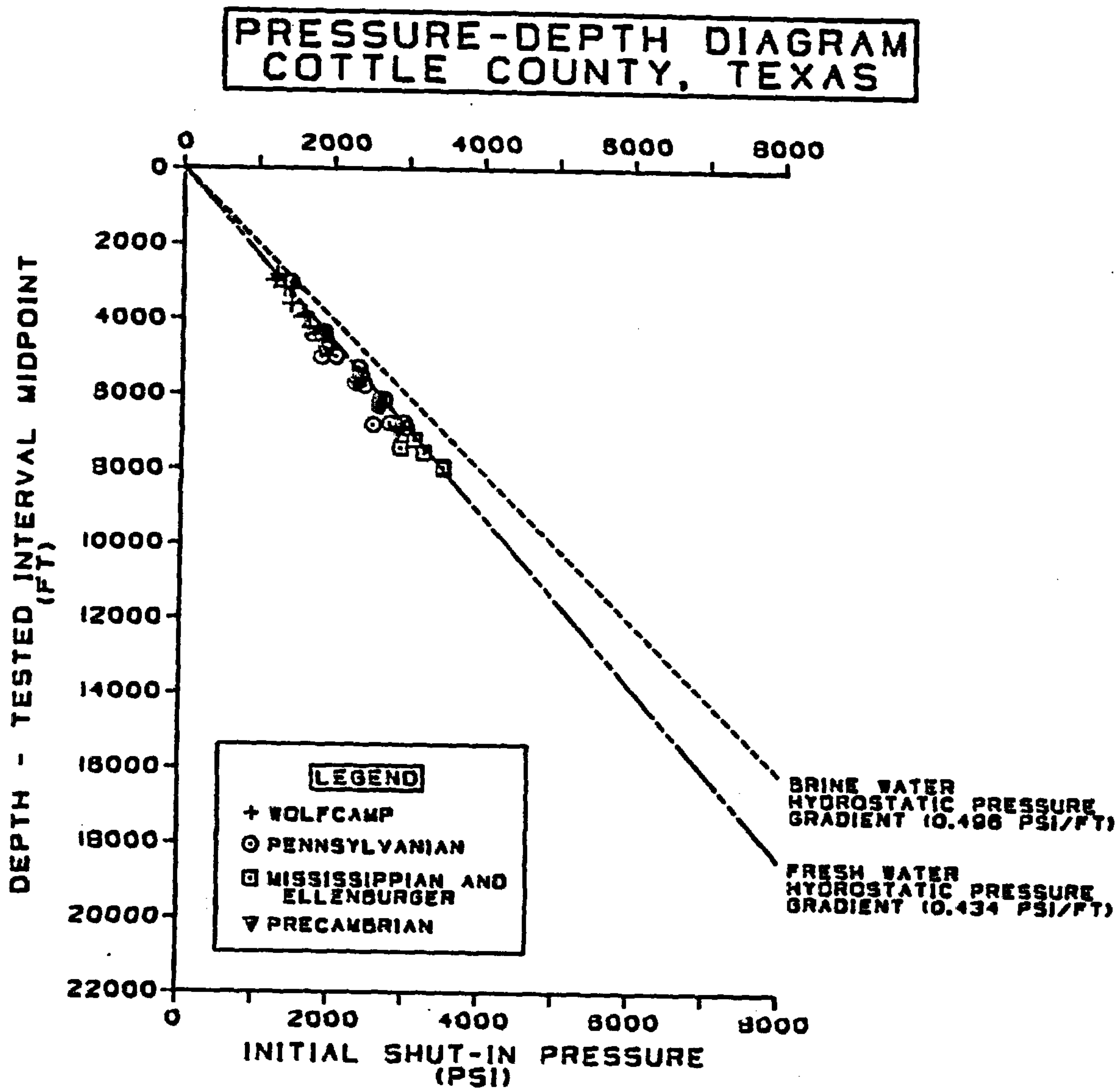


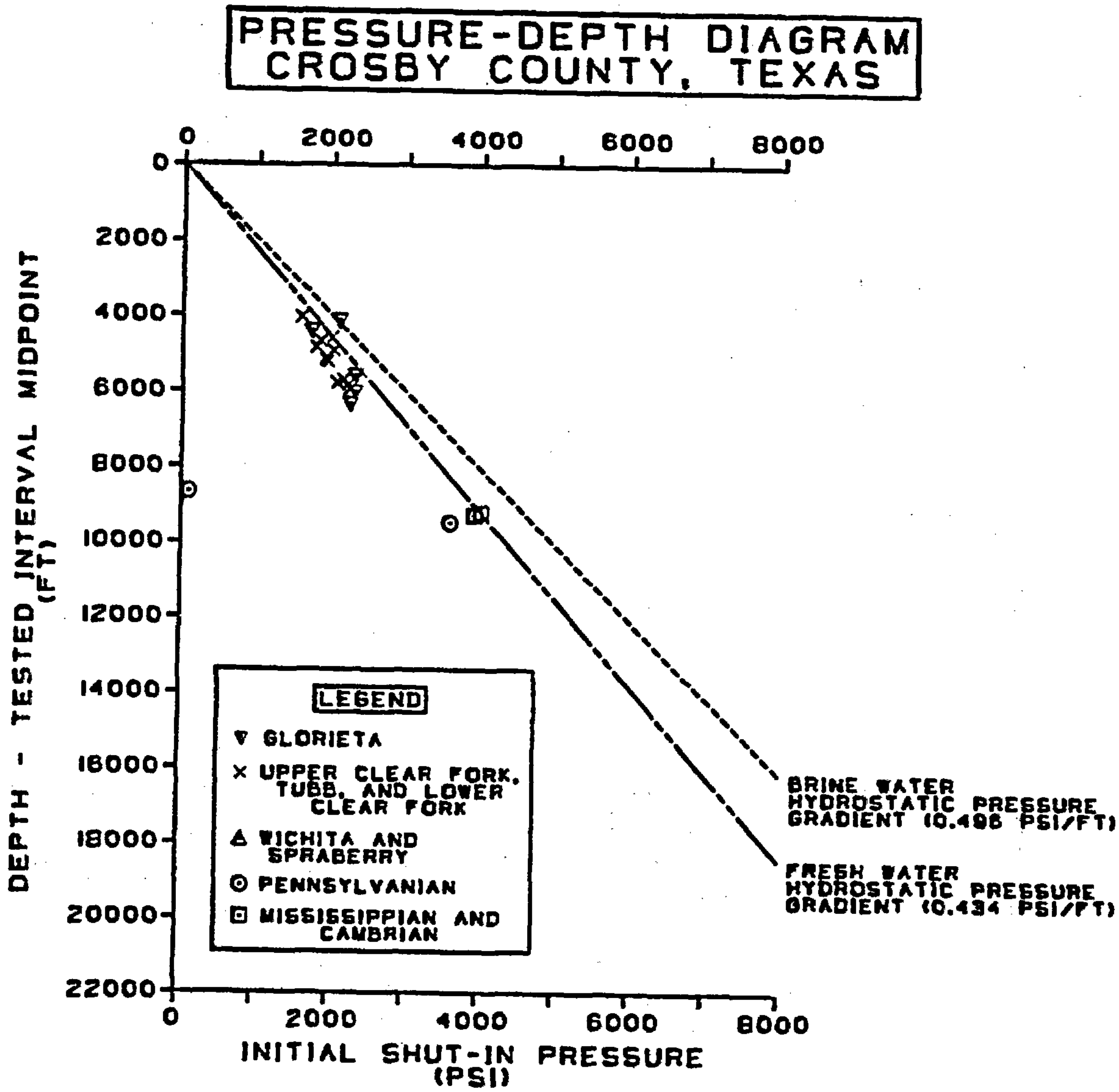
PRESSURE-DEPTH DIAGRAM
CASTRO COUNTY, TEXAS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (P=0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (P=0.434 PSI/FT)
LEGEND
+ WOLFCAMP

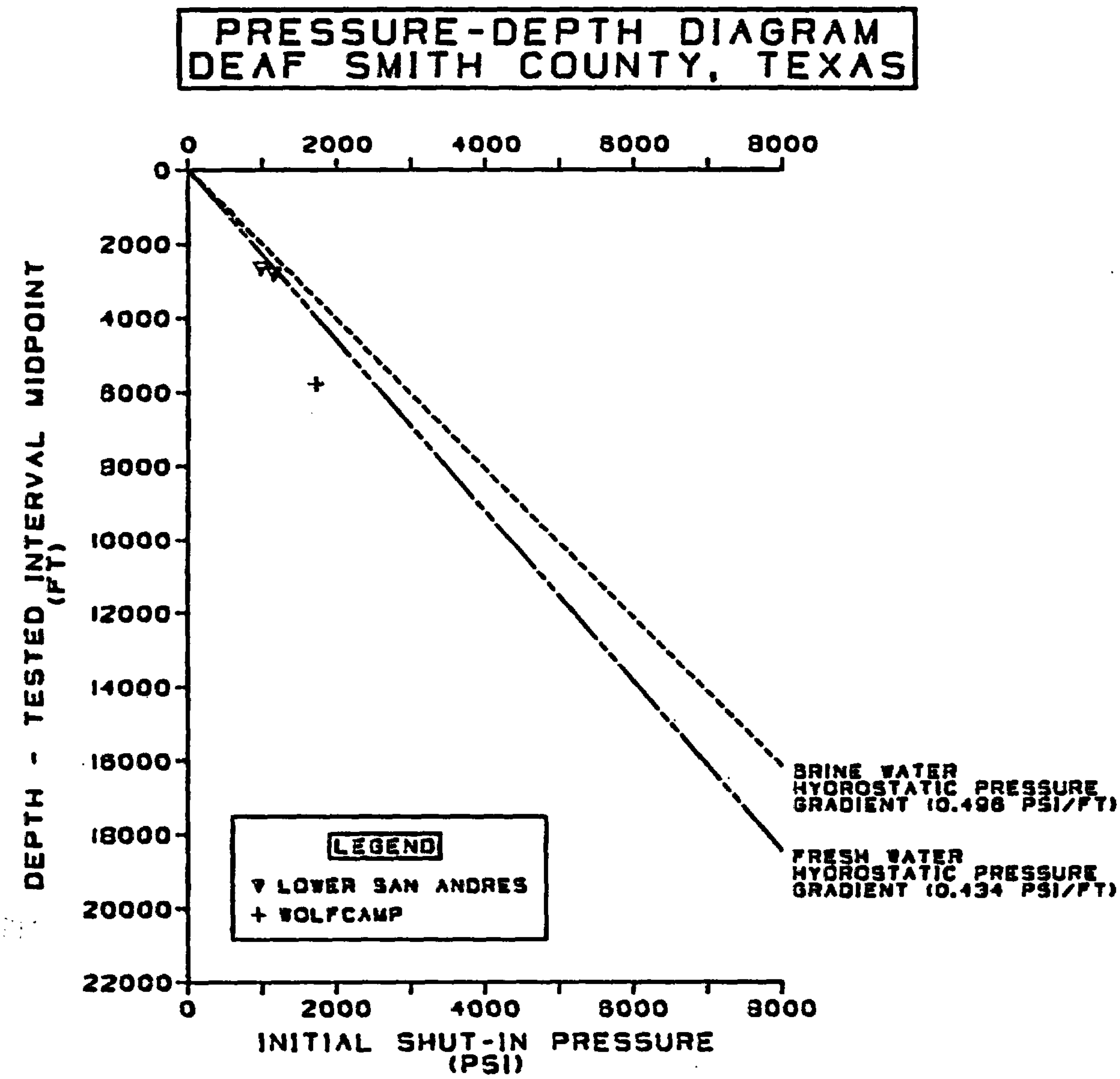


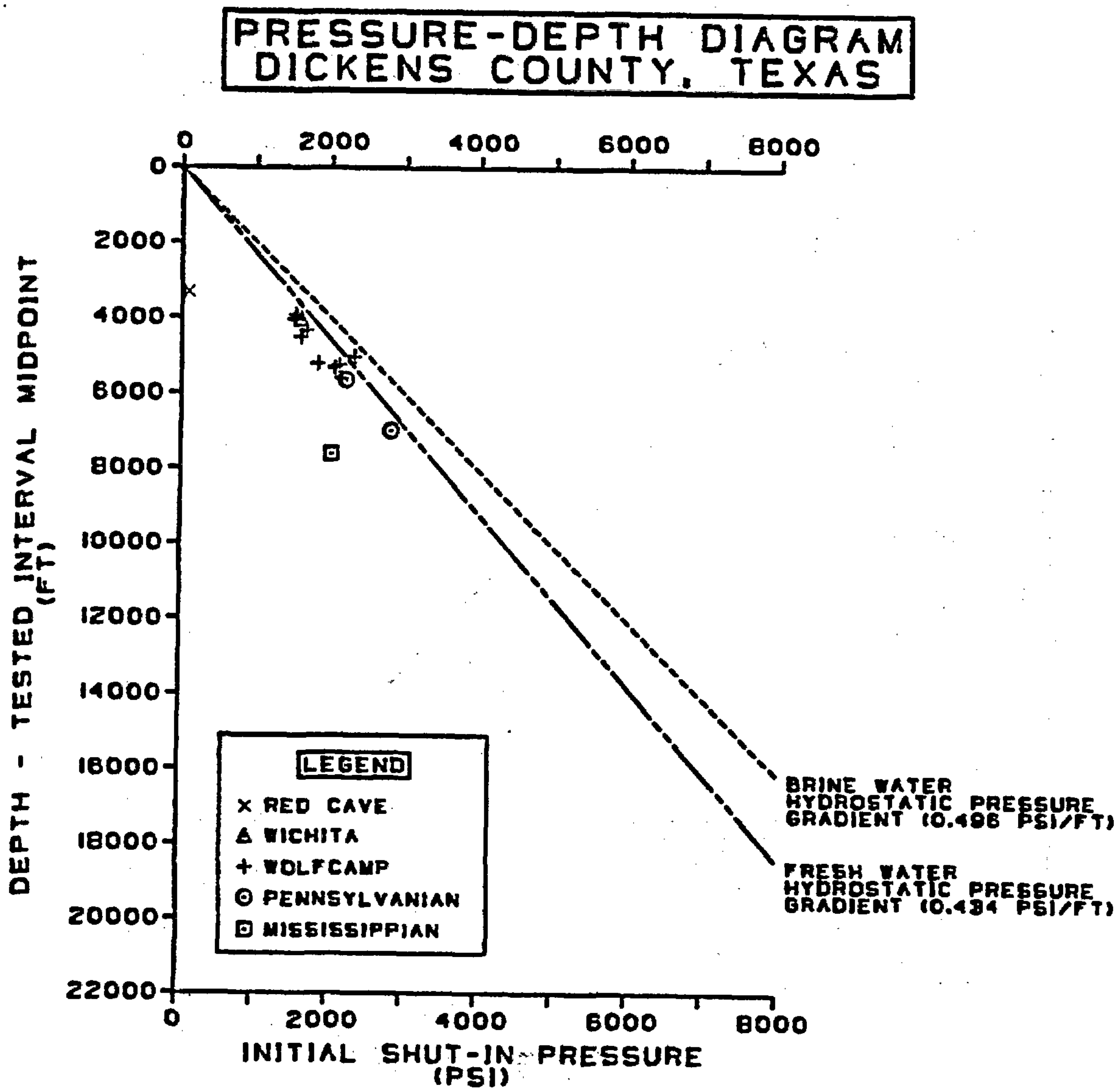
PRESSURE-DEPTH DIAGRAM
CHILDRESS COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
LEGEND
+ WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
INITIAL SHUT-IN PRESSURE (PSI)


PRESSURE-DEPTH DIAGRAM
COCHRAN COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
UPPER SAN ANDRES, LOWER SAN ANDRES, AND GLORIETA
PENNSYLVANIAN
MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

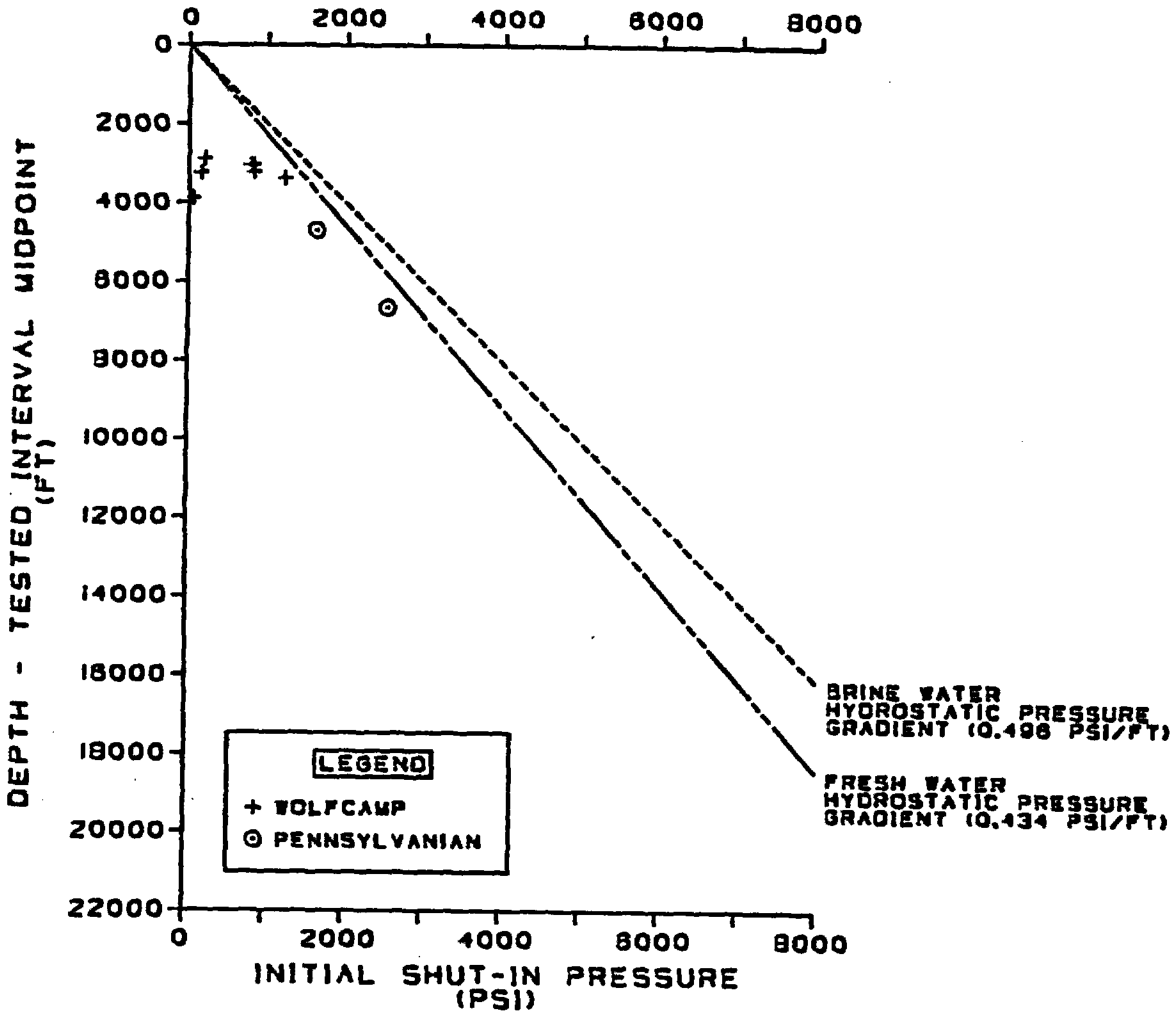

PRESSURE-DEPTH DIAGRAM
COTTLE COUNTY, TEXAS
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN
⊡ MISSISSIPPIAN AND ELLENBURGER
▽ PRECAMBRIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

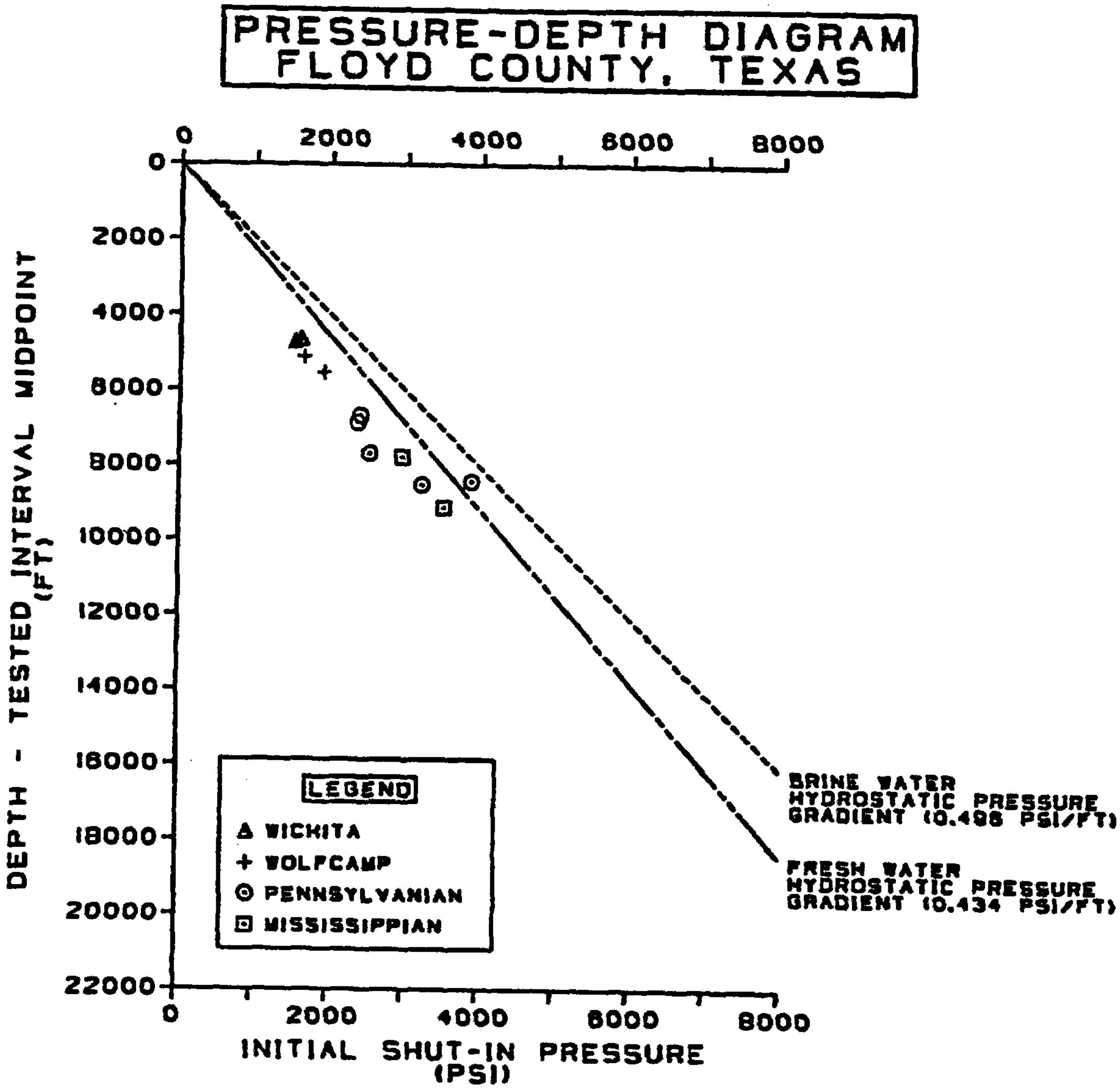

PRESSURE-DEPTH DIAGRAM
CROSBY COUNTY, TEXAS
0
2000
4000
6000
8000
DEPTH - TESTED INTERVAL MIDPOINT
(FT)
10000
12000
14000
16000
18000
20000
22000
LEGEND
GLORIETA
UPPER CLEAR FORK, TUBB, AND LOWER CLEAR FORK
WICHITA AND SPRABERRY
PENNSYLVANIAN
MISSISSIPPIAN AND CAMBRIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
INITIAL SHUT-IN PRESSURE
(PSI)

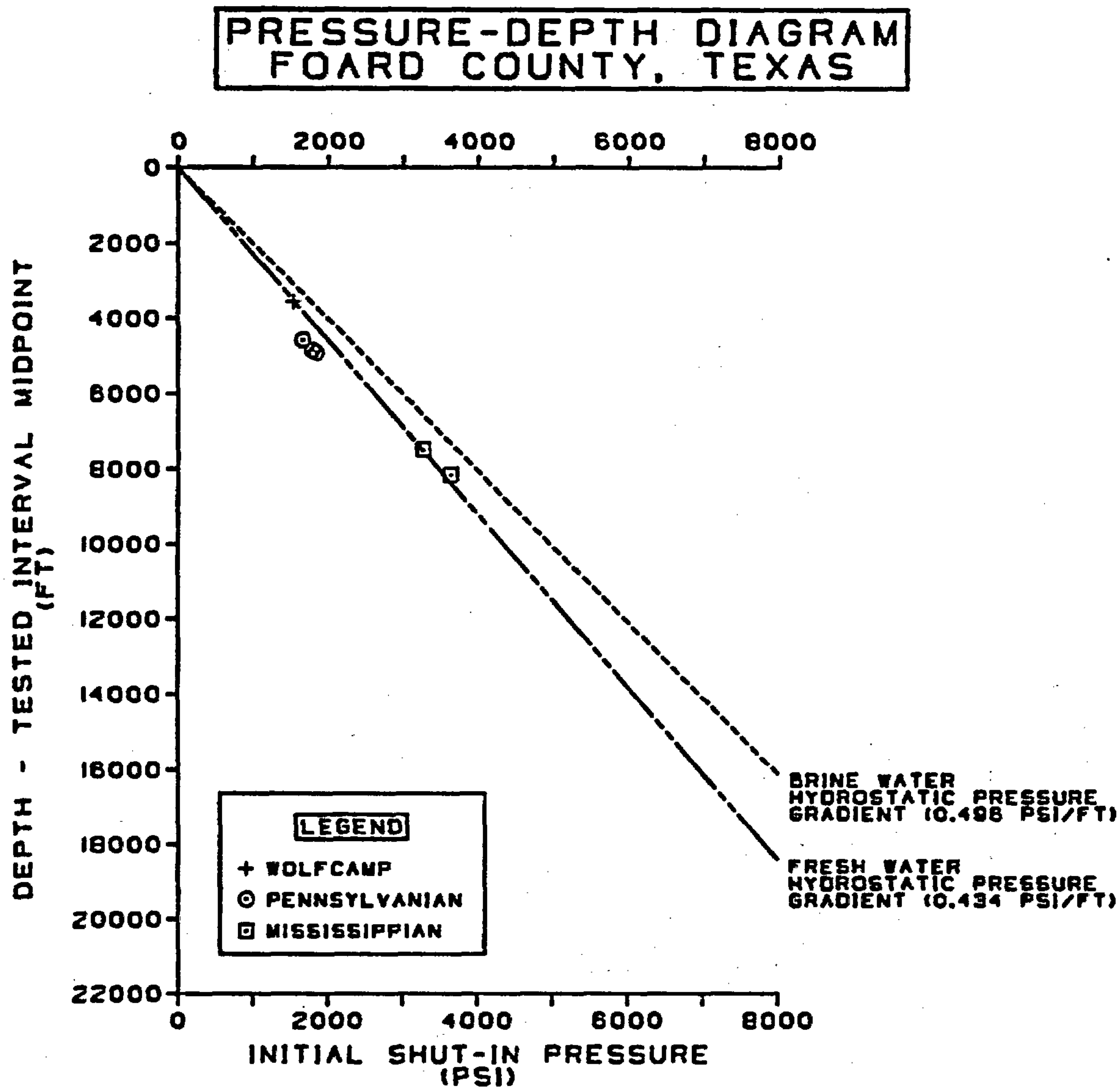

PRESSURE-DEPTH DIAGRAM
DEAF SMITH COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
▼ LOWER SAN ANDRES
+ WOLFCAMP

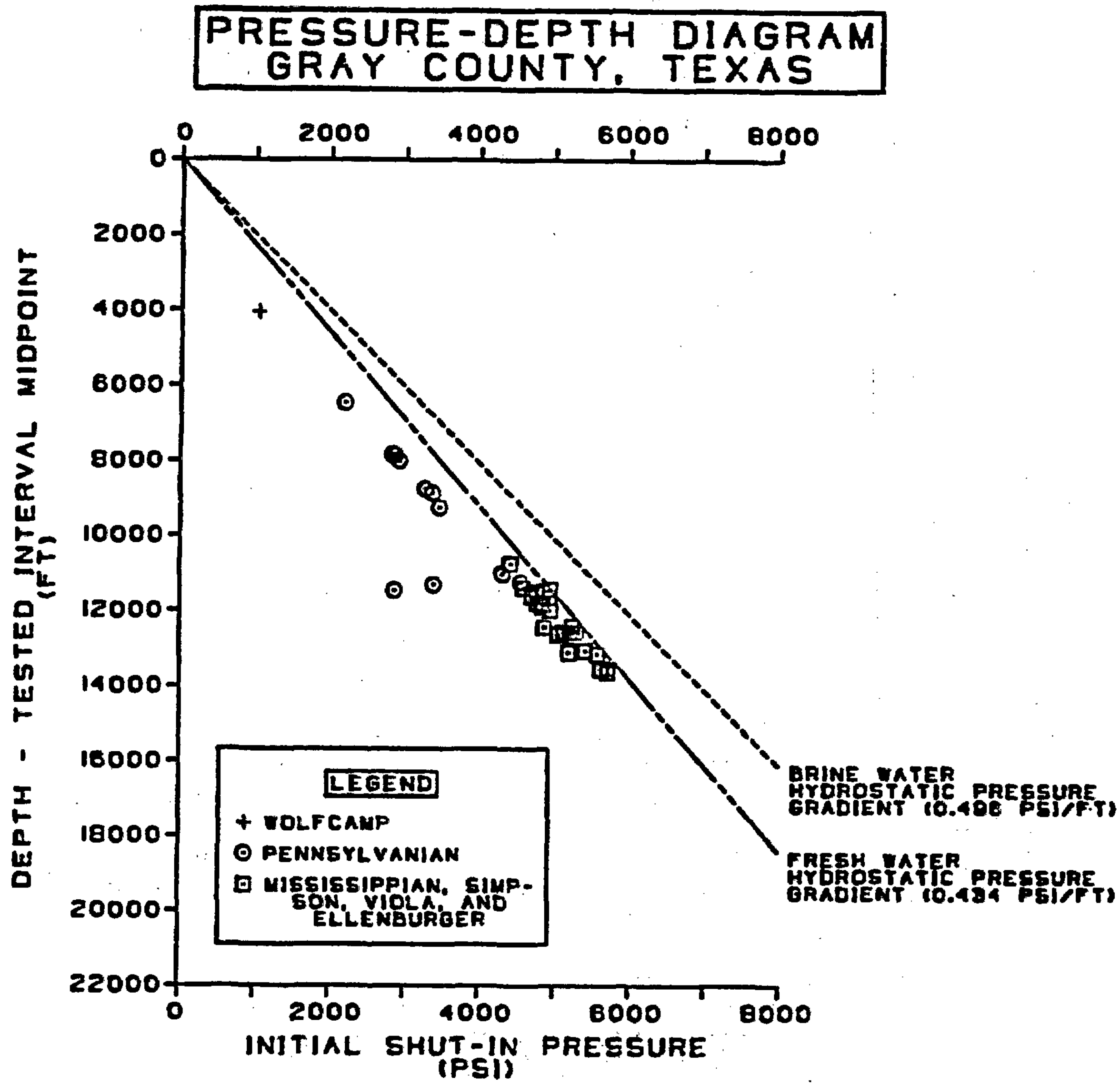

PRESSURE-DEPTH DIAGRAM
DICKENS COUNTY, TEXAS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
× RED CAVE
△ WICHITA
+ WOLFCAMP
⊙ PENNSYLVANIAN
⊡ MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

PRESSURE-DEPTH DIAGRAM
DONLEY COUNTY, TEXAS

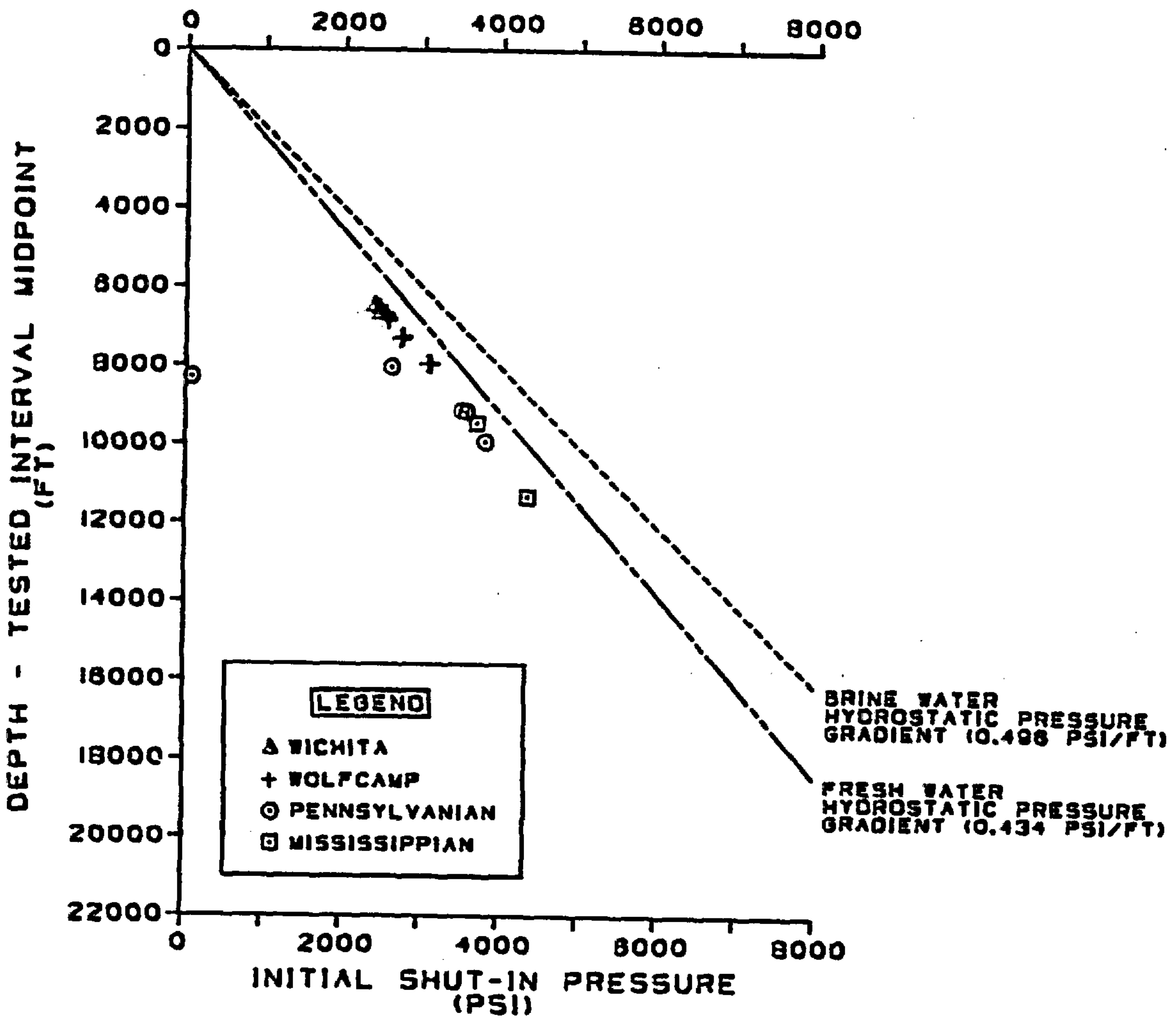


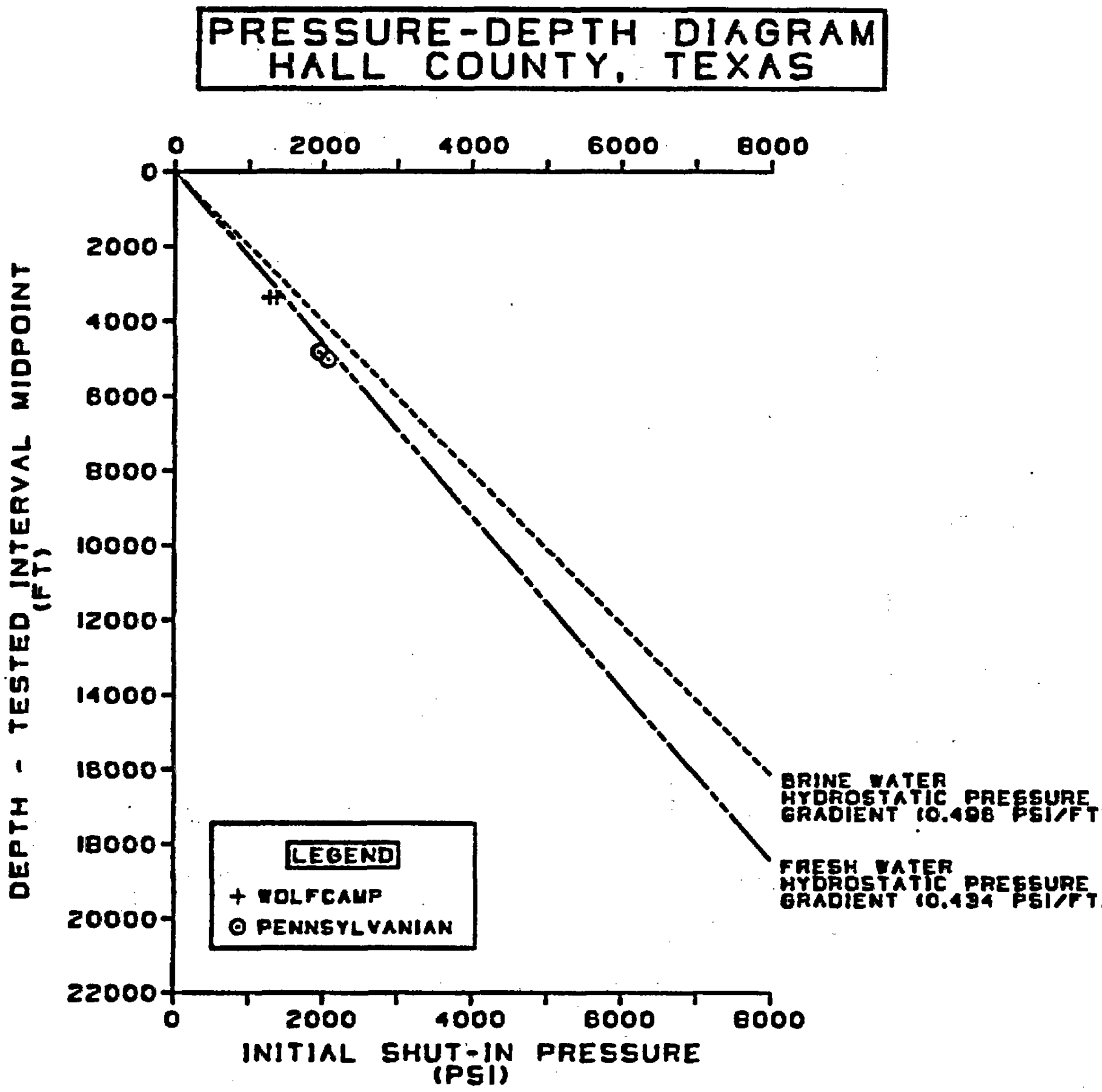

PRESSURE-DEPTH DIAGRAM
FLOYD COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
LEGEND
WICHITA
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
INITIAL SHUT-IN PRESSURE (PSI)

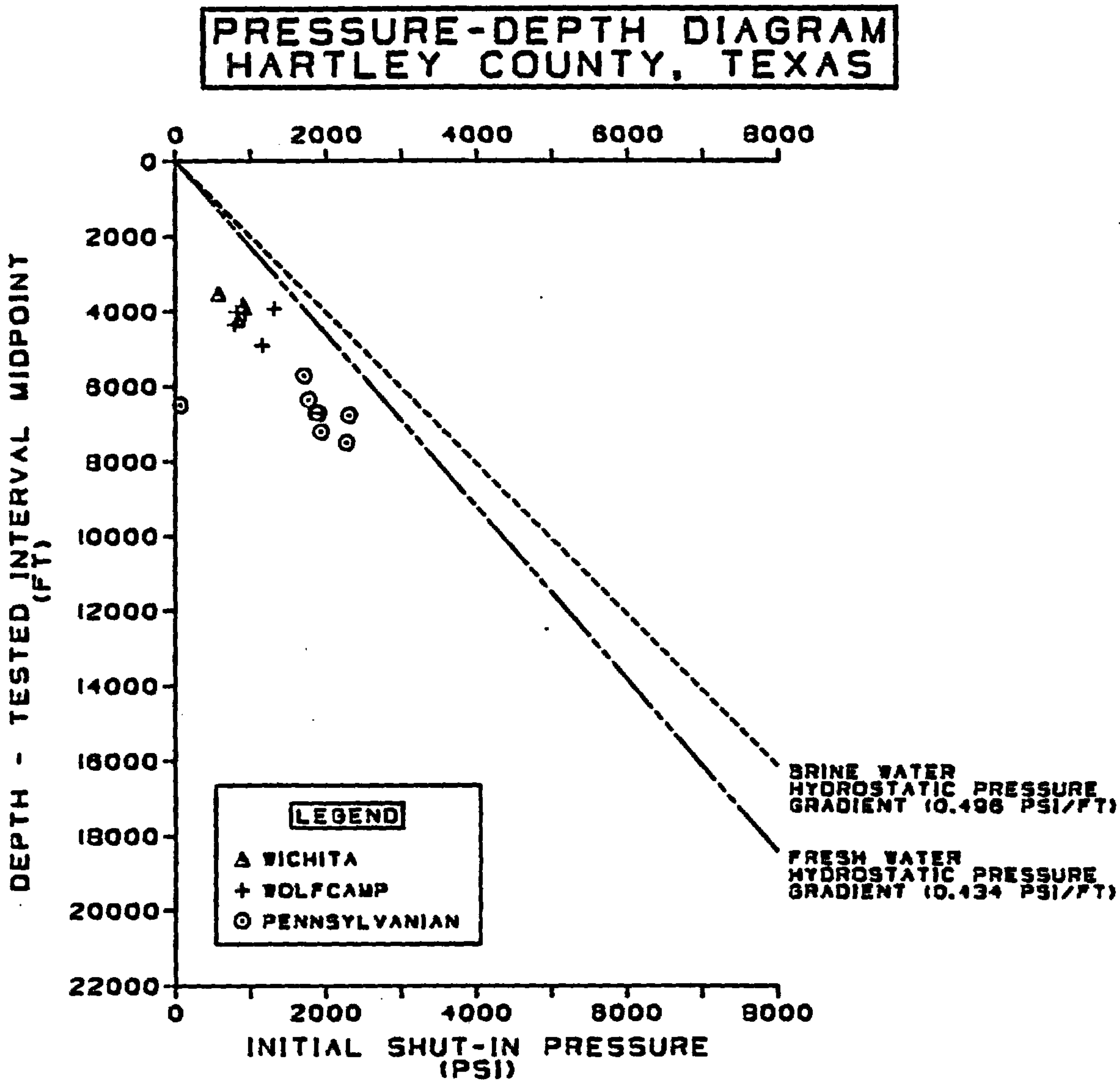

PRESSURE-DEPTH DIAGRAM
FOARD COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
+ WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

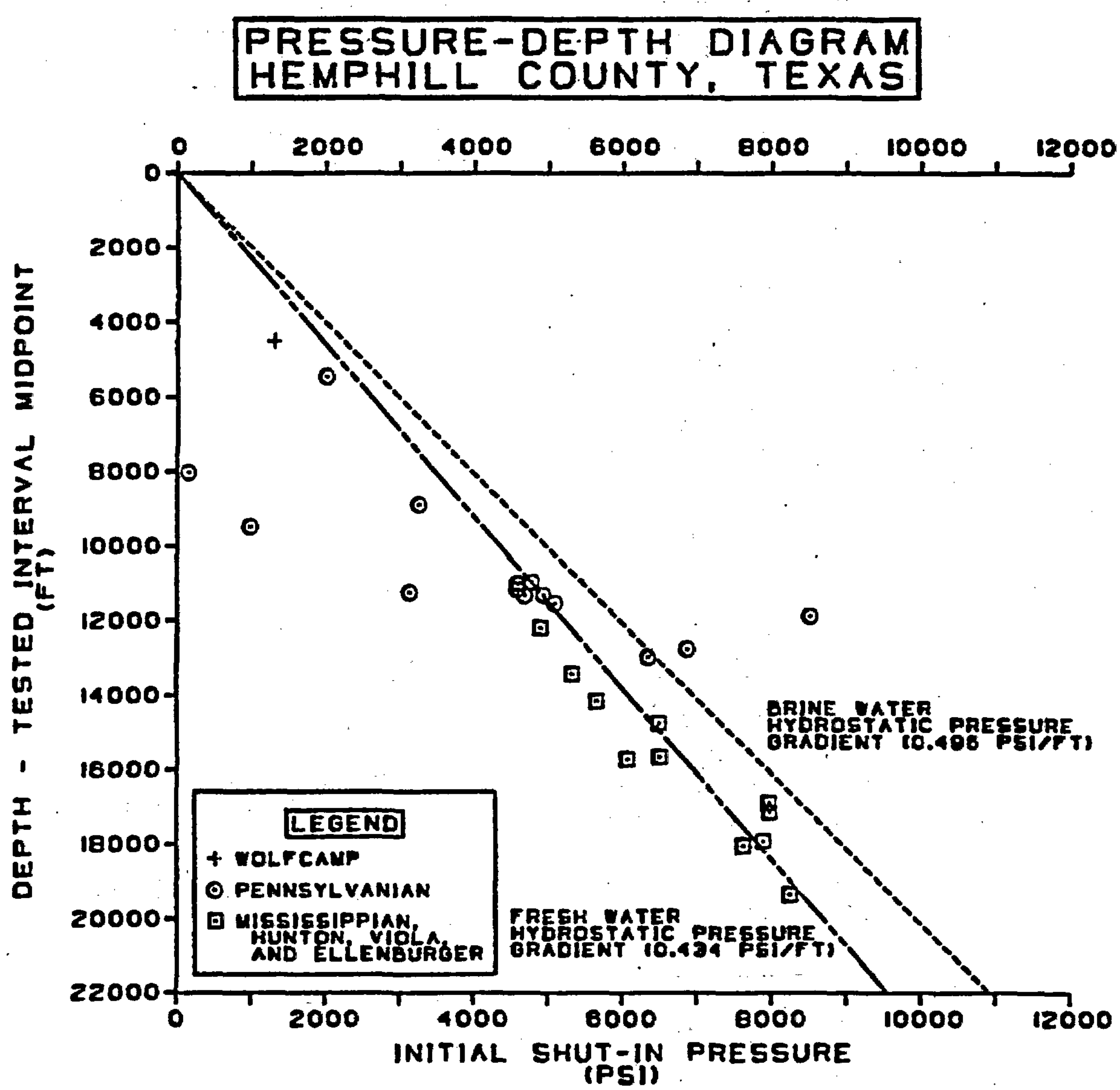

PRESSURE-DEPTH DIAGRAM
GRAY COUNTY, TEXAS
0
2000
4000
6000
8000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
+ WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN, SIMPSON, VIOLA, AND ELLENBURGER
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

PRESSURE-DEPTH DIAGRAM
HALE COUNTY, TEXAS

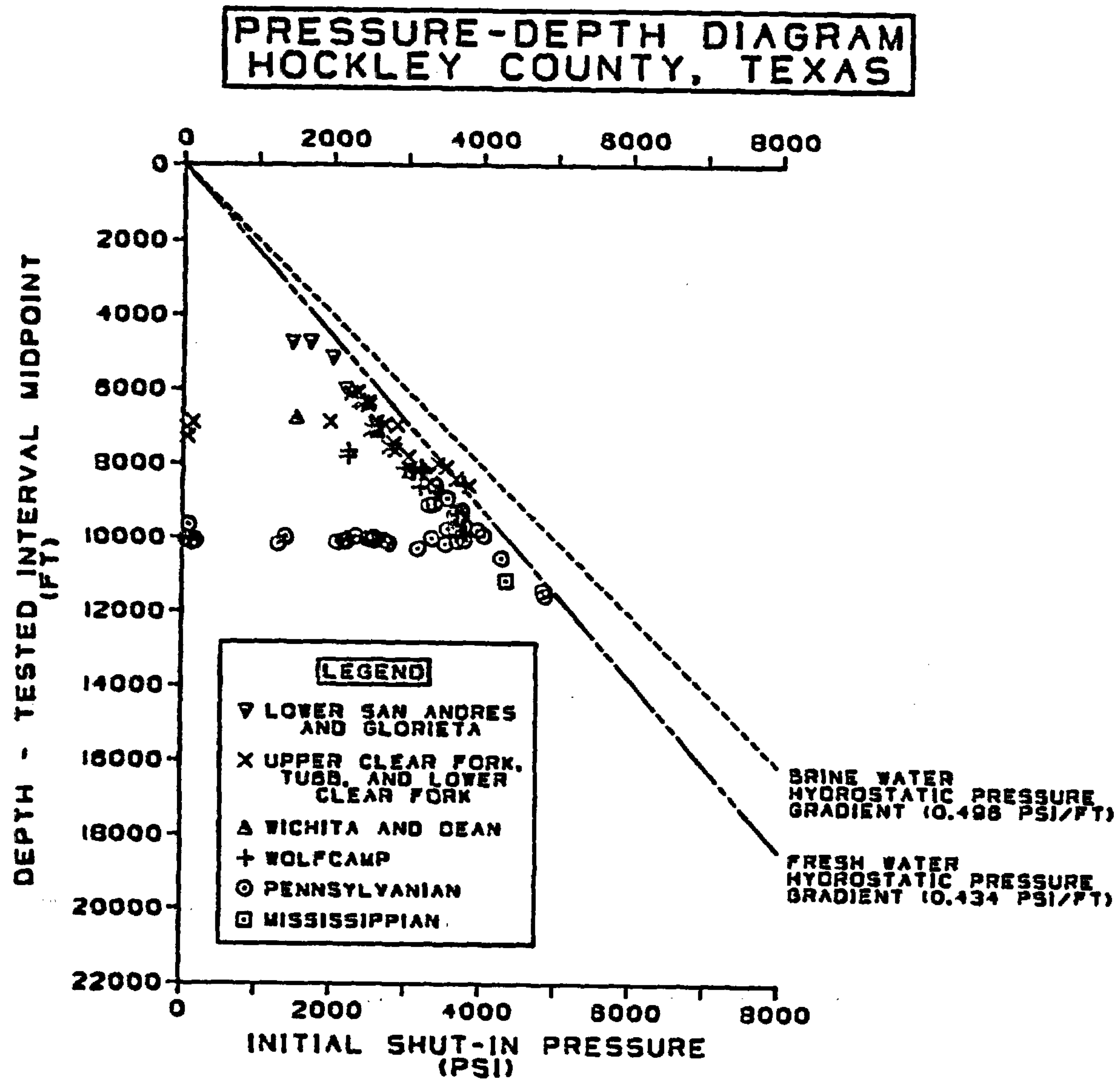



PRESSURE-DEPTH DIAGRAM
HALL COUNTY, TEXAS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN

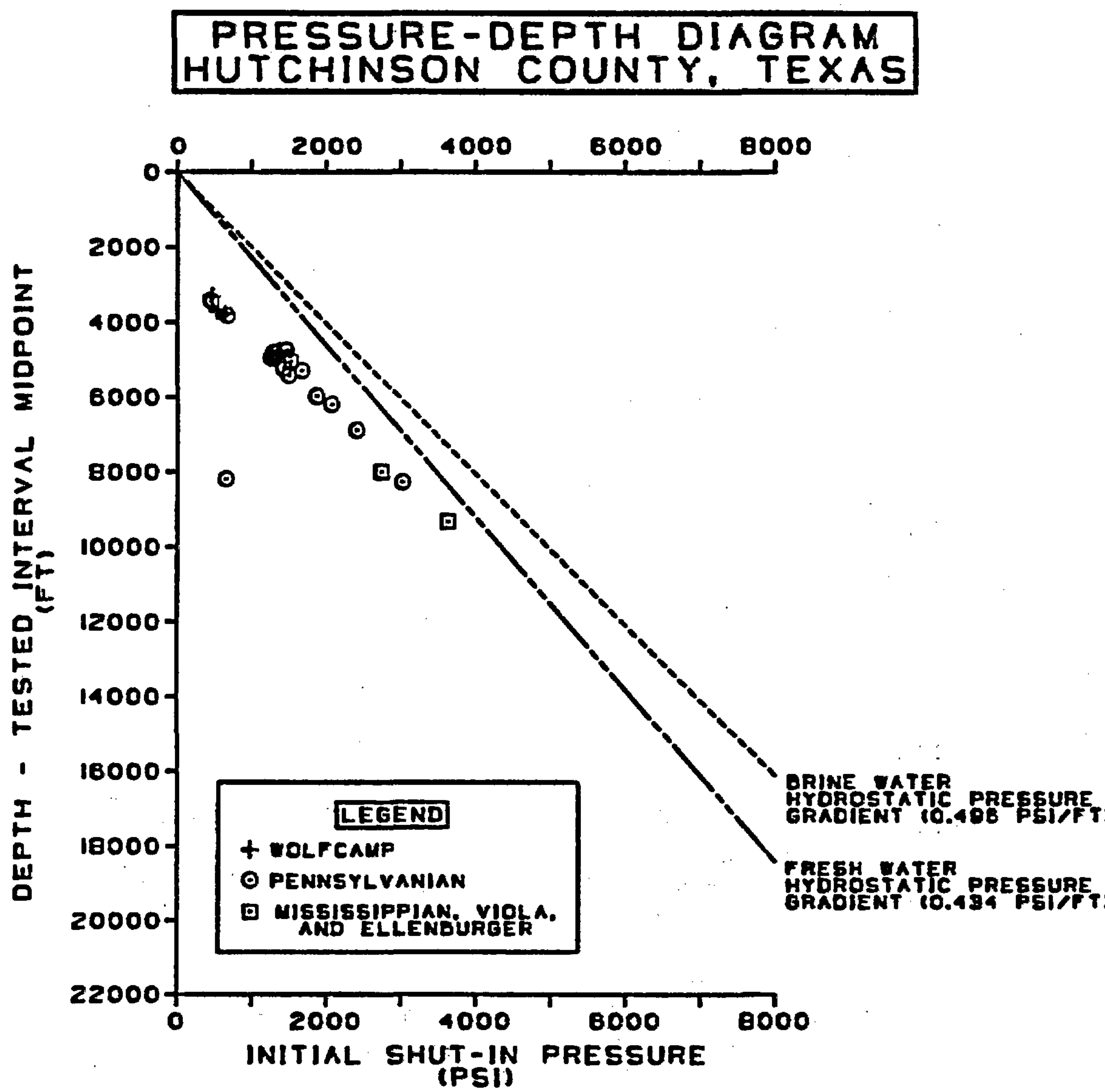

PRESSURE-DEPTH DIAGRAM
HARTLEY COUNTY, TEXAS
0
2000
4000
6000
8000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
WICHITA
WOLFCAMP
PENNSYLVANIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

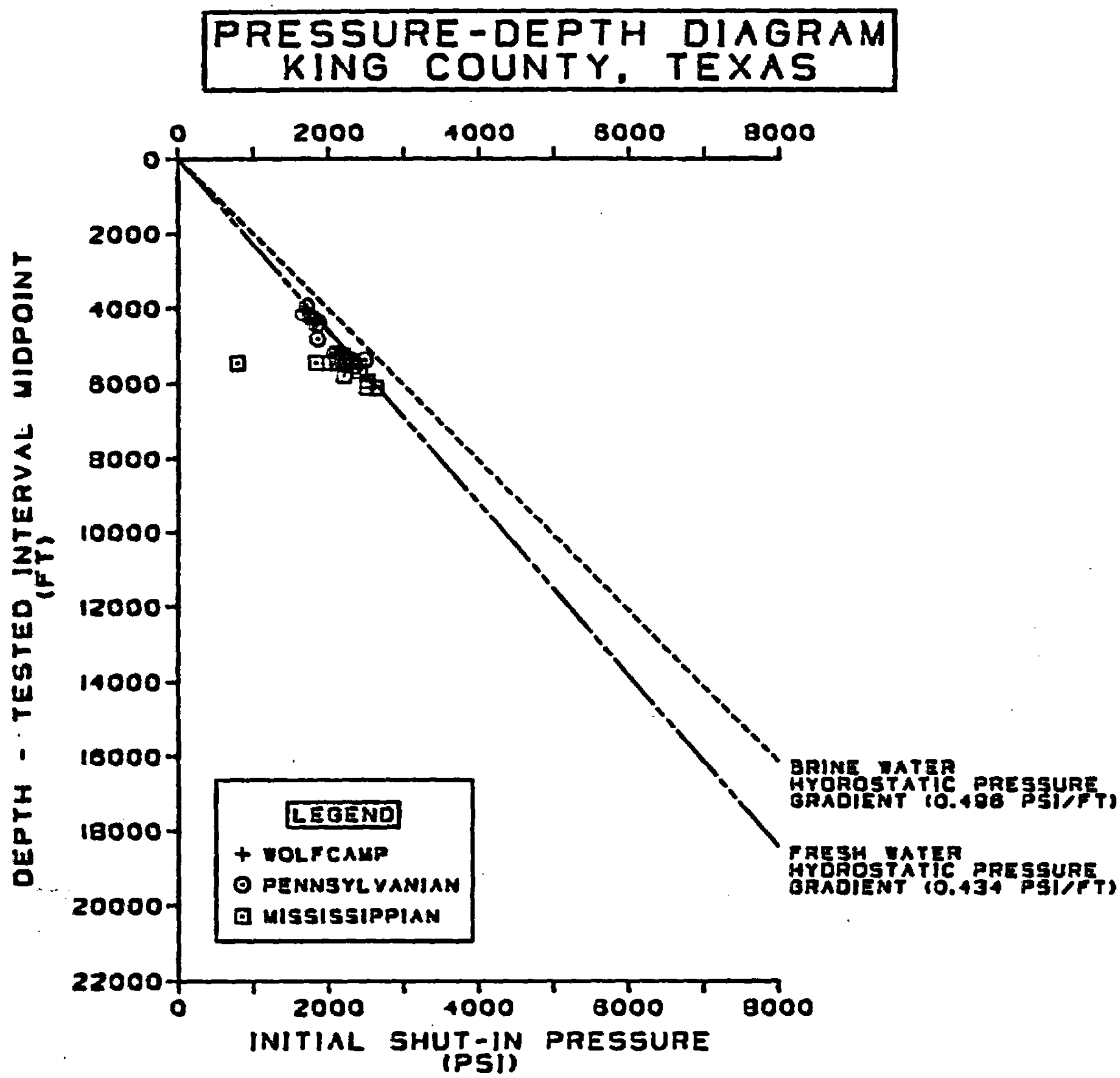


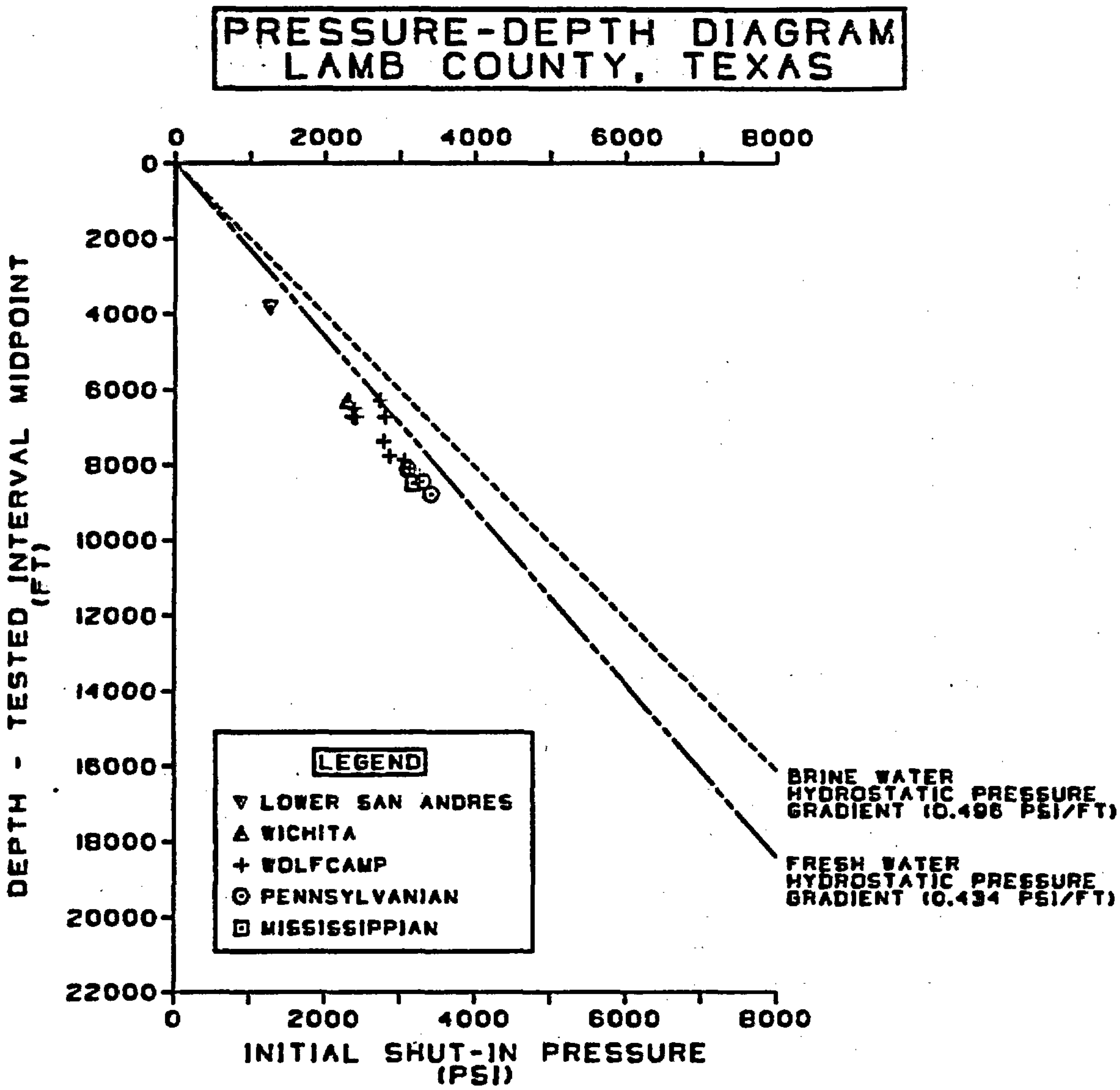
PRESSURE-DEPTH DIAGRAM
HEMPHILL COUNTY, TEXAS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.495 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
+ WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN, HUNTON, VIOLA, AND ELLENBURGER

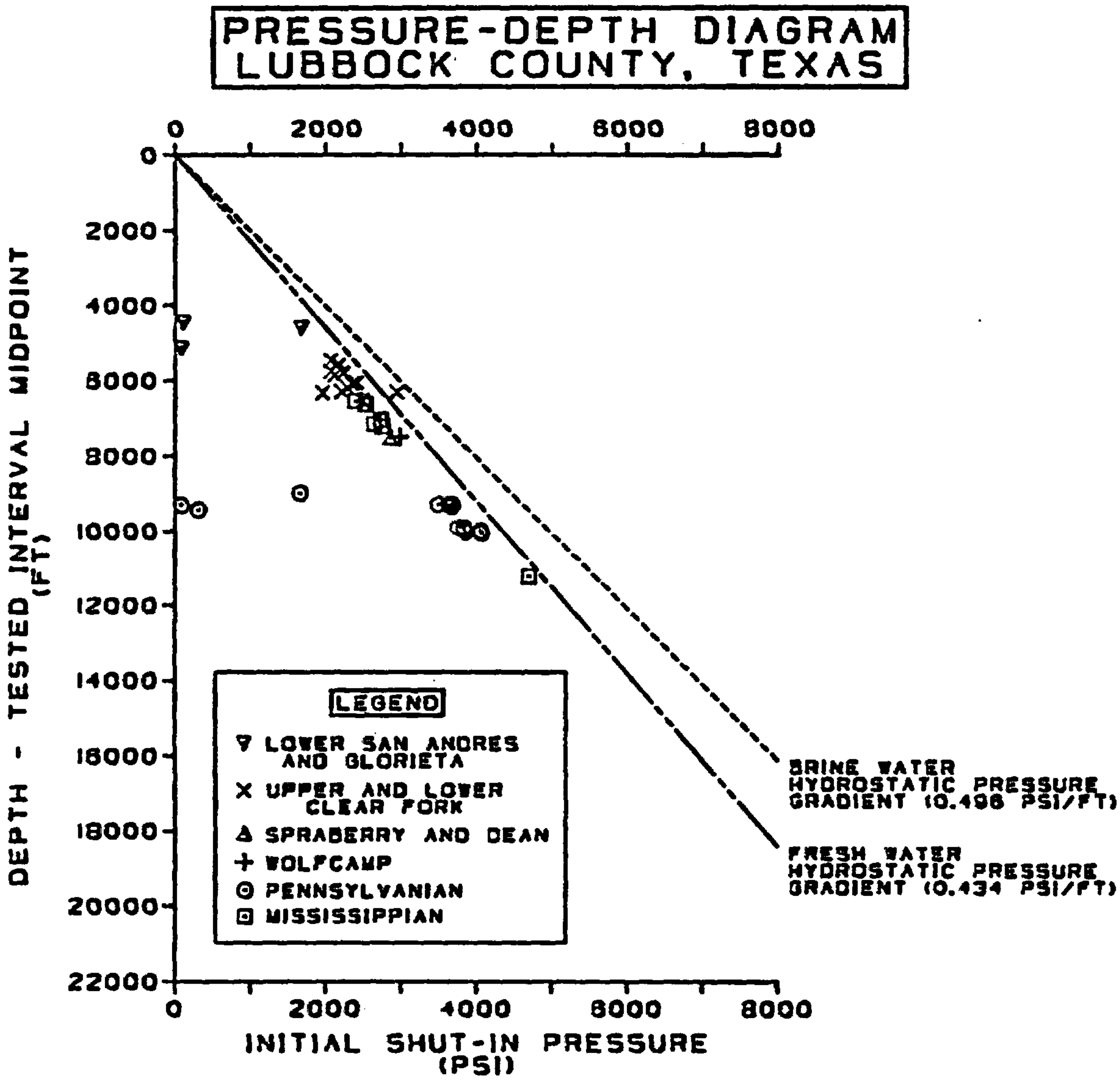


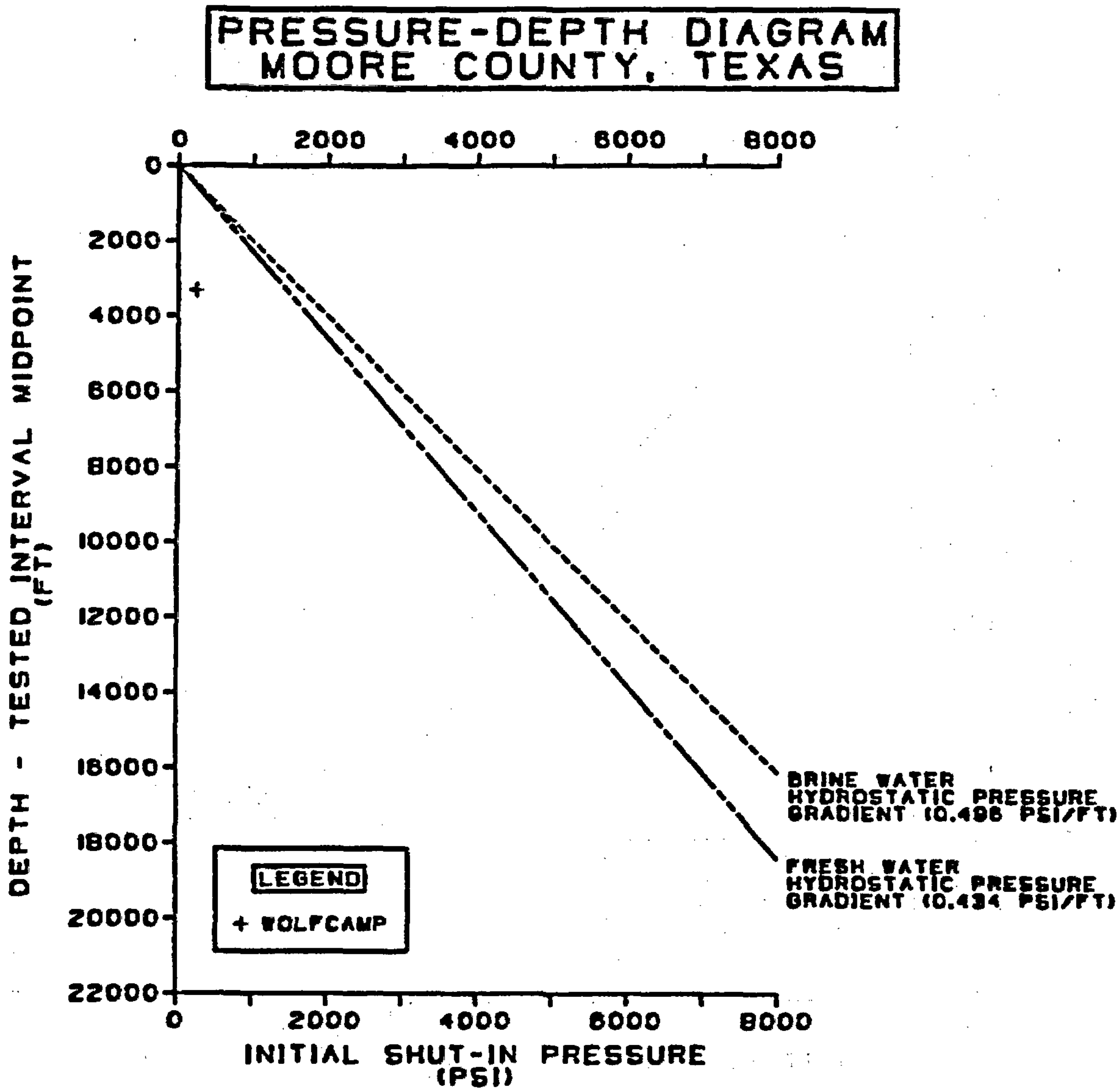
PRESSURE-DEPTH DIAGRAM
HOCKLEY COUNTY, TEXAS
0
2000
4000
6000
8000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
10000
12000
14000
16000
18000
20000
22000
LEGEND
LOWER SAN ANDRES AND GLORIETA
UPPER CLEAR FORK, TUBB, AND LOWER CLEAR FORK
WICHITA AND DEAN
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
INITIAL SHUT-IN PRESSURE (PSI)

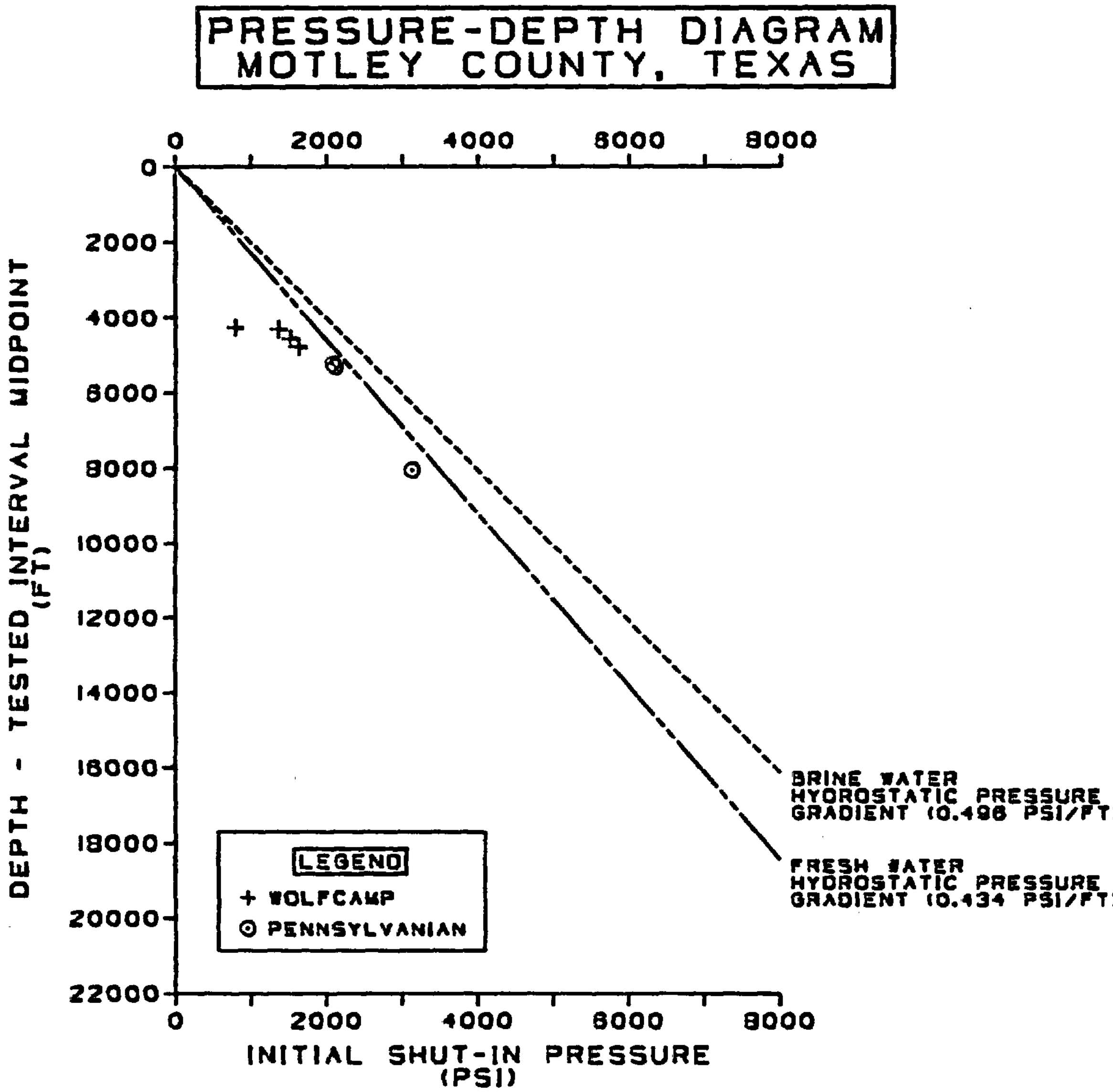

PRESSURE-DEPTH DIAGRAM
HUTCHINSON COUNTY, TEXAS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN, VIOLA, AND ELLENBURGER
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

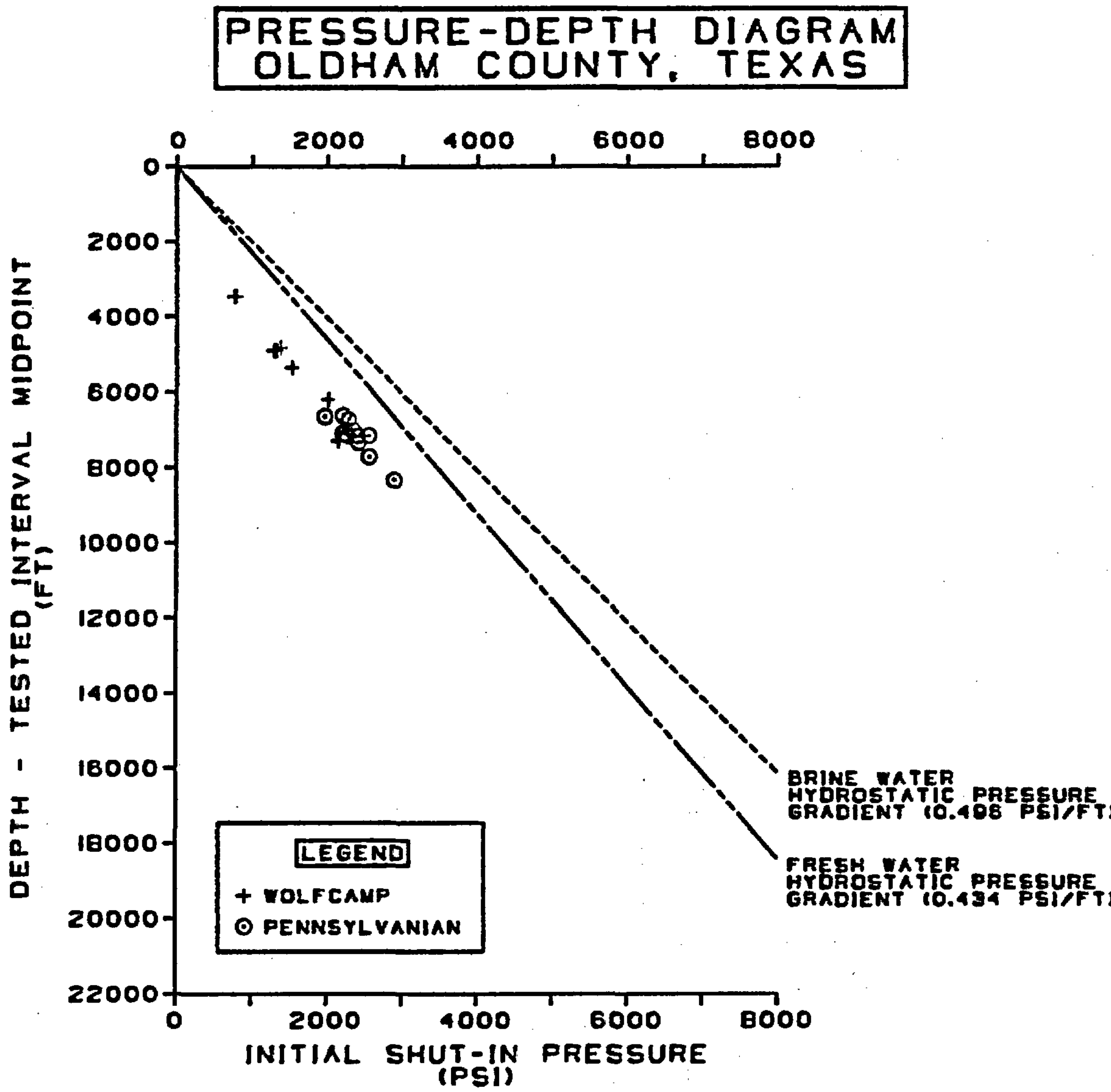

PRESSURE-DEPTH DIAGRAM
KING COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN
⊡ MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

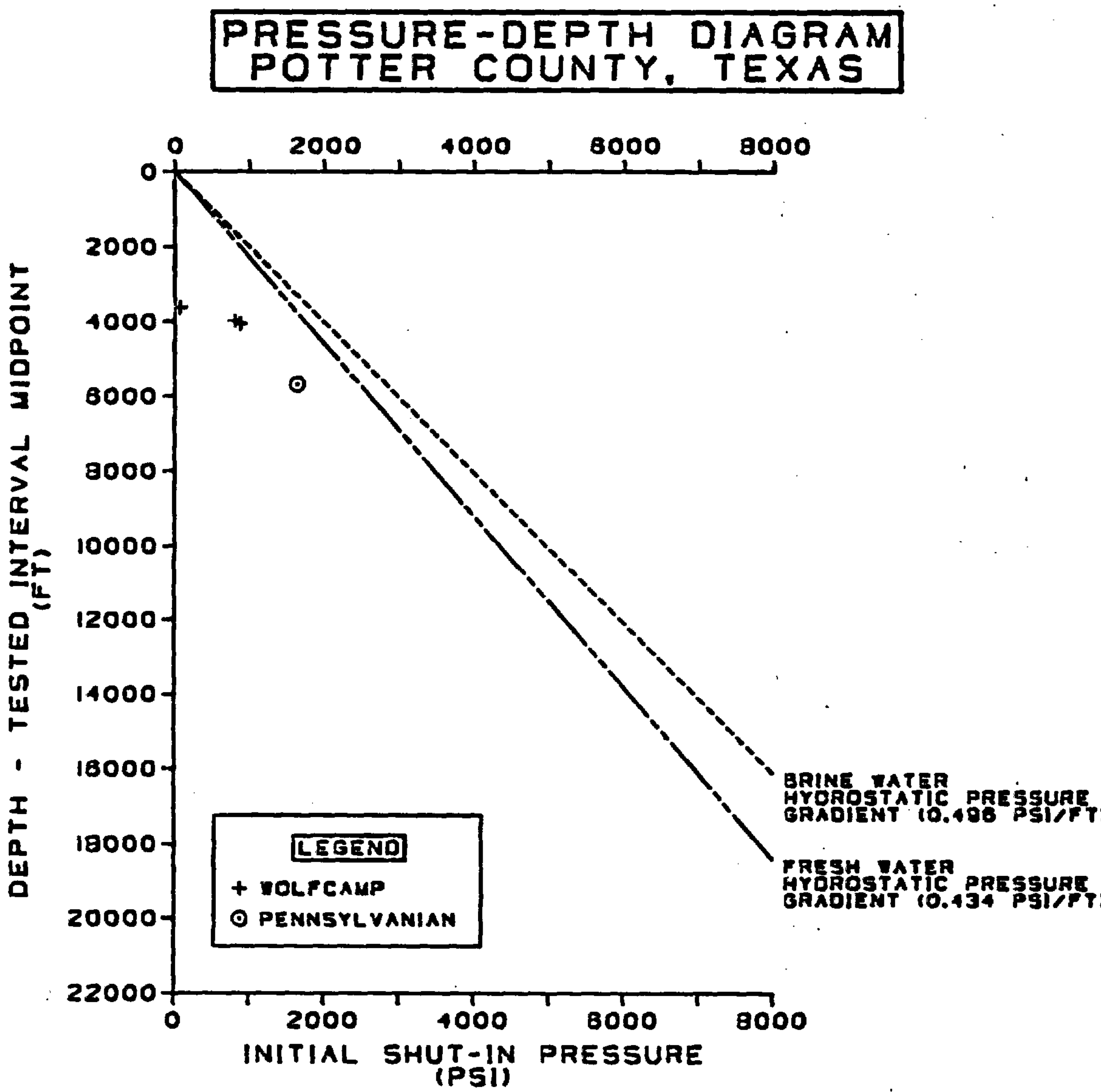

PRESSURE-DEPTH DIAGRAM
LAMB COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
LOWER SAN ANDRES
WICHITA
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

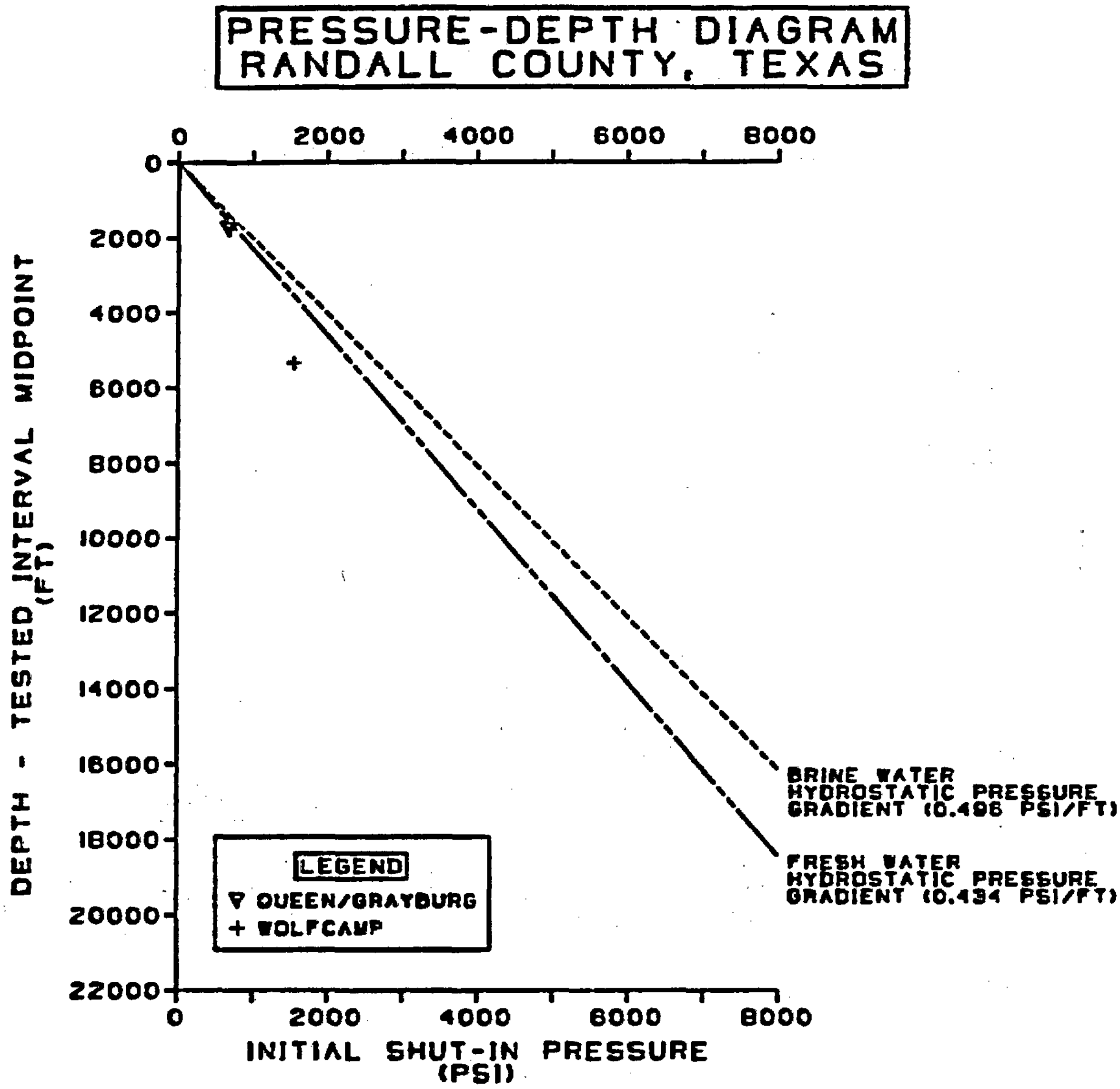

PRESSURE-DEPTH DIAGRAM
LUBBOCK COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
LOWER SAN ANDRES AND GLORIETA
UPPER AND LOWER CLEAR FORK
SPRABERRY AND DEAN
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

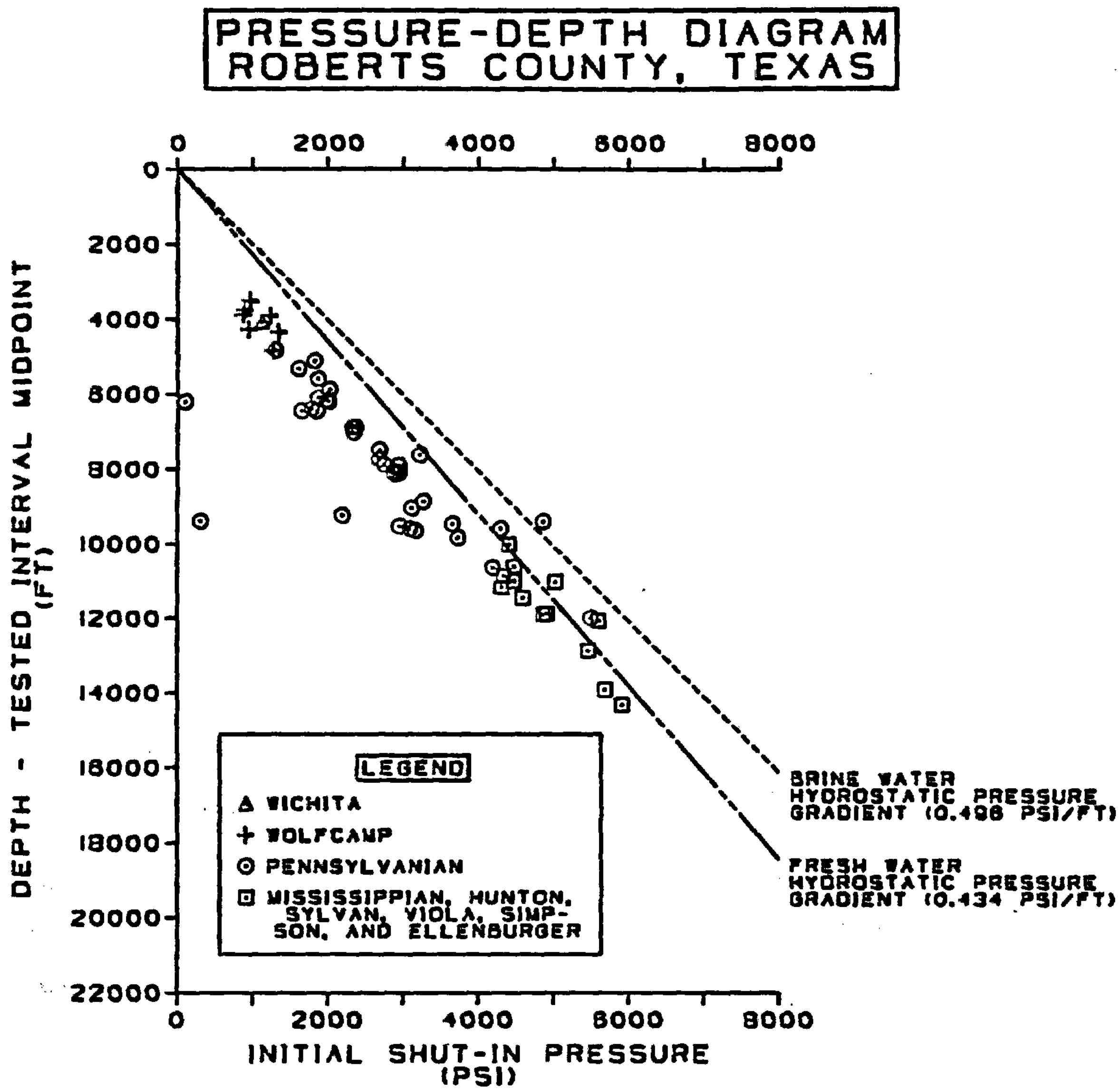

PRESSURE-DEPTH DIAGRAM
MOORE COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT
(FT)
BRINE WATER
HYDROSTATIC PRESSURE
GRADIENT (0.496 PSI/FT)
FRESH WATER
HYDROSTATIC PRESSURE
GRADIENT (0.434 PSI/FT)
LEGEND
+ WOLFCAMP
INITIAL SHUT-IN PRESSURE
(PSI)

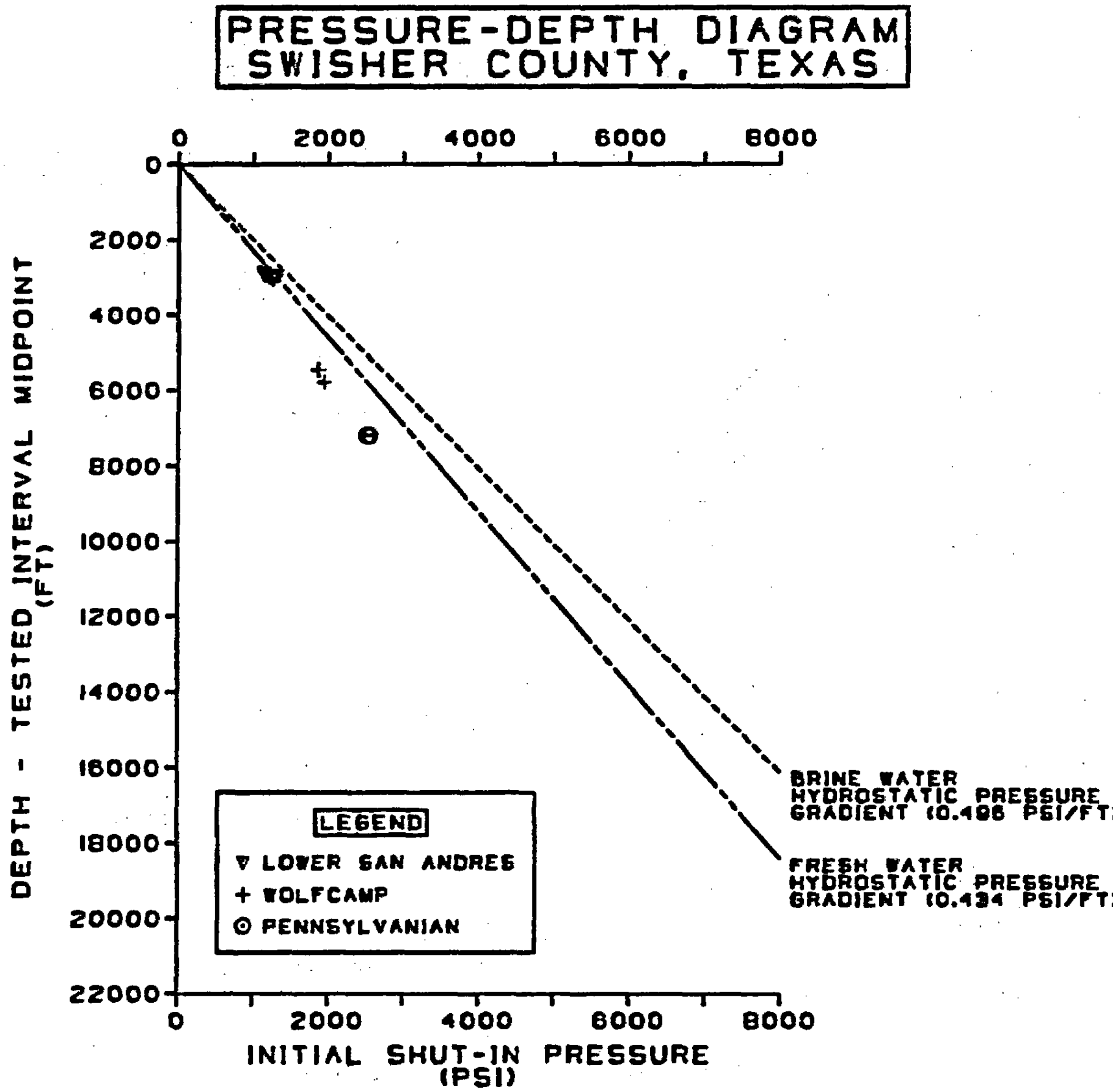

PRESSURE-DEPTH DIAGRAM
MOTLEY COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN

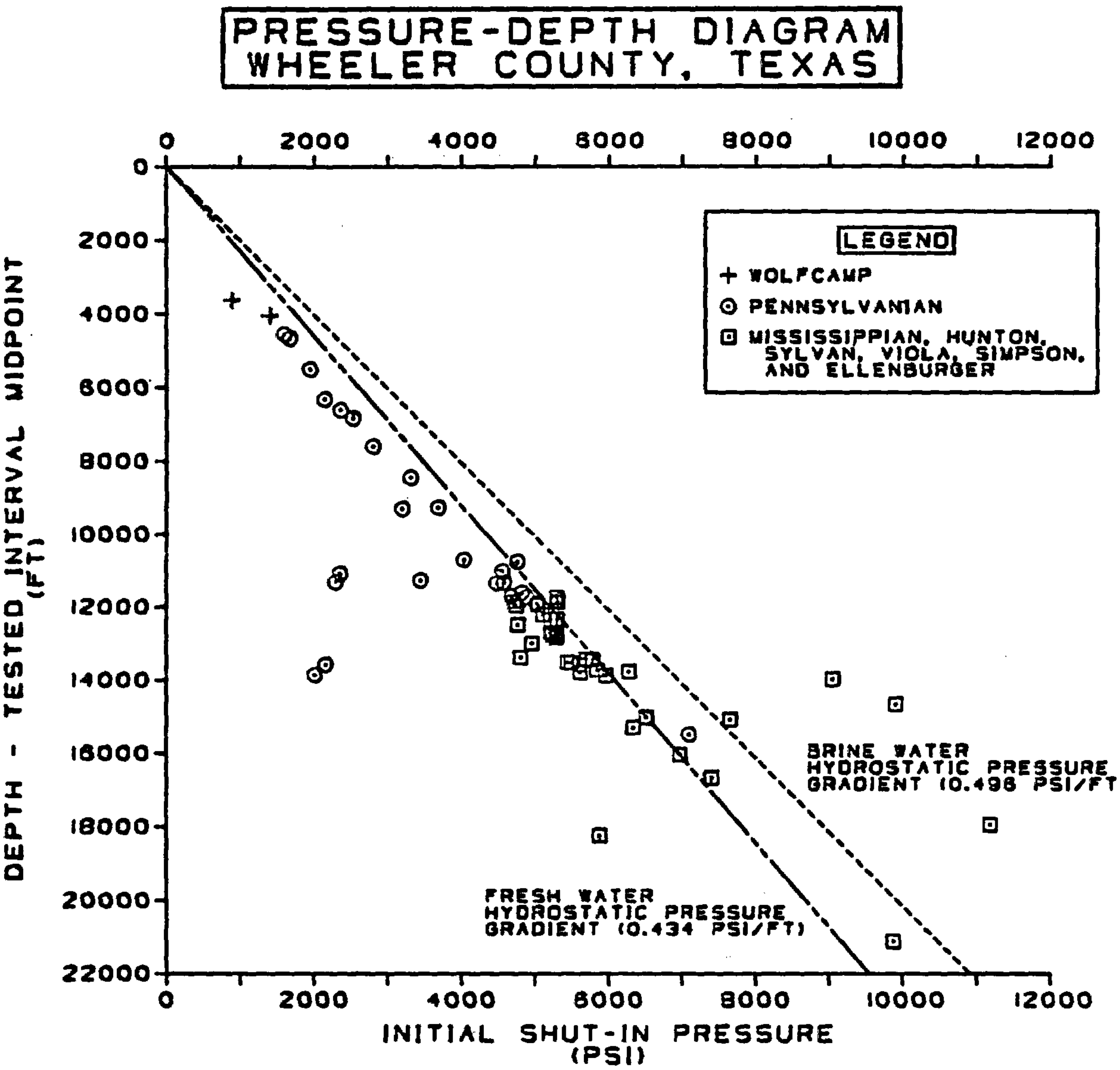

PRESSURE-DEPTH DIAGRAM
OLDHAM COUNTY, TEXAS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT
(FT)
INITIAL SHUT-IN PRESSURE
(PSI)
BRINE WATER
HYDROSTATIC PRESSURE
GRADIENT (0.498 PSI/FT)
FRESH WATER
HYDROSTATIC PRESSURE
GRADIENT (0.434 PSI/FT)
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN

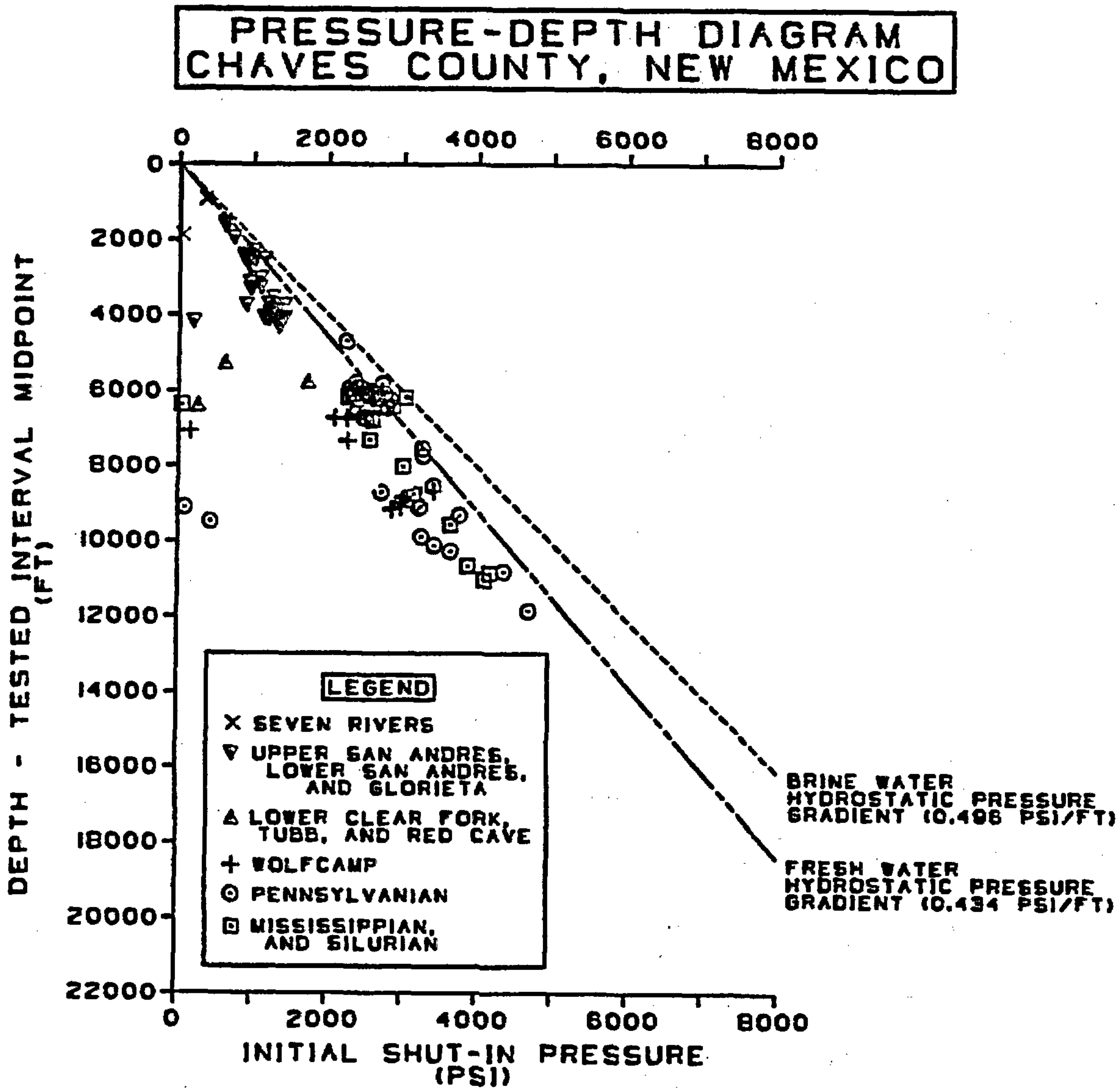

PRESSURE-DEPTH DIAGRAM
POTTER COUNTY, TEXAS
0
2000
4000
6000
8000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
10000
12000
14000
16000
18000
20000
22000
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN
INITIAL SHUT-IN PRESSURE (PSI)


PRESSURE-DEPTH DIAGRAM
RANDALL COUNTY, TEXAS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
▽ QUEEN/GRAYBURG
+ WOLFCAMP

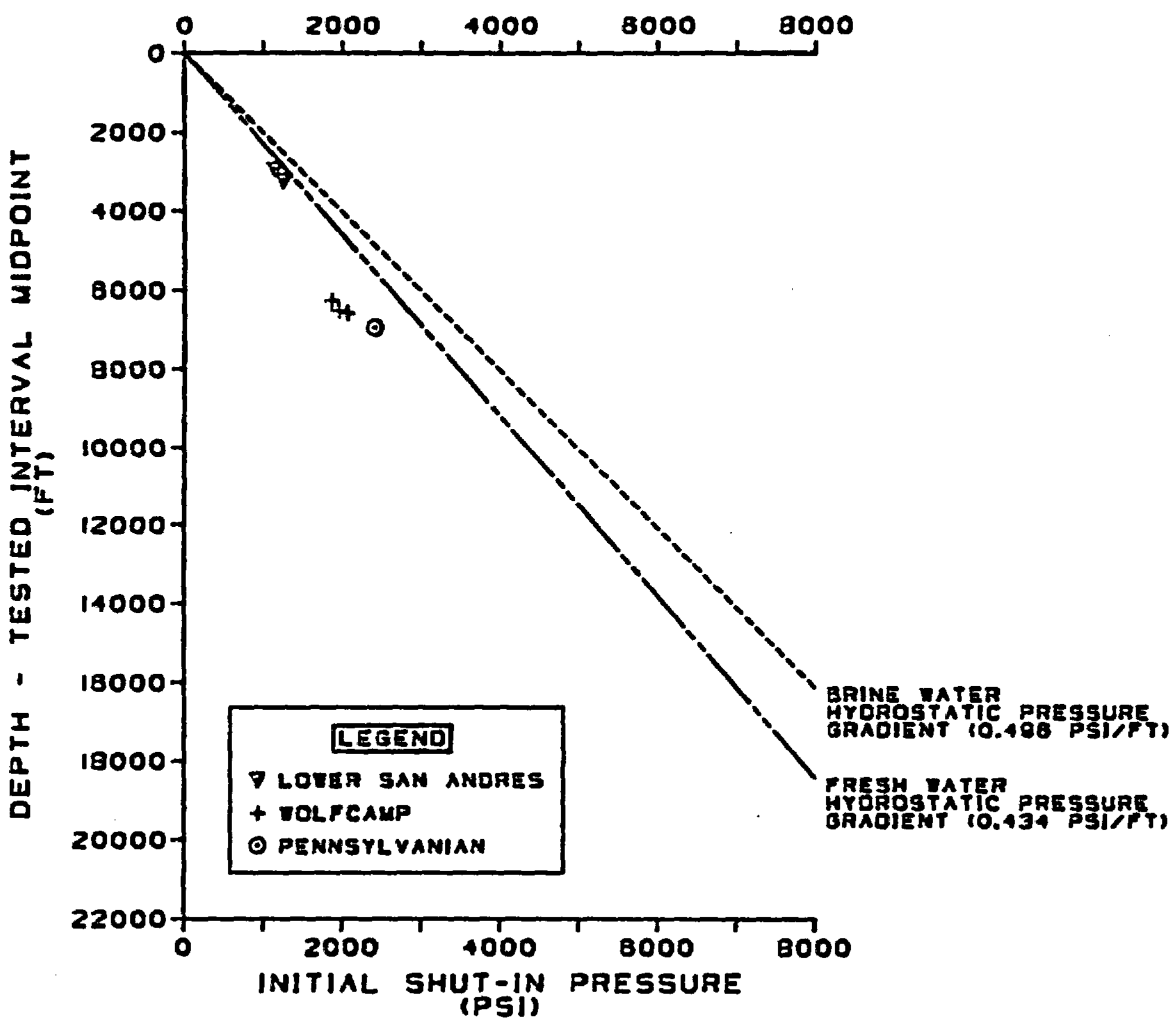

PRESSURE-DEPTH DIAGRAM
ROBERTS COUNTY, TEXAS
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
LEGEND
WICHITA
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN, HUNTON, SYLVAN, VIOLA, SIMPSON, AND ELLENBURGER
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)

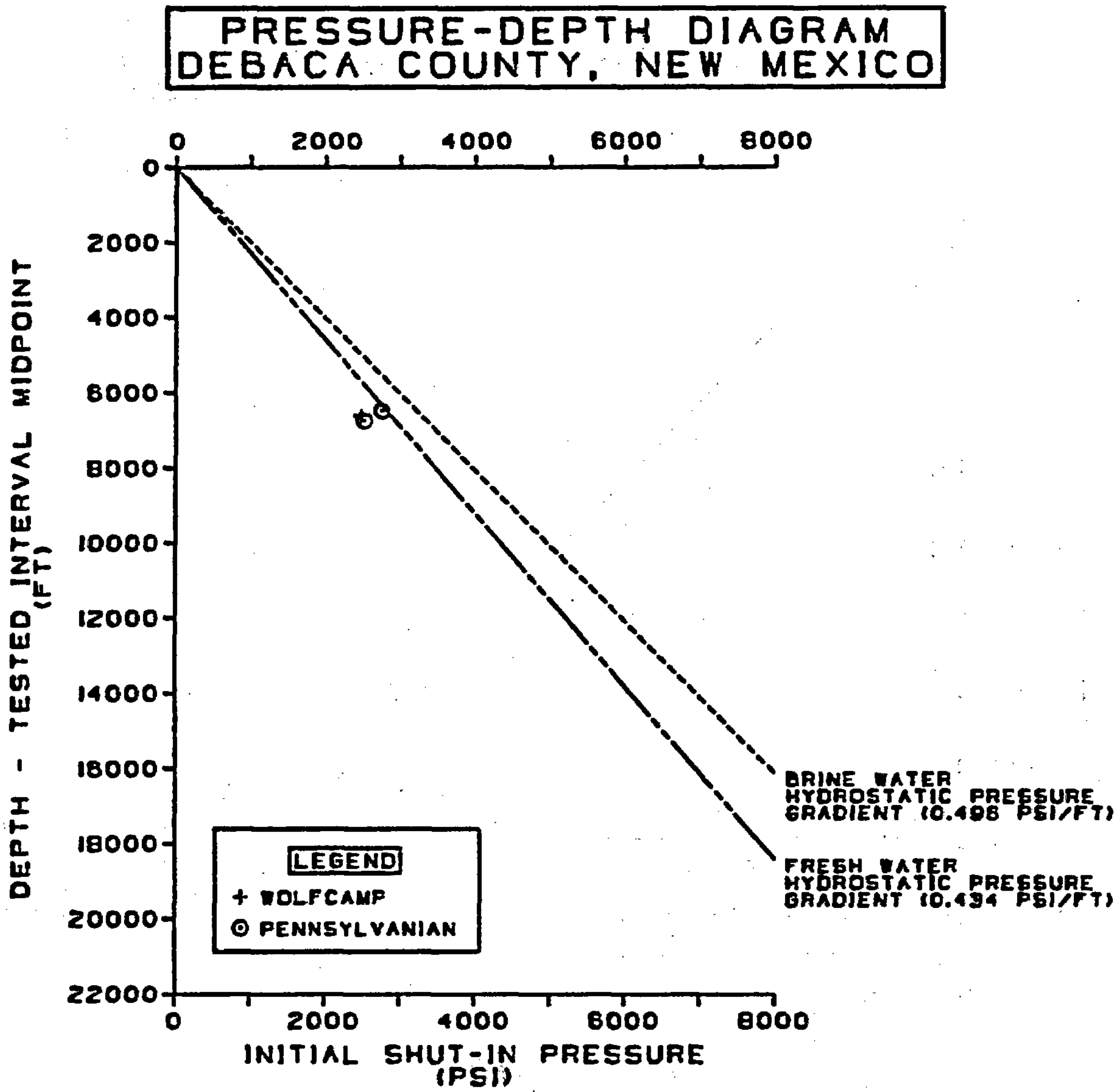

PRESSURE-DEPTH DIAGRAM
SWISHER COUNTY, TEXAS
0
2000
4000
6000
8000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
LOWER SAN ANDRES
WOLFCAMP
PENNSYLVANIAN


PRESSURE-DEPTH DIAGRAM
WHEELER COUNTY, TEXAS
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN
⊡ MISSISSIPPIAN, HUNTON, SYLVAN, VIOLA, SIMPSON, AND ELLENBURGER
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.498 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000


PRESSURE-DEPTH DIAGRAM
CHAVES COUNTY, NEW MEXICO
0 2000 4000 6000 8000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
LEGEND
SEVEN RIVERS
UPPER SAN ANDRES, LOWER SAN ANDRES, AND GLORIETA
LOWER CLEAR FORK, TUBB, AND RED CAVE
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN, AND SILURIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
INITIAL SHUT-IN PRESSURE (PSI)

PRESSURE-DEPTH DIAGRAM
CURRY COUNTY, NEW MEXICO




PRESSURE-DEPTH DIAGRAM
DEBACA COUNTY, NEW MEXICO
0
2000
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DEPTH - TESTED INTERVAL MIDPOINT (FT)
0
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12000
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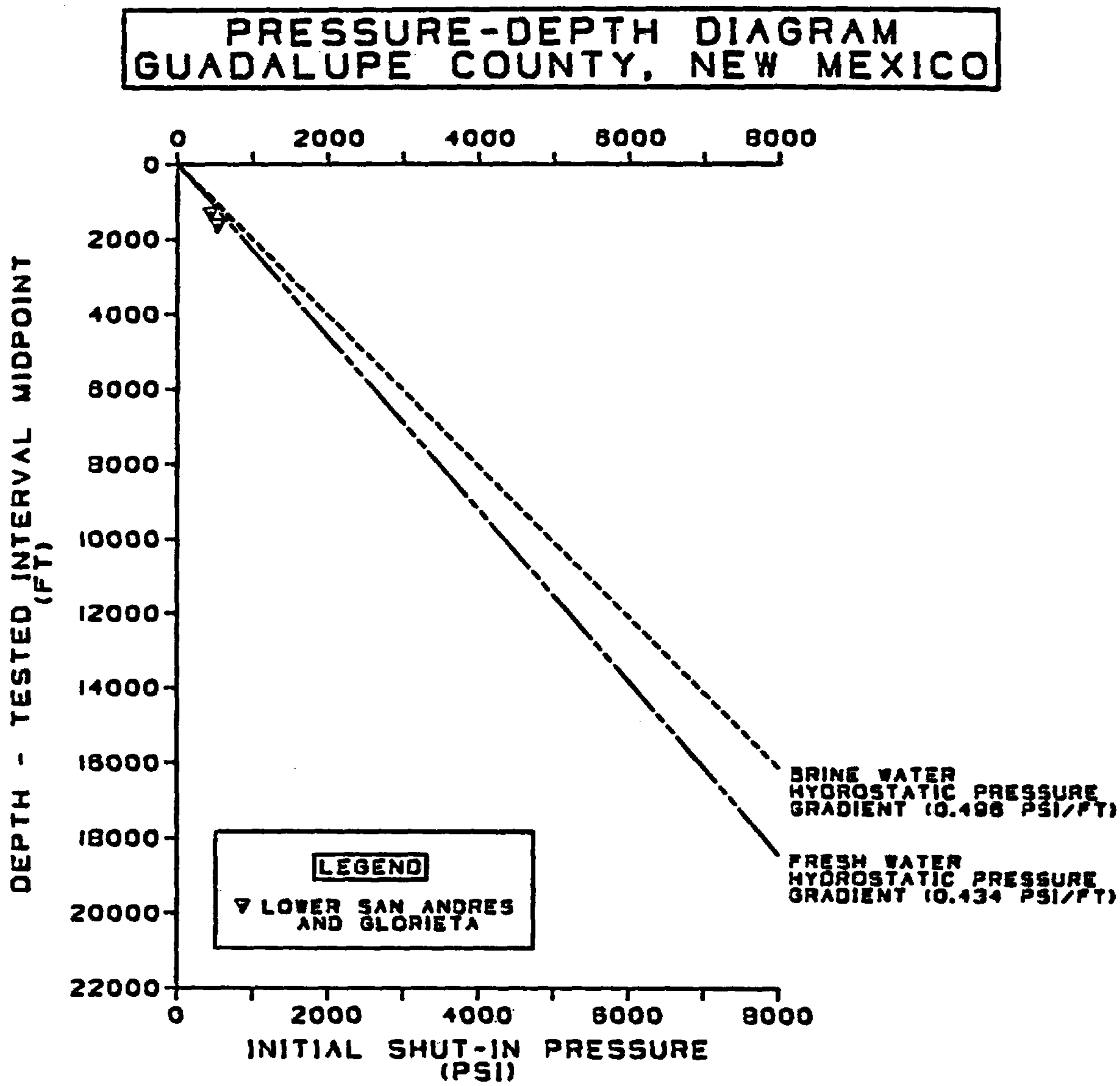
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
+ WOLFCAMP
⊙ PENNSYLVANIAN
INITIAL SHUT-IN PRESSURE (PSI)


PRESSURE-DEPTH DIAGRAM
GUADALUPE COUNTY, NEW MEXICO
0
2000
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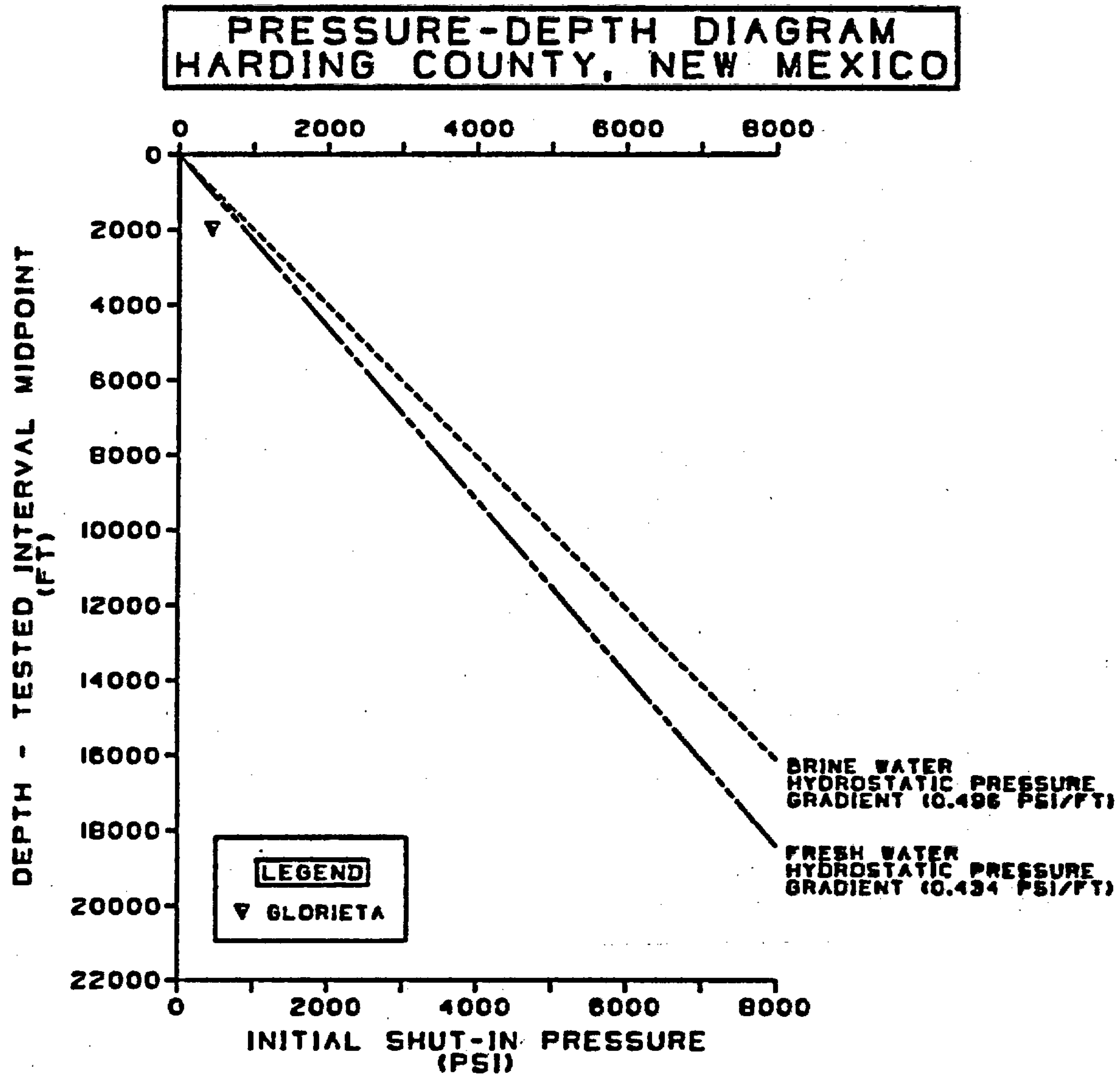
8000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
10000
12000
14000
16000
18000
20000
22000
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
▽ LOWER SAN ANDRES AND GLORIETA


PRESSURE-DEPTH DIAGRAM
HARDING COUNTY, NEW MEXICO
0
2000
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8000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
0
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12000
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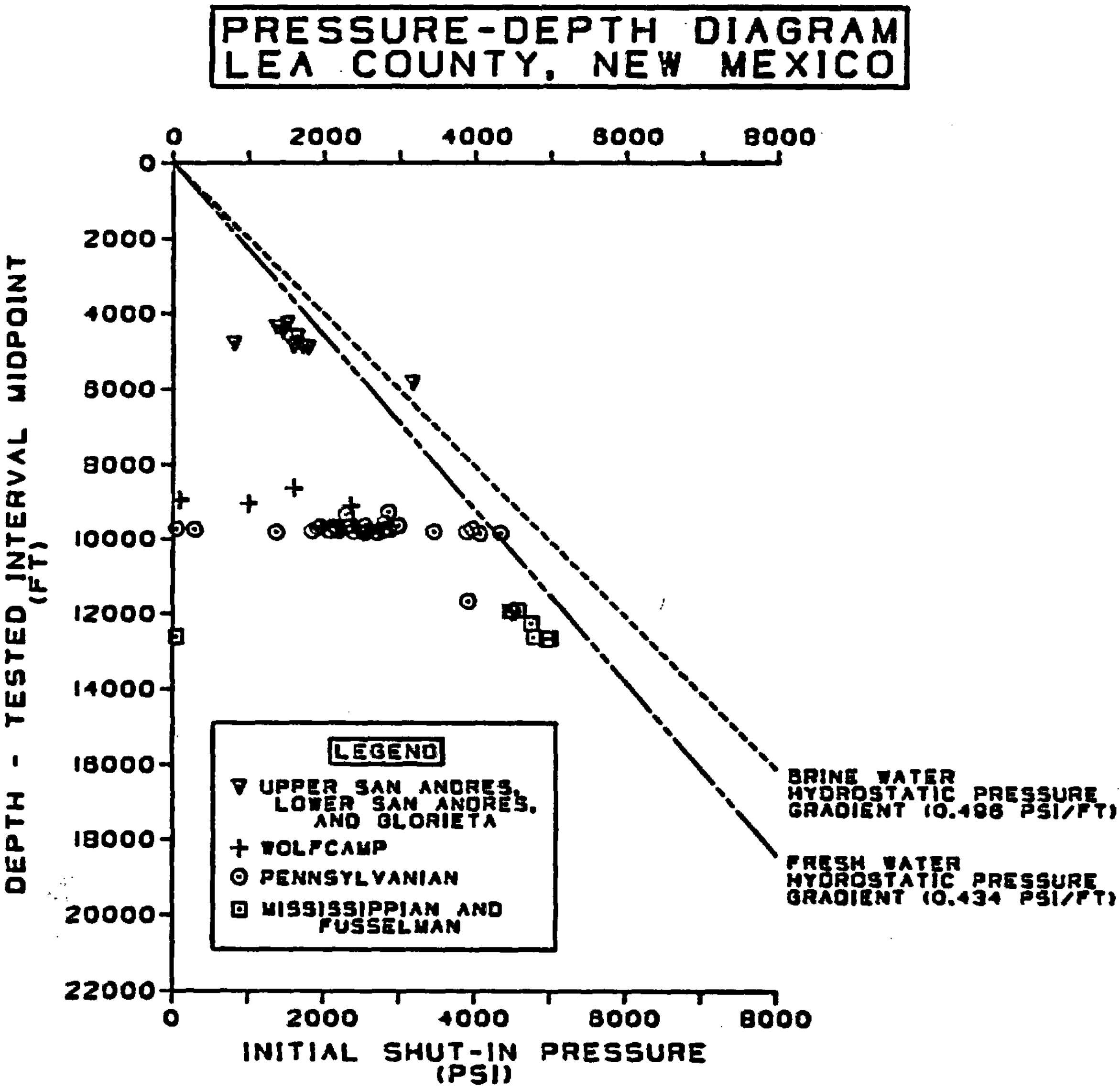
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
▼ GLORIETA
INITIAL SHUT-IN PRESSURE (PSI)


PRESSURE-DEPTH DIAGRAM
LEA COUNTY, NEW MEXICO
0
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DEPTH - TESTED INTERVAL MIDPOINT (FT)
10000
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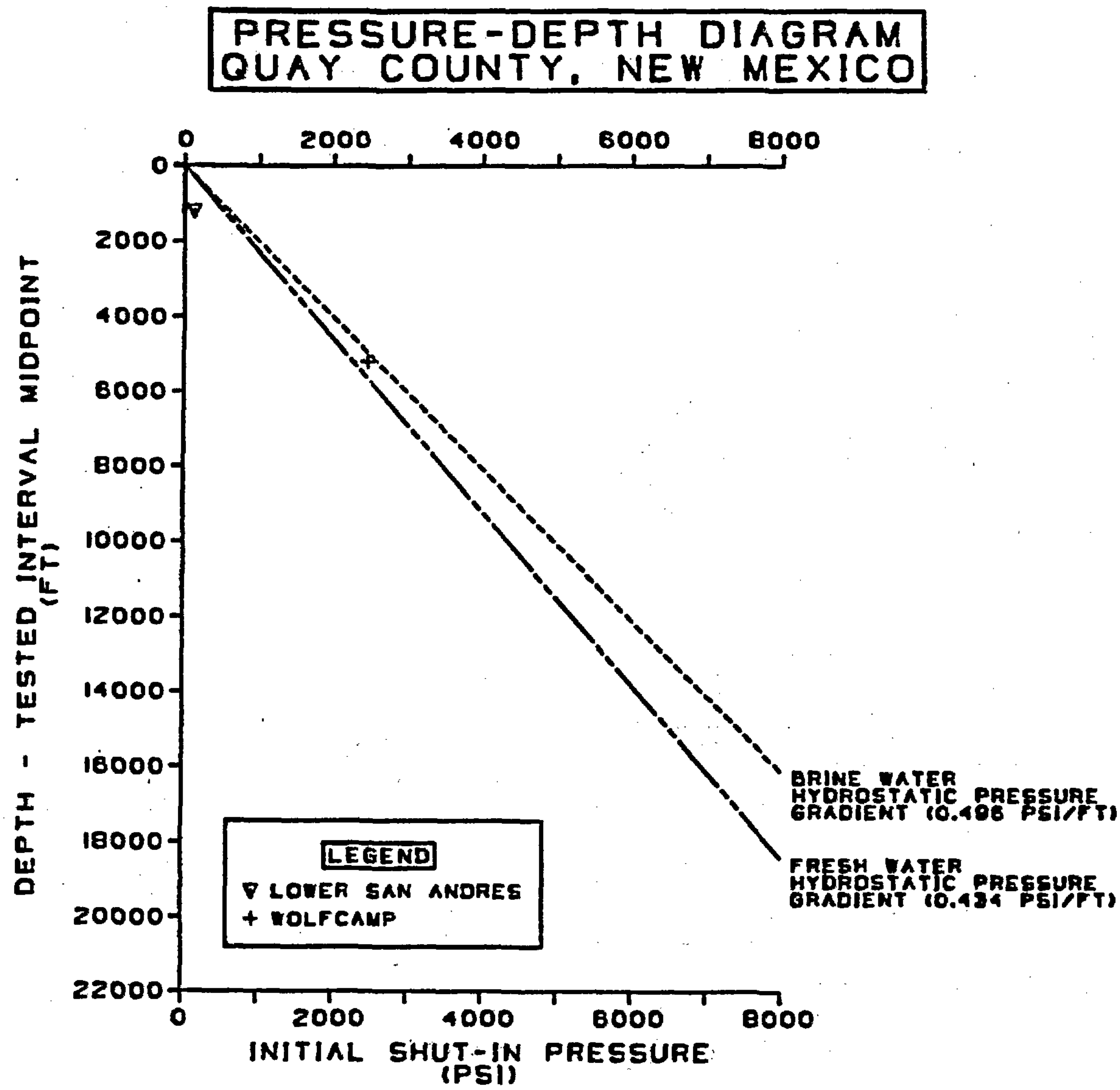
18000
20000
22000
LEGEND
UPPER SAN ANDRES, LOWER SAN ANDRES, AND GLORIETA
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN AND FUSSELMAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
INITIAL SHUT-IN PRESSURE (PSI)



PRESSURE-DEPTH DIAGRAM
QUAY COUNTY, NEW MEXICO
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14000
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18000
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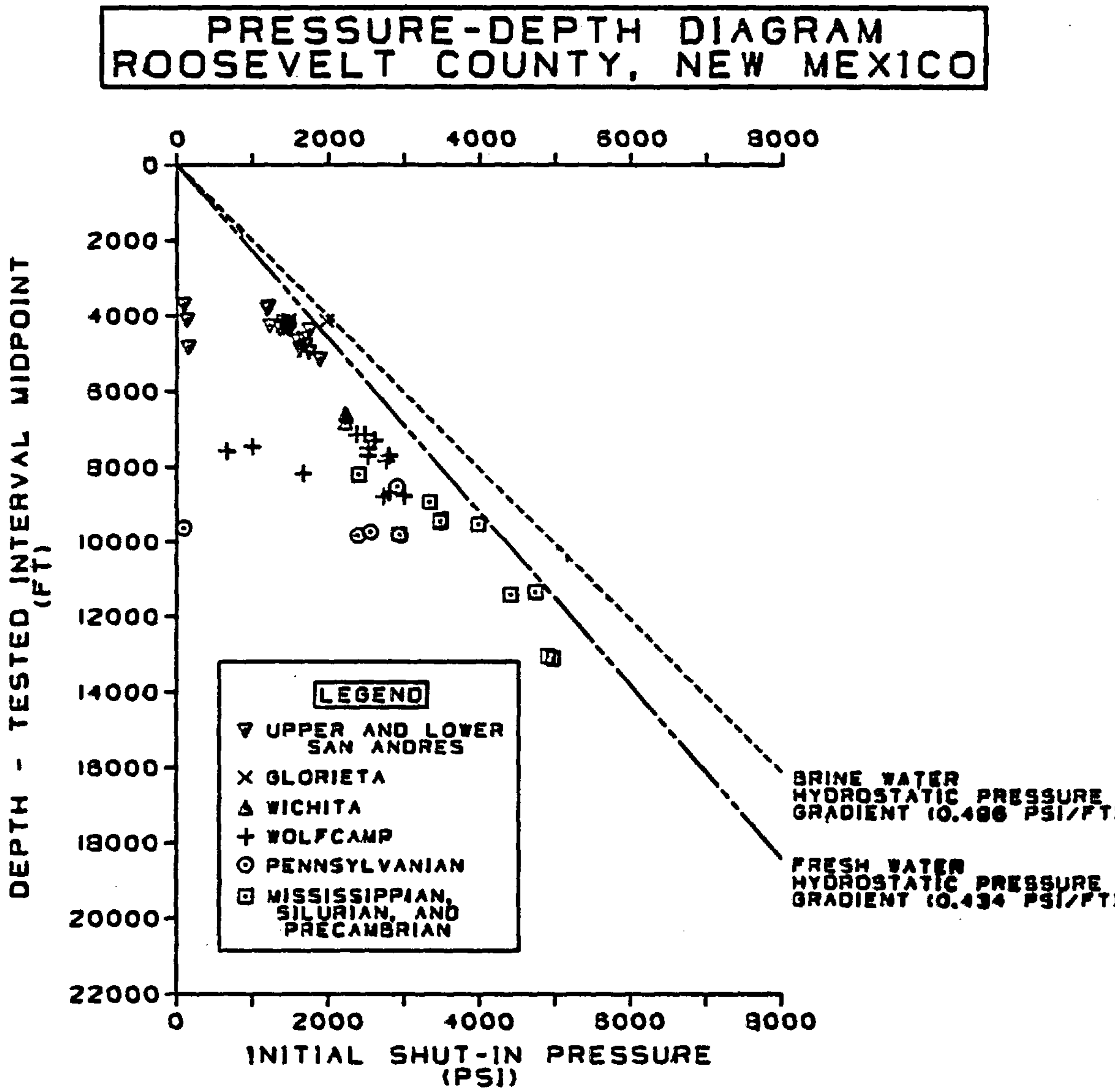
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
LOWER SAN ANDRES
+ WOLFCAMP


PRESSURE-DEPTH DIAGRAM
ROOSEVELT COUNTY, NEW MEXICO
0
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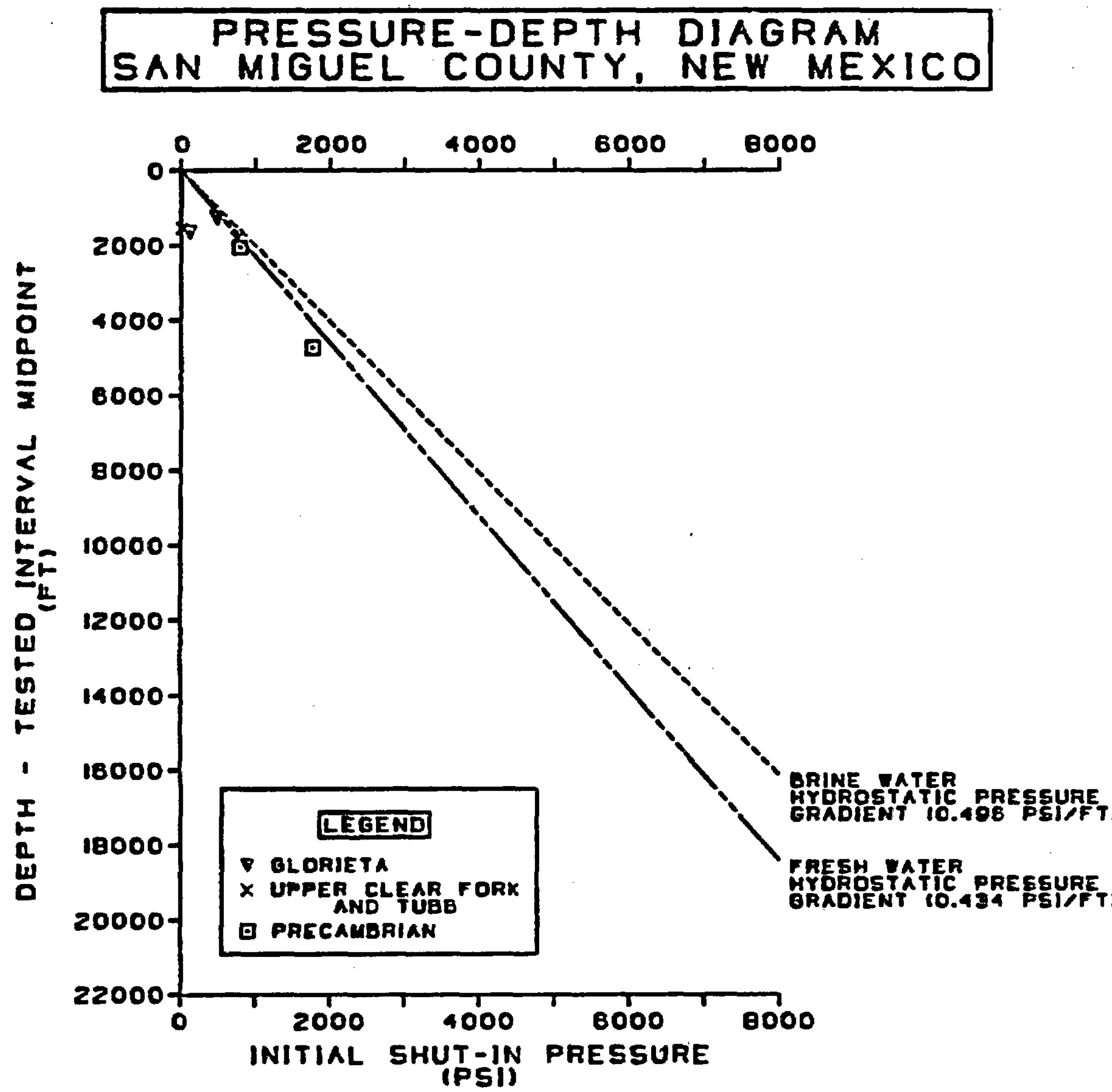
16000
18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
LEGEND
UPPER AND LOWER SAN ANDRES
GLORIETA
WICHITA
WOLFCAMP
PENNSYLVANIAN
MISSISSIPPIAN, SILURIAN, AND PRECAMBRIAN
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
INITIAL SHUT-IN PRESSURE (PSI)


PRESSURE-DEPTH DIAGRAM
SAN MIGUEL COUNTY, NEW MEXICO
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14000
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18000
20000
22000
DEPTH - TESTED INTERVAL MIDPOINT (FT)
INITIAL SHUT-IN PRESSURE (PSI)
BRINE WATER HYDROSTATIC PRESSURE GRADIENT (0.496 PSI/FT)
FRESH WATER HYDROSTATIC PRESSURE GRADIENT (0.434 PSI/FT)
LEGEND
GLORIETA
UPPER CLEAR FORK AND TUBB
PRECAMBRIAN

APPENDIX D

Mathematical Formulation of Hypothetical Topographic Planes

TABLE OF CONTENTS

Appendix D. Mathematical Formulation of Hypothetical Topographic Planes

The hypothetical topographic planes described in Section 5.2 were calculated by assuming that the hypothetical land surface elevation (z) was a linear function of longitude (x) and latitude (y), such that

$$z = a_1x + a_2y + a_3 \qquad \text{D-1}$$

where a_1, a_2, and a_3 are coefficients describing the plane. It also was assumed that pressure (p) was a linear function of tested depth below the surface of the hypothetical plane, such that

$$p = m(z + [d - h]) \qquad \text{D-2}$$

where d is the midpoint of the tested depth interval, h is the actual land surface elevation, and m is the fluid pressure gradient.

Solving for z in equation D-2, the following equation is obtained:

$$z = p/m - (d - h) \qquad \text{D-3}$$

Equating D-1 and D-3 and solving for p, the following equation is obtained:

$$p = a_1mx + a_2my + m(d - h) + a_3m \qquad \text{D-4}$$

Treating pressure (ISIP) as the dependent variable and x, y, and (d - h) as the independent variables, the coefficients a_1, a_2, and a_3 and the fluid pressure gradient, m, are solved for by linear regression. Table D-1 is a summary of the results obtained.

Table D-1. Coefficients from Planar Regression Analysis

	Coefficients a_1	a_2	a_3	m	Correlation Coefficient
Wolfcamp					
Before Culling	70.03	56.41	-7678.8	0.4811	0.810
After Culling	161.48	-141.38	-10705.8	0.4518	0.992
Pennsylvanian (South of Amarillo Uplift)					
Before Culling	231.65	36.24	-19348.1	0.2536	0.434
After Culling	205.20	-145.08	-14946.8	0.4288	0.992
Pennsylvanian (North of Amarillo Uplift)					
Before Culling	648.21	272.72	-74314.4	0.4605	0.763
After Culling	-40.23	-101.25	8122.3	0.4783	0.996

U.S. DEPARTMENT
OF ENERGY

SALT REPOSITORY PROJECT OFFICE

DEPARTMENT OF ENERGY
NUCLEAR REGULATORY COMMISSION

QUALITY ASSURANCE MEETING

DECEMBER 18-19, 1984

COLUMBUS, OHIO

AGENDA

DOE/NRC QUALITY ASSURANCE MEETING
SALT REPOSITORY PROJECT OFFICE
December 18-19, 1984

Location: Holiday Inn on the Lane
328 West Lane Avenue
Columbus, Ohio
General Custer Room, Ground Floor

December 18, 1984

7:30 a.m.	COFFEE	
8:00 a.m.	DOE INTRODUCTION AND WELCOME	J. Neff
	DOE/Contractor Staffs	
	Goals of Meeting	
	Agenda Discussion/Changes	
8:15 a.m.	NRC INTRODUCTION	J. Kennedy
	NRC Staff	
	Goals of Meeting	
	NRC Standard Review Plan	
9:15 a.m.	QUESTIONS FROM PUBLIC	
9:30 a.m.	DOE/SRPO PROGRAM	
	Organization	J. Neff
	History of SRPO QA	R. Lahoti
	QA Philosophy and Procedures	J. Reese
	Objective Planning	R. Wunderlich
	(COFFEE BREAK WHEN APPROPRIATE)	
12:00 Noon	LUNCH	
1:00 p.m.	DOE/SRPO PROGRAM, Continued	
	Peer Reviews	R. Wunderlich
	Procurement Document Control	J. England P. Van Loan
	Review of Technical Documents	T. Taylor R. Lahoti J. Sherwin
	Audits	J. Reese
	Q List	L. Casey
	QA Near Term Planning	J. Reese
	(COFFEE BREAK WHEN APPROPRIATE)	
4:00 p.m.	CLOSING REMARKS AND QUESTIONS FROM PUBLIC	J. Neff

December 19, 1984

7:30 a.m.	COFFEE	
8:00 a.m.	INTRODUCTION/AGENDA	J. Reese
8:10 a.m.	CONTRACTOR PRESENTATION	
	Review of BPMD Organization	N. Carter
	Review of ONWI Organization	W. Carbiener
	National Labs/Government Agencies	W. Carbiener
	BPMD Contractors	W. Carbiener
	BPMD QA Program for SRPO	C. Williams, Jr.
	QA Implementation Procedures	C. Knudsen D. Clark M. Balmert A. Funk
	(COFFEE BREAK WHEN APPROPRIATE)	
12:00 Noon	LUNCH	
1:00 p.m.	SUB-CONTRACTOR PRESENTATION	
	QA Program Controls	I. Levy
	Field QA Procedures (Rock Coring/Log Preparation)	C. Foster
	Field QA Procedures (Pump Testing/Fluid Sampling)	C. Foster
2:00 p.m.	CLOSING/QUESTIONS/PUBLIC COMMENTS	J. Reese
2:15 p.m.	EXIT MEETING PREPARATION Participants caucus to prepare for exit meeting	
3:30 p.m.	EXIT MEETING Discussion of meeting results and conclusions Preparation of meeting minutes (COFFEE BREAK WHEN APPROPRIATE)	
5:00 p.m.	ADJOURN	

SRP THEMES

- TECHNICAL EXCELLENCE
  - EXPERIENCED TECHNICAL PERSONNEL IN DOE, DOE CONTRACTORS AND SUBCONTRACTORS
  - MAXIMUM USE OF FEDERAL/STATE/LOCAL EXPERTISE
  - USE OF PEER REVIEWS
- MANAGEMENT EXCELLENCE
  - CLEAR STATEMENT OF OBJECTIVES, PRIORITIES, RESPONSIBILITIES AND AUTHORITIES
  - REALISTIC AND WELL DEVELOPED PLANS "OWNED" BY TECHNICAL PERSONNEL
  - EFFICIENT, EFFECTIVE MANAGEMENT INFORMATION SYSTEM WITH USER ORIENTATION
  - AUDIT SYSTEMS TO ALLOW REVIEW, EVALUATION AND MODIFICATION OF INEFFICIENT AND INEFFECTIVE ACTIVITIES

OBJECTIVES

NEAR TERM

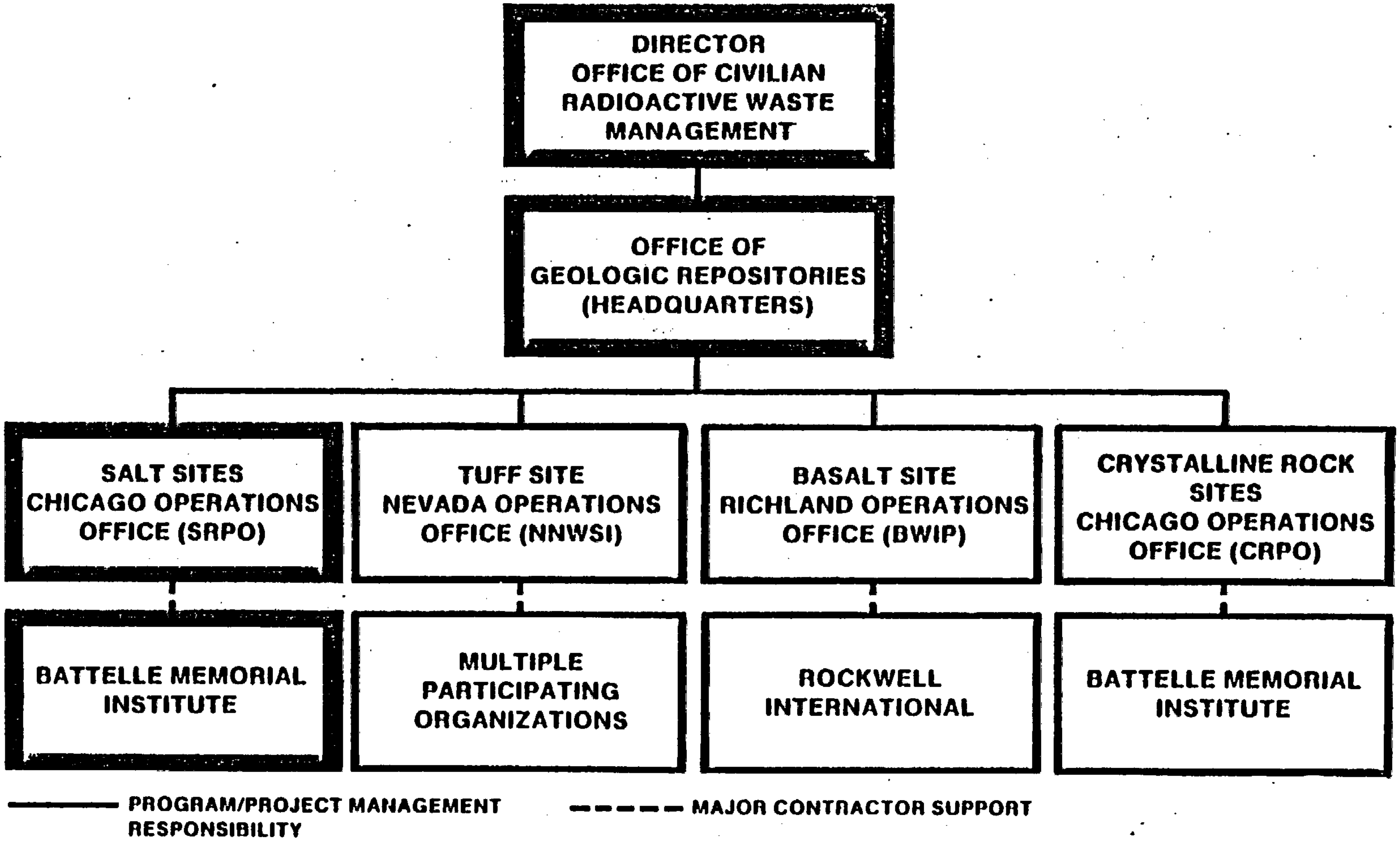
- COMPLETE DRAFT/FINAL EAs
- DEVELOP REALISTIC WORK PLAN AND COST PROJECTIONS FOR FY 1985 AND OUTYEARS
- INTEGRATE ALL NEW PERSONNEL INTO OFFICE STRUCTURE

LONG TERM (1-5 YRS.)

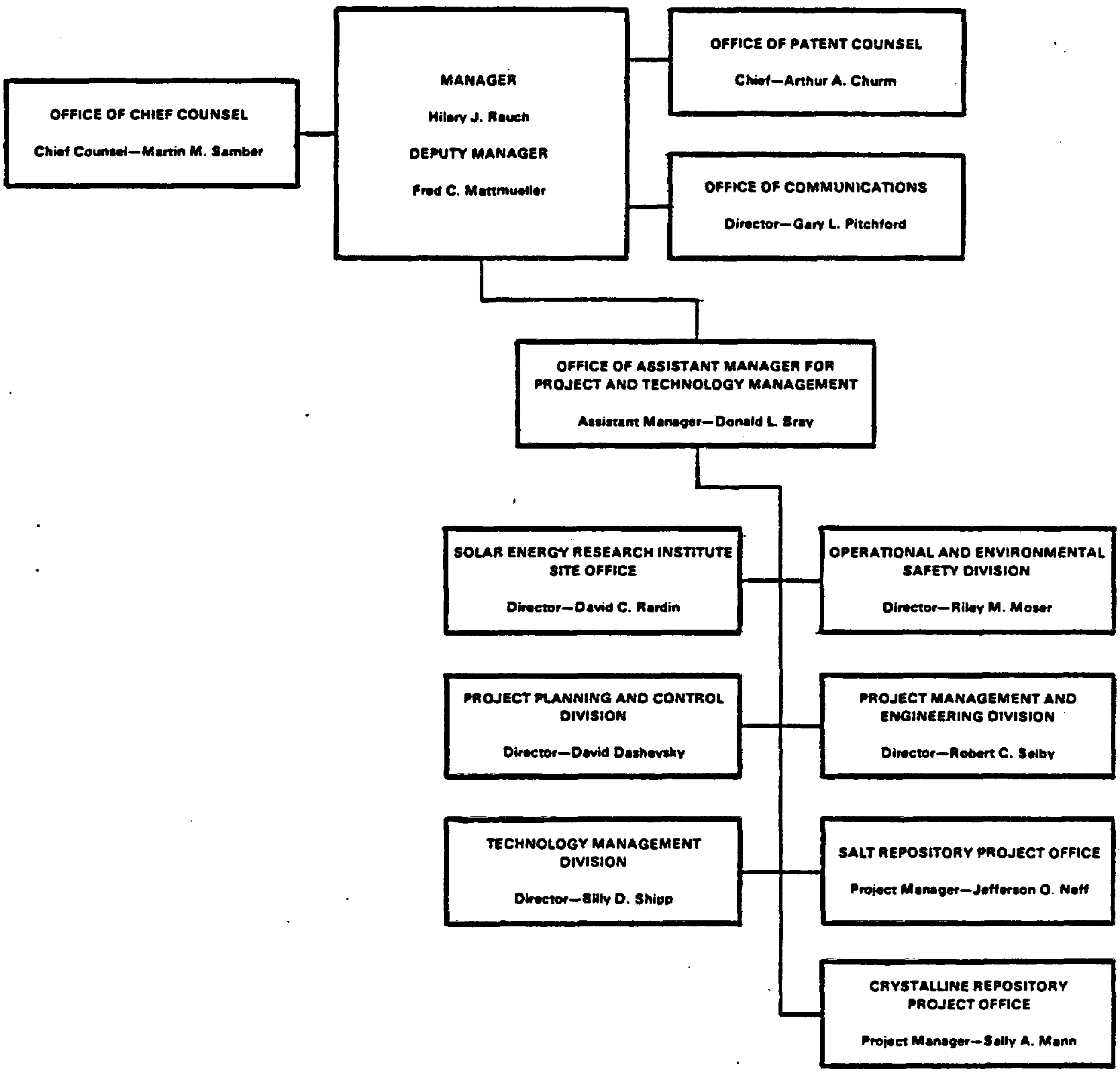
- DEPLOY SITE OFFICE NEAR RECOMMENDED SITE
- RESOLVE PERMITTING ISSUES FOR PROCEEDING AT RECOMMENDED SITES
- DETERMINE IF RECOMMENDED SALT SITE IS QUALIFIED AS A POTENTIAL REPOSITORY SITE

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

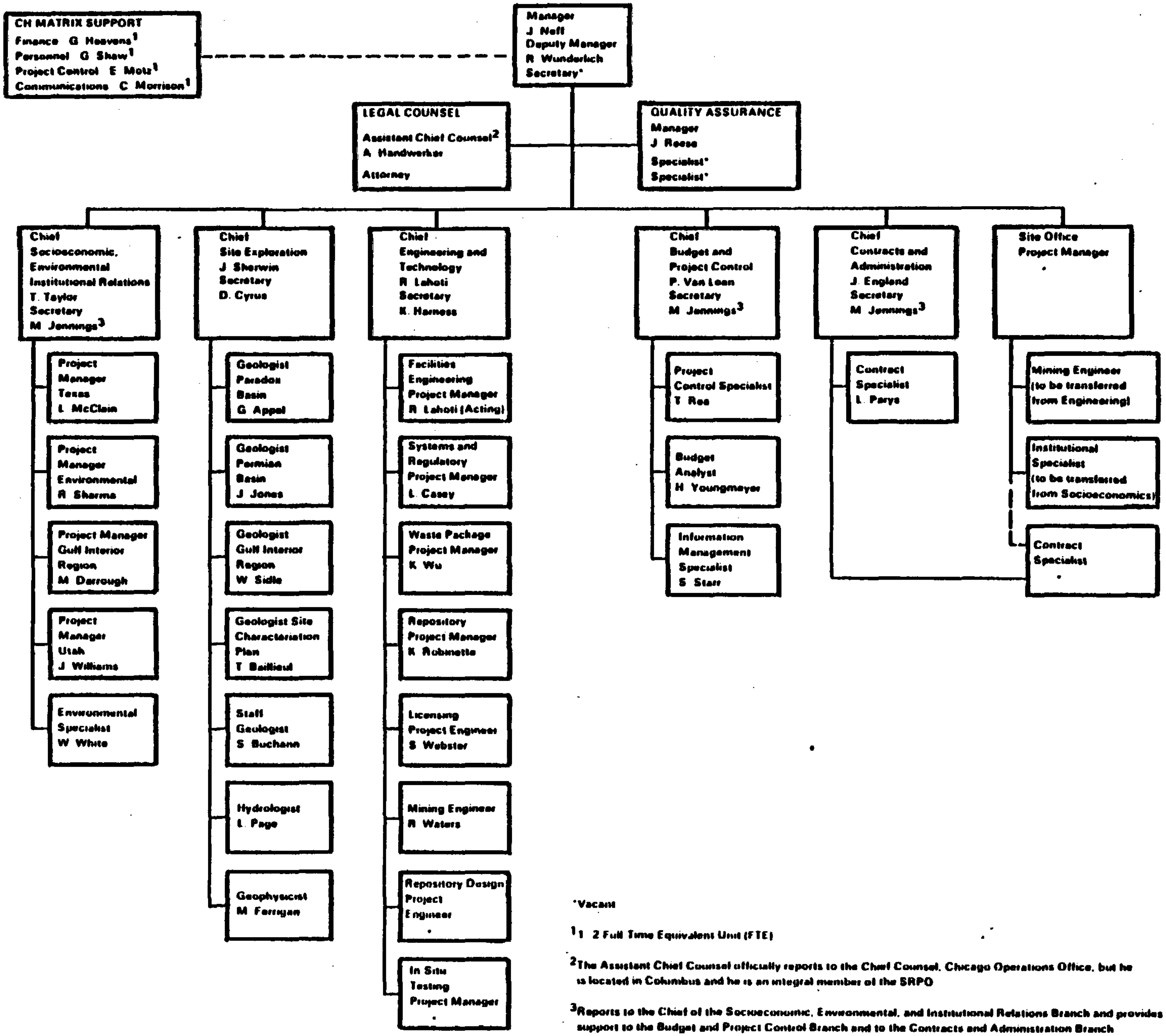
FIELD OFFICE AND CONTRACTOR MANAGEMENT RESPONSIBILITY FOR OGR PROJECTS



CHICAGO OPERATIONS OFFICE



SALT REPOSITORY PROJECT OFFICE CHICAGO OPERATIONS OFFICE



*Vacant

[1] 1 2 Full Time Equivalent Unit (FTE)

[2] The Assistant Chief Counsel officially reports to the Chief Counsel, Chicago Operations Office, but he is located in Columbus and he is an integral member of the SRPO

[3] Reports to the Chief of the Socioeconomic, Environmental, and Institutional Relations Branch and provides support to the Budget and Project Control Branch and to the Contracts and Administration Branch

SRPO
POLICY ON QA

. . . . Quality assurance is a multidisciplinary system of management controls which addresses environmental protection, safety, reliability, maintainability, operability, performance, and other technical concerns. Quality assurance shall not be regarded as the sole domain of the SRPO Quality Assurance Manager; rather, line organizations should look to this person as an advisory resource in performing their quality assurance activities.

from SRPO QA Manual

QA MANAGER DUTIES

- INTERPRET DOE/HQ POLICY ON QA
- MAINTAIN LIAISON WITH HQ AND CH QA PEOPLE
- PROVIDE EVALUATIONS AND RECOMMENDATIONS ON QA
- DIRECT AUDITS OF SRPO CONTRACTORS
- NOTIFY MANAGEMENT RE. UNSATISFACTORY WORK (STOP WORK WITH MANAGER'S APPROVAL)
- PROVIDE QA GUIDANCE TO SRPO STAFF
- MAINTAIN THE SRPO QA MANUAL
- COORDINATE THE ANNUAL QA REVIEW

BPMD/ONWI QA

— PRINCIPLE AGENTS FOR DOE/SRPO

— DOCUMENTED IN ONWI QA MANUAL
APPROVED BY DOE/SRPO
VERIFIED THROUGH AUDIT (10/84)

— BASED UPON ANSI/ASME NQA-1-1983

— MORE TOMORROW

PARSONS REDPATH QA

— EXPLORATORY SHAFT FACILITY

— DOCUMENTED IN PR QA MANUAL

APPROVED BY DOE/SRPO

VERIFIED THROUGH ANNUAL AUDIT (11/84)

— BASED UPON ANSI/ASME NQA-1-1983

— RESIDENT QA MANAGER IN COLUMBUS TO WORK WITH STAFF OF ABOUT 16

FLUOR QA

— REPOSITORY CONCEPTUAL DESIGN

— DOCUMENTED IN FLUOR QA MANUAL
  APPROVED BY DOE/SRPO
  VERIFIED THROUGH ANNUAL AUDIT (7/84)

— BASED UPON ANSI/ASME NQA-1-1983

— ONE LOCAL REPRESENTATIVE

— QA MANAGER IN IRVINE, CAL. WITH FLUOR SALT PROJECT TEAM

— OTHERS UNDER FLUOR INCLUDE:
  MORRISON-KNUDSEN CO.
  ENGINEERED SYSTEMS DEVELOPMENT CORP.
  SCIENCE APPLICATIONS, INC.
  WOODWARD-CLYDE CONSULTANTS

OTHER DOE CONTRACTORS

TBEG	— Texas Bureau of Economic Geology
BFEC	— Bendix Field Engineering Corporation
BNL	— Brookhaven National Laboratory
ORNL	— Oak Ridge National Laboratory
LLL/LBL	— Lawrence Livermore/Berkeley Laboratories
PNL	— Pacific Northwest Laboratories
USGS	— U.S. Geological Survey
WES/COE	— Waterways Exper. Station, Corps of Engineers
ANL	— Argonne National Laboratory

HISTORY OF SRPO QA

Year	Month	Event
1981	April	Draft procedures prepared for major control areas
		Procedures refined
1982	March	Draft Manual sent to HQ
	October	All comments incorporated
1983	January	NWTS Program Office (NPO) QA Manual, Rev. 0, issued for use
	December	Additional procedures developed
1984	March	SRPO QA Manual, Rev. 1, issued for use
	July	SRPO QA Manual, Rev. 2, issued for use

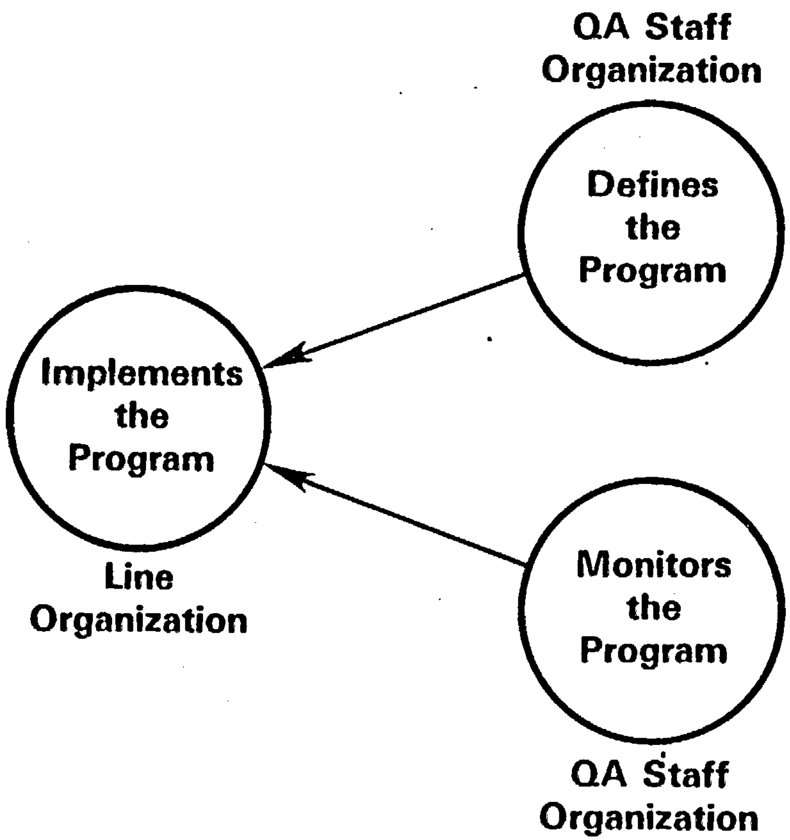
18 BASIC REQUIREMENTS

DOE FUNCTION TODAY

1. ORGANIZATION
2. PROGRAM
3. DESIGN CONTROL
4. PROCUREMENT DOCUMENT CONTROL
5. INSTRUCTIONS, PROCEDURES, AND DRAWINGS
6. DOCUMENT CONTROL
7. PURCHASED ITEMS AND SERVICES

15. NONCONFORMING MATERIAL
16. CORRECTIVE ACTION
17. QA RECORDS
18. AUDITS

QUALITY ASSURANCE ROLES



QA DIRECTION

DOE	NRC
Order 5700.6A—Quality Assurance	10CFR60
Order CH 5700.6A—Quality Assurance	10CFR50, Appendix B
NQA-1-1983	Standard Review Plan
OGR QA Plan	

QUALITY ASSURANCE MANUAL

Salt Repository Project Office (SRPO)

Salt Repository Project

QAP No.	Page 1 of 2	
Rev. 2	Issued 7/27/84	

TITLE
TABLE OF CONTENTS

SRPO MANAGER	QA MANAGER	PREPARED BY

Procedure No TABLE OF CONTENTS	Rev 2	Issued 7/27/84	Page 2 of 2

OBJECTIVE PLANNING

QAP 2.1

TO PROVIDE FOR—

- LONG-RANGE PLANNING FOR THE SALT REPOSITORY EFFORT
- A CLEAR DEFINITION OF THE CONTRIBUTIONS OF THE VARIOUS PARTIES
- A SYSTEMATIC ANNUAL EXAMINATION OF SRPO AND CONTRACTOR CONTRIBUTIONS TO THE PROJECT

OBJECTIVE PLANNING

STATUS

• FIRST USE OF THIS PROCEDURE	
• HQ BUDGET AND GUIDANCE MEETING	11/84
• HQ DIRECTION EXPECTED	12/84
• FIRST PLANS PREPARED	1/85
• PLANS ASSEMBLED AND ISSUED	2/85

OBJECTIVE PLANNING

FORMAT

1. OVERALL NATIONAL OBJECTIVE AND TIMING
2. CURRENT FY PLANNING
   - GOALS
   - CONTRACTOR CONTRIBUTION
   - SRPO CONTRIBUTION
3. OUTYEAR PLANNING
   - GOALS
   - CONTRACTORS
   - DELIVERABLES
4. APPROVALS

PEER REVIEWS

PURPOSE

TO VERIFY THE TECHNICAL WORK DONE BY CONTRACTORS

REQUIRED WHEN

- UNIQUE APPLICATION OF AN ESTABLISHED OR STANDARD PRACTICE
- WORK GOES BEYOND THE STATE OF THE ART
- NEW OR UNUSUAL EXPERIMENTAL TECHNIQUES USED BY A CONTRACTOR
- MAJOR CHANGES BEING MADE IN A GEOLOGIC INVESTIGATION OR REPOSITORY DESIGN
- REPORTS OF SIGNIFICANCE
- CORRECTIVE ACTIONS OF MAJOR IMPACT

PROCESS FOR PEER REVIEW

1. Develop List of Program Milestones
2. Select Documents Requiring Peer Review
3. Schedule Timing for Peer Review
4. Develop Guidance for Review (Identify Areas Requiring Review)
5. Select Review Team Members
6. Conduct Peer Review
7. Document Peer Review Recommendations and Comments
8. Provide Peer Review Report to Author and Resolve Comments and Recommendations
9. Perform Follow-up to Ensure Changes Are Incorporated
10. Approve or Reject Documents for Printing

CONTRACTING

- BPMD/ONWI
- PARSONS REDPATH
- UNIVERSITY OF TEXAS (BUREAU OF ECONOMIC GEOLOGY)
- FLUOR
- U.S. GEOLOGICAL SURVEY
- WATERWAYS EXPERIMENT STATION
- BUREAU OF MINES (PROPOSED)

NRC-21-A

DATE: ____________________

TO: Addresses Listed Below

FROM: Contract & Administration

SUBJECT: Contractual Document (s) For Review, Comments and Initialing

The document (s) listed below (is) (are) forwarded for your review, comments initials. Upon completion of your review, please attach your comments, if any, and forward to next in line. Expeditious handling of this matter will be appreciated.

(Synopsis of Action for Review) ____________________

Addressee	Recommend (X) Approval	Disapproval	Initial	Date
Q.A. Manager				

Return To:

Contract & Administration

BUDGET

Brookhaven—Chicago Operations

Pacific Northwest Labs—Richland Operations

Bendix—Idaho Operations/Grand Junction Area

Oak Ridge National Lab—Oak Ridge Operations

Lawrence Livermore—San Francisco Operations

Lawrence Berkeley—San Francisco Operations

TECHNICAL REVIEWS—SEIR

TYPICAL DOCUMENT TYPES

- CONTRACTOR SOCIOECONOMIC PROGRAM ACTIVITY PLAN
- SUBCONTRACTOR SOCIOECONOMIC DATA BASE REPORTS
- SUBCONTRACTOR COMPUTER MODEL DOCUMENTATION REPORTS
- CONTRACTOR REPORTS OF RESPONSES TO COMMENTS MADE IN PUBLIC HEARINGS
- CONTRACTOR REPORTS IDENTIFYING EXPRESSED PUBLIC ISSUES FOR INCORPORATION INTO STATUTORY ENVIRONMENTAL ASSESSMENTS
- CONTRACTOR AND SUBCONTRACTOR REPORTS ON ENVIRONMENTAL STUDIES

ATTACHMENT B

REVIEW OF CONTRACTOR DOCUMENTS

Document Title:______________________ I.D. No:__________

Contractor:______________________________________

(1) REVIEW

Reviewer:______________________________ Date:__________

Comments (continue on additional sheets if necessary and attach to this form):

(2) RESOLUTION OF COMMENTS

Date Comments Sent to Contractor:________ Date of Response: __________
(Attach copy of contractor's response)

Actions Required (continue on additional sheets if necessary and attach to this form).

All Actions Completed: ______________________ Date:__________
Reviewer

TECHNICAL REVIEW—ENGINEERING

TYPICAL DOCUMENTS

- ONWI ESF RECOMMENDATION FOR 2ND SHAFT
- ONWI FUNCTIONAL DESIGN CRITERIA
- BOREHOLE SEALING TEST IN SALT
- LARGE-SCALE LAB PERMEABILITY TESTING
- DEVELOPMENT OF CEMENTITIOUS MATERIAL FOR REPOSITORY SEALING

TECHNICAL REVIEW—ENGINEERING

CHECKLIST FROM QA MANUAL

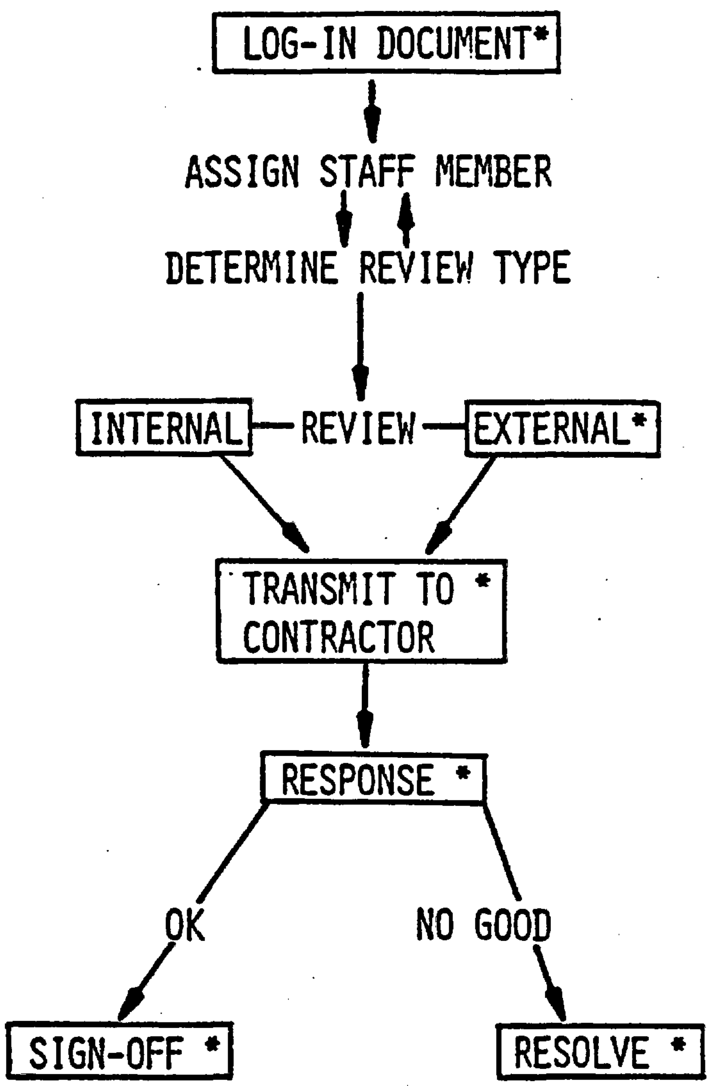
A. TECHNICAL CONCERNS

- APPROACH
- ASSUMPTIONS/LIMITATIONS
- SPECULATIVE STATEMENTS IDENTIFIED
- FIGURES, TABLES, MAPS APPROPRIATE
- CONCLUSIONS SUPPORTED BY DATA
- METHODS IDENTIFIED
- DISCUSSION IS SOUND
- CONCLUSIONS VALID AND MEET WORK OBJECTIVE
- REPORT IS SUITABLE AND APPROPRIATE
- QUALITY ASSURANCE PROGRAM ADEQUATE

B. EDITORIAL CONCERNS

- TITLE IS CLEAR
- PURPOSE IS CLEAR
- WELL ORGANIZED
- CLEARLY WRITTEN
- ABSTRACT INCLUDED

TECHNICAL REVIEW PROCEDURE



* DOCUMENTATION STEP

ATTACHMENT A

CHECKLIST FOR REVIEW OF DOCUMENTS

A. TECHNICAL CONCERNS

1. Approach is correct.
2. Assumptions and limitations are adequately stated.
3. Speculative statements are clearly identified as such.
4. Figures, tables, and maps are appropriate and useful.
5. Data support interpretations and conclusions.
6. Reasoning by which interpretations and conclusions are reached is given adequately and clearly.
7. Technical discussions are sound.
8. Conclusions are sound (valid) and meet the work objective.
9. Report is suitable and appropriate for its intended use.
10. Report has been prepared under a suitable QA program. It may be desirable to request documentation from the contractor specific to the checks performed on the report.
11. If the QA program that was applied to the document is in doubt, perform the following:

   (a) Verify mathematics:

   - mathematical expressions are accurate
   - computations are correct
   - results are clearly and correctly stated

   (b) Verify tables, figures, and maps:

   - agree with sources
   - are consistent with text and other tables, figures, and maps
   - all locations in text are shown on maps or are adequately described

   (c) Verify references:

   - agree with sources
   - available to the public

Procedure No 7.1	Rev 2	Issued 7/27/84	Page 4 of 5

B. EDITORIAL CONCERNS

1. Title clearly indicates subject.
2. Purpose of report is clearly and fully discussed.
3. Report is well organized.
4. Report is clearly written: proper grammer, sentence structure, word usage, and spelling.
5. Appropriate style guides have been used.
6. A clear and understandable abstract is included.

NRC-28-C

Procedure No 7.1	Rev 2	Issued 7/27/84	Page 5 of 5

ATTACHMENT B

REVIEW OF CONTRACTOR DOCUMENTS

Document Title:______________________ I.D. No:__________

Contractor:______________________________________

(1) REVIEW

Reviewer:______________________ Date:__________

Comments (continue on additional sheets if necessary and attach to this form):

(2) RESOLUTION OF COMMENTS

Date Comments Sent to Contractor:________ Date of Response: __________
(Attach copy of contractor's response)

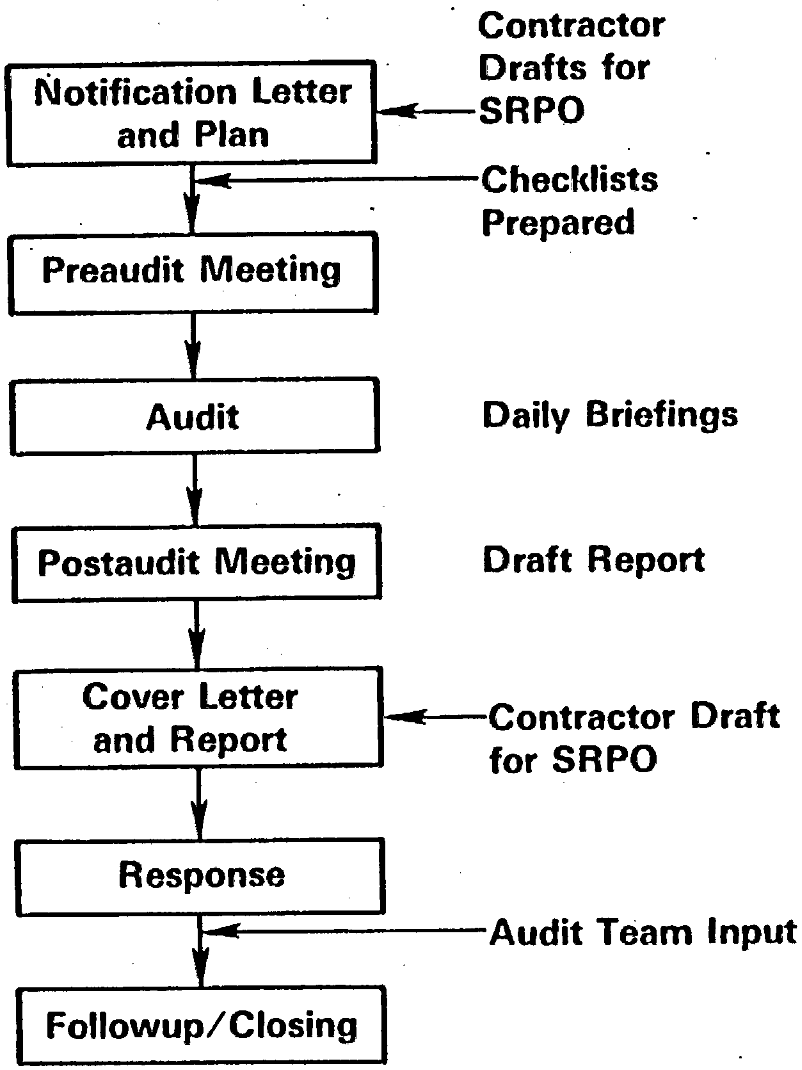
Actions Required (continue on additional sheets if necessary and attach to this form).

All Actions Completed: ______________________ Date:__________
Reviewer

AUDITS

- EXTERNAL
- INTERNAL
- PERFORMED ON SRPO BY OTHERS

AUDITS


Notification Letter and Plan
Contractor Drafts for SRPO
Checklists Prepared
Preaudit Meeting
Audit
Daily Briefings
Postaudit Meeting
Draft Report
Cover Letter and Report
Contractor Draft for SRPO
Response
Audit Team Input
Followup/Closing

AUDITS OF DOE-DIRECT CONTRACTORS (1983 and 1984)

Audited Organization	Location	Date Conducted	Conducted by (ONWI or DOE)
TBEG	Austin TX	3-/29-30/83	ONWI
ONWI	Columbus OH	6/21-24/83	DOE (SRPO)
PNL	Richland WA	8/8-10/83	ONWI
LBL	Berkeley CA	11/30/83	DOE (SAN)
LLNL	Livermore CA	11/29-30/83	DOE (SAN)
Parsons-Redpath	Columbus OH	11/28-29/83	ONWI
ONWI	Columbus OH	12/6-8/83	DOE (SRPO)
TBEG	Austin TX	3/29-30/84	DOE (SRPO)
USGS	Denver CO	4/5-6/84	DOE SRPO)
Bendix	Grand Junction CO	5/15-17/84	ONWI
PNL	Richland WA	7/18-20/84	ONWI
COE (WES)	Vicksburg MS	8/7-8/84	ONWI
ONWI	Columbus OH	10/30-11/2/84	DOE (SRPO)
Parsons-Redpath	Columbus OH	11/19-20/84	DOE (SRPO)

AUDITS

AUDITS OF SRPO BY OTHERS:

— AUGUST 1983 BY HEDL

— DECEMBER 1984 BY CHICAGO AND HQ

AUDITS

GENERIC PROBLEMS UNCOVERED:

- QA REQUIREMENTS TO DOERS
- LACK OF PROCEDURES
- INADEQUATE RECORDS
- APPROPRIATE QA FOR RESEARCH

LICENSING COORDINATING GROUP

Member	Organization
Charles Head, Chairperson	
Carl Newton	DOE/HQS
Dick Baker	CRPO
Ken Yates	OCRD/Battelle
Leslie Casey	SRPO
David Dawson	ONWI
Larry Fitch	RHO
Jim Mecca	RL/BWIP
Jerry Szymanski	DOE/Nevada
Joe LaRue	SAI/Nevada
Mike Glora	SAI/Nevada
Bill Griffin	Fluor Engineers
Robert Rihs	Parsons/Redpath
Hank Bermanis	Weston

PRELIMINARY STUDIES ADDRESSING SAFETY DESIGNATIONS

- Guidance for Determining Safety-Related Features of Geologic Repositories
  - Anticipated ONWI Publication Date: 5/85
- Structures, Systems, and Components Classification System Definitions
  - Anticipated Fluor Publication Date: 5/85

FUTURE QA ACTIONS

- QA MANUAL REVISION—START IN JANUARY 85
  - INCORPORATE COMMENTS TO DATE
  - DEVELOP NEW PROCEDURES FOR CONSTRUCTION-TYPE ACTIVITIES
  - INCORPORATE APPLICABLE PARTS OF NRC REVIEW PLAN
- REVIEW AND ANALYSIS OF SRP—START IN JANUARY 85
- REGULARLY SCHEDULED INTERNAL AUDITS
- START WORK ON "QA CHAPTER" FOR SALT SITE CHARACTERIZATION PLAN

I. BPMD ORGANIZATION

BATTELLE MEMORIAL INSTITUTE ORGANIZATION

OFFICE OF THE CHAIRMAN
Chairman of the Board and Chief Executive Officer
S. L. Fawcett

OFFICE OF THE PRESIDENT
President and Chief Operating Officer
R. S. Paul
Executive Vice President
D. E. Olesen

Business Operations

COLUMBUS DIVISION
Director and Vice President BMI
E. W. Ungar

BATTELLE-INSTITUT e.V.* (FRANKFURT)
Managing Director and Vice President BMI
H. Haeske

GENEVA DIVISION
Director General and Vice President BMI
V. Stingelin

BATTELLE DEVELOPMENT CORPORATION**
Chairman of the Board
S. L. Fawcett
President
T. J. Atterbury

PACIFIC NORTHWEST DIVISION
Director
W. R. Wiley

PROJECT MANAGEMENT DIVISION
General Manager and Vice President BMI
N. E. Carter

SCIENTIFIC ADVANCES, INC.**
Chairman of the Board
S. L. Fawcett
President
C. G. James

Corporate Functions

COMMUNICATIONS AND PUBLIC AFFAIRS
Corporate Director and Vice President BMI
C. R. Tipton, Jr.

LEGAL
General Counsel, Secretary and Vice President BMI
P. T. Santilli

FINANCE
Corporate Director, Treasurer and Vice President BMI
M. G. Stark

MARKETING
Corporate Director and Vice President BMI
G. B. Johnson

HUMAN RESOURCES
Corporate Director and Vice President BMI
L. L. German

MULTICOMPONENT OPERATIONS
Corporate Director and Vice President BMI
T. W. Ambrose

*An association: S. L. Fawcett and R. S. Paul, Chairman and Vice Chairman, respectively.
**Wholly owned subsidiaries.

July 1984

BATTELLE PROJECT MANAGEMENT DIVISION

FINANCE
CONTROLLER AND MANAGER
B. R. Williams

HUMAN RESOURCE SERVICES AND BUSINESS DEVELOPMENT MANAGER
J. H. Domask

INFORMATION MANAGEMENT SYSTEMS MANAGER
I. S. Seeds

GENERAL MANAGER
N. E. Carter

LEGAL AND CONTRACTS MANAGER
J. W. Maynard

QUALITY ASSURANCE MANAGER
C. Williams, Jr.

WASHINGTON, D.C., OFFICE MANAGER
P. L. Collyer

OFFICE OF CRYSTALLINE REPOSITORY DEVELOPMENT DIRECTOR
W. J. Madia

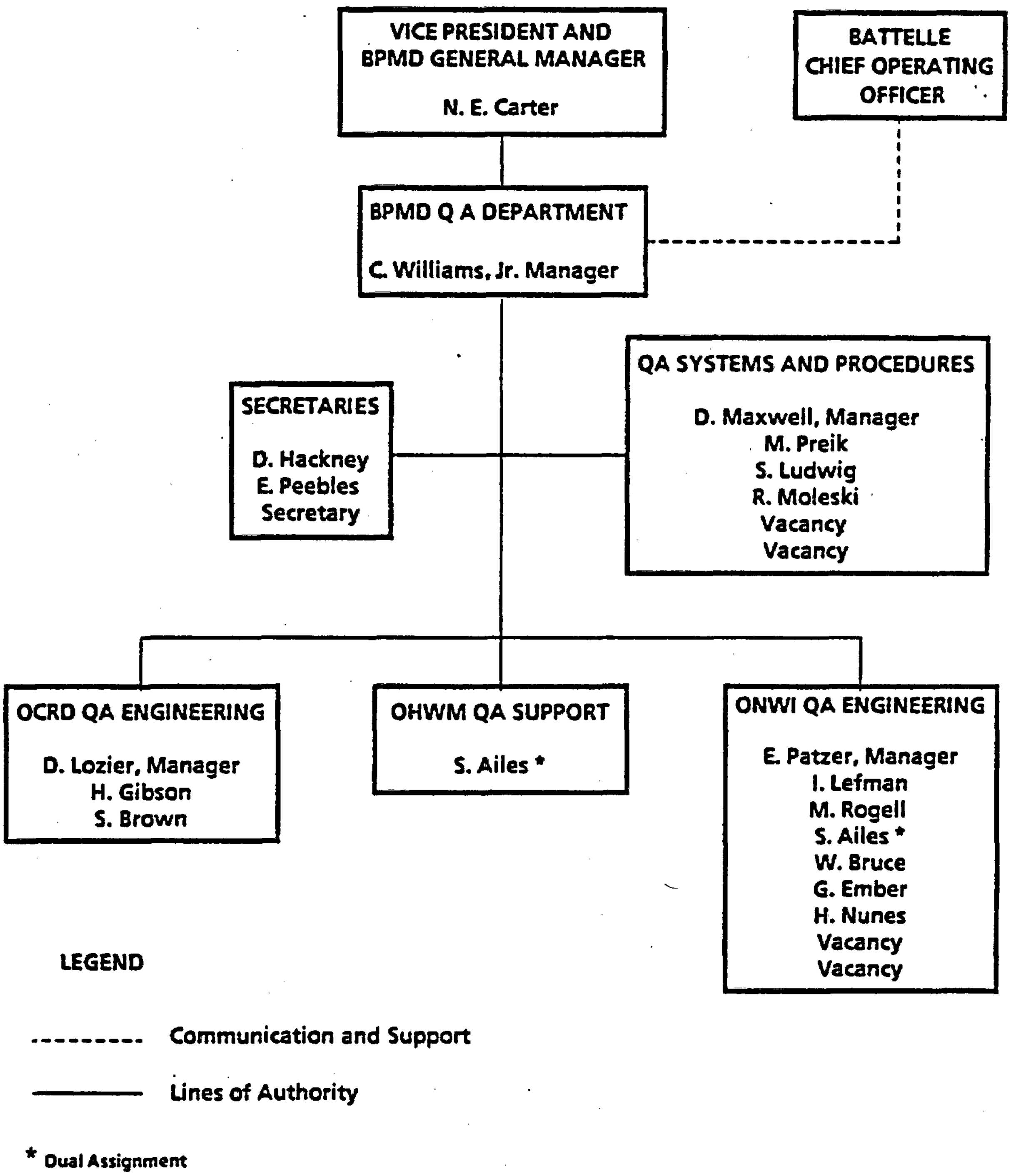
DEPUTY
M. Kehnemuyi

OFFICE OF NUCLEAR WASTE ISOLATION PROGRAM MANAGER
W. A. Carbiener

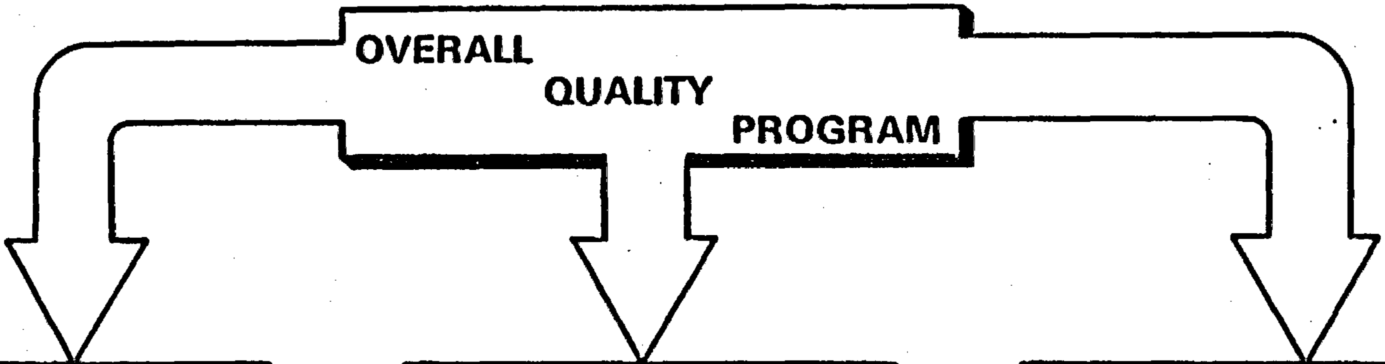
OFFICE OF HAZARDOUS WASTE MANAGEMENT DIRECTOR
G. W. Dawson

6/1/84

BPMD QA ORGANIZATIONAL STRUCTURE AND STAFFING



BPMD QUALITY ASSURANCE— A TEAM EFFORT



ADMINISTRATIVE AND SUPPORT GROUPS

QA PROGRAM SUPPORT

- PURCHASING
- RECORDS COLLECTION AND STORAGE
- DOCUMENT CONTROL CENTER
- COMPUTER SUPPORT
- MAIL DISTRIBUTION CENTER
- QA ADMINISTRATIVE/ SUPPORT PROCEDURES
- QA TRAINING FOR SUPPORT STAFF

TECHNICAL GROUPS

QUALITY ACHIEVEMENT AND TECHNICAL VERIFICATION

- QUALITY/TECHNICAL PLANNING
- TECHNICAL PROCEDURES
- QA SPECIFICATIONS
- SAFETY CLASSIFICATIONS
- QA RECORDS
- QA TRAINING FOR TECHNICAL STAFF
- DESIGN CONTROL
- CONTROL OF SUBCONTRACTS
- PEER/TECHNICAL REVIEWS
- TECHNICAL REPORT
- TECHNICAL STUDIES
- COMPUTER PROGRAM VERIFICATION AND VALIDATION

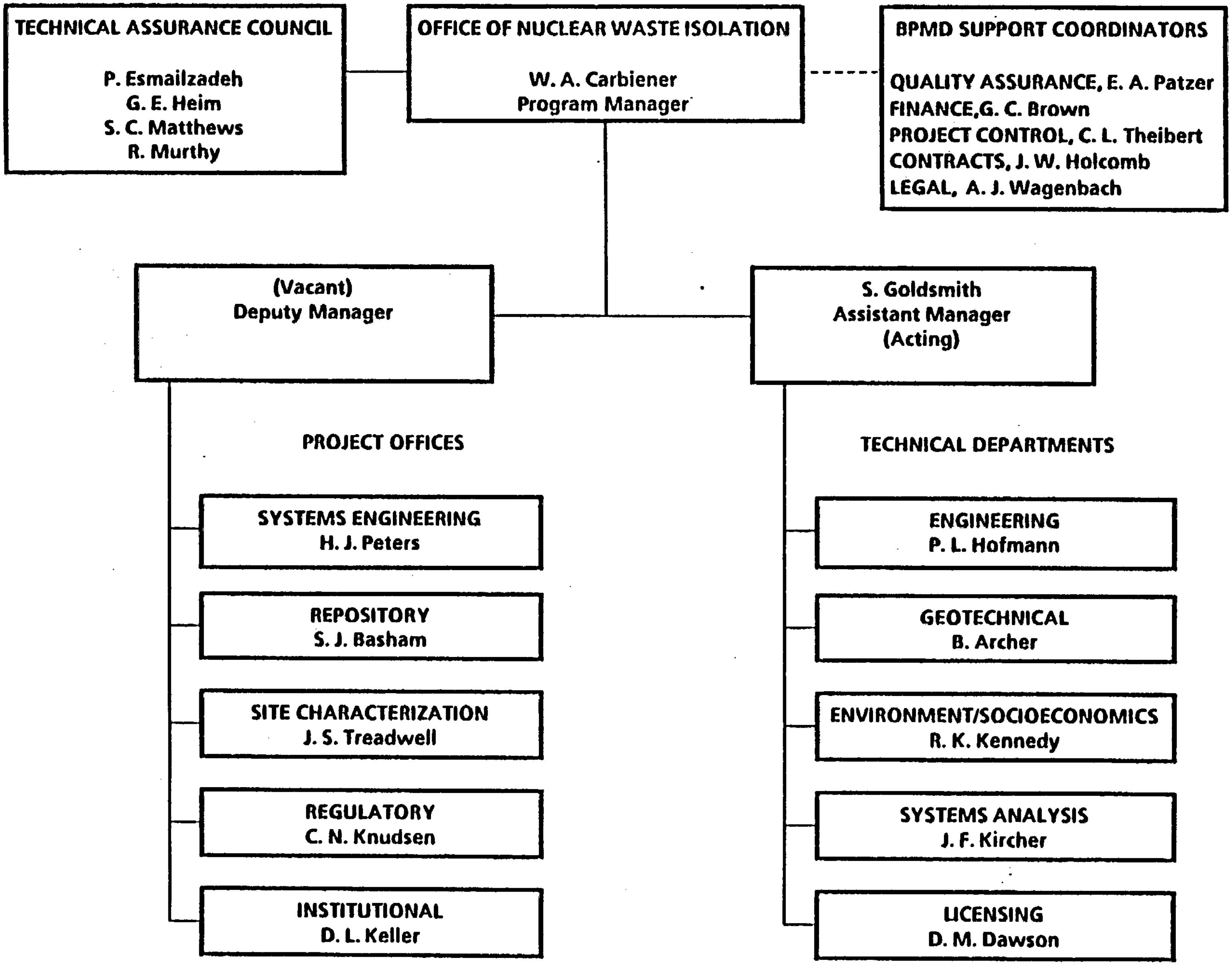
QUALITY ASSURANCE DEPARTMENT

QA PROGRAM COORDINATION AND MONITORING

- QA MANUAL
- QA PLANS
- QA PROCEDURES
- QA AUDITS/SURVEILLANCE
- TRAINING
- QA REVIEW OF DOCUMENTS
- CORRECTIVE ACTION REQUESTS
- STOP WORK AUTHORITY

II. ONWI ORGANIZATION

OFFICE OF NUCLEAR WASTE ISOLATION



III. WORK PERFORMED BY NATIONAL LABS AND GOVERNMENT AGENCIES IN SUPPORT OF SALT PROJECT

OVERVIEW OF WORK SCOPES OF NATIONAL LABORATORIES AND GOVERNMENT AGENCIES SUPPORTING THE SALT PROJECT

Laboratory or Agency	Scope of Work
Texas Bureau of Economic Geology	West Texas Palo Duro Basin Project, Geologic and Hydrologic Studies, Core Custodian
Bendix Field Engineering	Geochemical Assistance Project Geochemical Analyses Related to Selection and Characterization of the Repository Sites, Engineering Design, Performance Demonstration
Brookhaven National Laboratory	Salt Radiation Effects Project Characterize Radiation Damage in Rocks and Other Materials

OVERVIEW OF WORK SCOPES OF NATIONAL LABORATORIES AND GOVERNMENT AGENCIES SUPPORTING THE SALT PROJECT
(Continued)

Laboratory or Agency	Scope of Work
U.S. Geological Survey	Provide Independent Objective Technical Review and Evaluation of DOE-Contractor Hydrologic Models and Model Results, Applied to the Characterization of Salt Dome and Bedded Salt Potential Repository Sites
Waterways Experiment Station Corps of Engineers	Laboratory Services and Analytical and Evaluation Services on Materials That May Be Used in Repository Sealing
Argonne National Laboratory	Provide Technical Assistance for Environmental Assessment and Licensing Activities

NATIONAL LABORATORY AND GOVERNMENT AGENCIES SUPPORTING THE SALT PROJECT
(Continued)

Oak Ridge National Laboratory	Computer Technology and Environmental Assessment
Lawrence Livermore/Berkeley Labs	Computer Code Development Laboratory Thermal Mechanical Properties Tests
	Laboratory Experiments to Simulate and Measure Hydraulic Fracturing Stess in Rock Salt
Pacific Northwest Labs	Development and Application of Performance Assessment Models
	Waste Package Program Perform Shielding Calculations Laboratory Testing of Waste Forms and Package Materials

METHODS USED TO ESTABLISH WORK SCOPES

General statement of work, objectives, and required deliverables provided by SRPO/BPMD technical staff to contractor. Specifics for accomplishment provided by contractor for SRPO/BPMD review and approval in field task proposal agreement. Finalized FTPA, deliverables, and QA specification provided to contractor with fiscal year funding.

METHODS USED BY SRPO/BPMD TO CONTROL WORK ACTIVITIES

- SAFETY CLASSIFICATION DETERMINED BY TECHNICAL STAFF WITH QA CONCURRENCE (PMP-19)

- QUALITY ASSURANCE SPECIFICATIONS PREPARED BY BPMD JOINTLY BY TECHNICAL AND QA STAFFS USING GRADED APPROACH, SUBMITTED TO DOE/SRPO FOR REVIEW AND APPROVAL, TRANSMITTED TO LAB/AGENCY WITH FY FUNDING

- LAB/AGENCY QA PLANS, ACTIVITY PLANS, TECHNICAL PROCEDURES AND TECHNICAL DELIVERABLES SUBMITTED TO SRPO/BPMD FOR REVIEW AND APPROVAL

- LAB/AGENCY QA ADMINISTRATIVE PROCEDURES SUBMITTED FOR INFORMATION

- ANNUAL SRPO/BPMD QA AUDITS SUPPLEMENTED BY TECHNICAL AND QUALITY ASSURANCE VISITS

IV. WORK PERFORMED BY BPMD CONTRACTORS IN SUPPORT OF SALT PROJECT

OVERVIEW OF WORK SCOPES OF MAJOR BPMD/ONWI CONTRACTORS SUPPORTING THE SALT PROJECT

Contractor	Scope of Work
Stone-Webster	Geologic Project Manager for the Permian Basin—Field Geologic Investigations
Woodward-Clyde	Geologic Project Manager for the Paradox Basin—Field Geologic Investigations
NUS Corporation	Regulatory Project Manager for the Permian Basin—Environmental Field Studies
Earth Technology	Geologic Project Manager for the Southern Region Salt—Field Geologic Investigations

OVERVIEW OF WORK SCOPES OF MAJOR BPMD/ONWI CONTRACTORS SUPPORTING THE SALT PROJECT

(Continued)

Contractor	Scope of Work
Parsons-Brinckerhoff	Design of the Exploratory Shaft Facility and Technical Support Activities
Bechtel National	Regulatory Project Manager for the Gulf Interior Region and Paradox Basin—Environmental Field Studies
Intera Technologies	Performance Assessment Model Development and Application
RE/SPEC, Inc.	An Integrated Computational and Laboratory Effort to Predict the Response of the Host Rock

OVERVIEW OF WORK SCOPES OF MAJOR BPMD/ONWI CONTRACTORS SUPPORTING THE SALT PROJECT

(Continued)

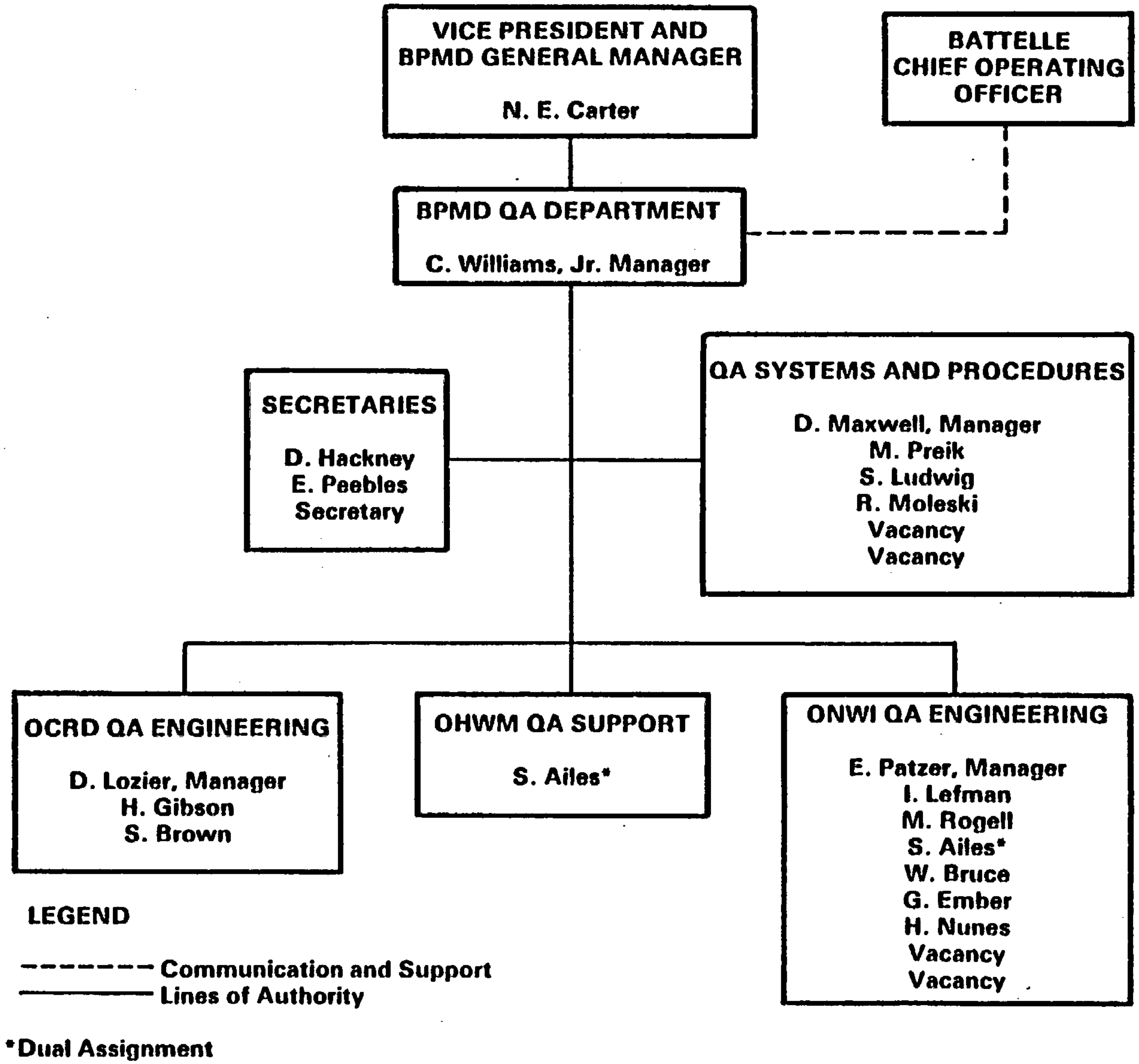
Contractor	Scope of Work
Ebasco Services	Licensing Project Manager—Responsible for Licensing Activity Support
Golder Associates	Design and Conduct In Situ Tests to Provide Site Characterization Data

METHODS USED TO CONTROL CONTRACTOR WORK ACTIVITIES

- STATEMENTS OF WORK PREPARED BY TECHNICAL STAFF, REVIEWED AND APPROVED BY QA
- SAFETY CLASSIFICATION DETERMINED BY TECHNICAL STAFF WITH QA CONCURRENCE (PMP-19)
- CONTRACTOR SELECTION, EVALUATION, AND CONTRACT AWARD MADE IN ACCORDANCE WITH BPMD'S APPROVED PROCUREMENT SYSTEM
- QA SPECIFICATION PREPARED JOINTLY BY TECHNICAL AND QA STAFFS USING GRADED APPROACH
- CONTRACTOR QA PLANS, ACTIVITY PLANS, TECHNICAL PROCEDURES AND TECHNICAL DELIVERABLES SUBMITTED TO BPMD FOR REVIEW AND APPROVAL
- CONTRACTOR QA ADMINISTRATIVE PROCEDURES SUBMITTED FOR INFORMATION
- MAJOR BPMD CONTRACTORS AUDITED ANNUALLY BY QA, SUPPLEMENTED BY TECHNICAL AND QUALITY ASSURANCE VISITS
- OTHER BPMD CONTRACTORS ARE AUDITED PERIODICALLY AS DETERMINED BY PERFORMANCE AND IMPORTANCE/COMPLEXITY OF WORK, SUPPLEMENTED BY TECHNICAL AND QUALITY ASSURANCE VISITS

V. BPMD'S QA PROGRAM FOR THE SALT PROJECT

BPMD QA ORGANIZATIONAL STRUCTURE AND STAFFING



ONWI QUALITY ASSURANCE PROGRAM

- THE ONWI QUALITY ASSURANCE MANUAL COVERS THE 18 CRITERIA OF 10CFR50 APPENDIX B AND ANSI/ASME NQA-1-1983
- THE ONWI QUALITY ASSURANCE MANUAL, REV 6, HAS BEEN APPROVED BY DOE/SRPO
- THE ONWI QUALITY ASSURANCE MANUAL REQUIREMENTS ARE IMPLEMENTED BY:
  - PROJECT MANAGEMENT PROCEDURES
  - PROJECT TECHNICAL PROCEDURES
  - BPMD OPERATING GUIDE PROCEDURES
  - DIVISION DEPARTMENT PROCEDURES

ONWI QUALITY ASSURANCE MANUAL

ONWI QA Manual Section	Key Features
1. Organization	• Describes BPMD and ONWI Organizational Structure • Describes Organizational Responsibilities for the ONWI QA Program • Describes the QAD's Interfaces With BPMD and ONWI
2. Quality Assurance Program	• Describes the Development, Implementation, Maintenance and Evaluation of the ONWI QA Program • Describes BPMD's Approach for Graded Application of QA Requirements • Describes QA Indoctrination and Training Requirements • Makes Provisions for Annual QA Program Assessments • Establishes Authority for Stop Work Orders

ONWI QUALITY ASSURANCE MANUAL
(Continued)

ONWI QA Manual Section	Key Features
3. Control of Design, Site Selection, and Site Characterization Activities	• Establishes Requirements for the Control of: — Design Activities — Activities Performed in Support of Site Selection and Site Characterization (e.g., Geotechnical Field and Laboratory Activities) • Describes Requirements for Interface Control • Describes Requirements for Verification and Validation, Including: — Management Review — Design Review — Peer Review — Technical Review • Establishes Change Control Requirements

ONWI QUALITY ASSURANCE MANUAL
(Continued)

ONWI QA Manual Section	Key Features
4. Procurement Document Control	• Establishes Requirements for the Inclusion of Quality Assurance Requirements in Procurement Documents • Establishes Requirements for Quality Assurance Review and Approval of Procurement Documents
5. Instructions, Procedures, and Drawings	• Describes Requirements for the Development and Implementation of Instructions, Procedures, and Drawings for Quality-Related Activities • Establishes Requirement for the QAD to Monitor the Implementation of These Procedures
6. Document Control	• Establishes Requirements for Controlling Documents That Specify or Prescribe Requirements for ONWI Activities Affecting Quality • Describes Requirements for QAD Review and Approval of These Documents Including any Changes Thereto Prior to Issuance

ONWI QUALITY ASSURANCE MANUAL
(Continued)

ONWI QA Manual Section	Key Features
7. Control of Purchased Services and Items	• Describes Measures for: — Procurement Planning — Evaluation and Selection of Procurement Sources — Evaluation of Contractor Performance — Verification of Purchased Services and Items — Control of Deficiencies • Establishes Requirements for QAD: — To Participate in Source Selection — To Monitor Contractor Performance and Acceptance — To Participate in the Review and Acceptance of Contractor Deliverables
8. Identification and Control of Items	• Establishes Requirements for Identifying and Controlling Items to Assure That Only Accepted Items Are Used in Performing ONWI Quality-Related Activities

ONWI QUALITY ASSURANCE MANUAL
(Continued)

ONWI QA Manual Section	Key Features
9. Control of Processes	• Describes Requirements for Controlling Processes That Affect the Quality of ONWI Services and Items • Provides Requirements for QAD to Monitor Necessary Qualification of Personnel, Procedures, and/or Equipment
10. Inspection	• Establishes Requirements for the Inspection or Verification of ONWI Services and Items • Provides for QAD Participation in Inspection/ Verification Processes • Includes Provisions for Inspection Planning, Identifying Mandatory Hold Points, Inspection Personnel Qualifications, and Inspection Records
11. Test Control	• Describes Requirements for the Planning and Control of ONWI Test Activities • Includes Provisions for Developing and Documenting Test Requirements in Approved Test Plans, Procedures, or Specifications; Documenting and Verifying Test Results, and Test Records

ONWI QUALITY ASSURANCE MANUAL
(Continued)

ONWI QA Manual Section	Key Features
12. Control of Measuring and Test Equipment	• Describes Requirements for the Calibration and Control of Measuring and Test Equipment Used for ONWI Quality-Related Activities
13. Handling, Storage, and Shipping	• Provides Requirements for Assuring Proper Physical Care of ONWI Items During Handling, Shipping, and Storage
14. Inspection, Test, and Operating Status	• Describes Requirements for Identifying the Inspection, Test, or Operating Status of ONWI Items
15. Nonconformances, Incidents, and Unusual Occurrences	• Establishes Requirements for the Identification, Control, Evaluation, and Disposition of Nonconformances, Incidents, and Unusual Occurrences

ONWI QUALITY ASSURANCE MANUAL
(Continued)

ONWI QA Manual Section	Key Features
15. Nonconformances, Incidents, and Unusual Occurrences (Continued)	• Incident and Unusual Occurrence Reporting Are Required by DOE Orders 5484.1 and 5484.2 • Describes QAD Responsibilities for the Control of Nonconforming Items • Describes QAD Participation in the Evaluation of Incidents and Unusual Occurrences
16. Corrective Action	• Establishes Requirements for Identifying, Documenting, and Reporting Conditions Adverse to Quality; Determining and Implementing Corrective Action; and Verifying Satisfactory Resolution of These Problems • Describes QAD Responsibilities for Implementing a System to Identify and Obtain Resolution for Conditions Adverse to Quality

ONWI QUALITY ASSURANCE MANUAL
(Continued)

ONWI QA Manual Section	Key Features
17. Quality Assurance Records	• Describes Requirements for the Specification, Preparation, Storage, Maintenance, and Retrieval of QA Records • Includes Provisions for Safekeeping, Controlled Access, and Preservation of These Records
18. Audits	• Establishes Requirements for the QAD's Performance of Quality Audits of ONWI Activities Affecting Quality, Both Internally at BPMD and Externally at Contractor Facilities/Sites, to Evaluate the Effectiveness and Adequacy of Implementation of the ONWI QA Program. • Includes Provisions for the Qualification and Certification of Auditors; Preparation of Audit Schedules, Plans, and Checklists; and Documentation, Followup, and Close-out of Audit Results and Deficiencies

ISSUED QA ADMINISTRATIVE PROCEDURES BY 10CFR50 APPENDIX B CRITERIA

Criteria	Procedure Number
1	—
2	PMP-11, PMP-15, PMP-19, ENG-02, ENG-06, GEO-01, GEO-02, GEO-03, SCP-07, SCP-09
3	PMP-05, PMP-06, PMP-17, PMP-21, EAO-05, EAO-06, EAO-07, ENG-08, ENG-09, ENG-11, ENG-17, GEO-12, SCP-10, SCP-11, SCP-12, SYS-02, SYS-14
4	CP-02, FIN-02, PMS, C&P-1, C&P-2
5	PMP-01, OG-01, EAO-01, ENG-01, GEO-05, GEO-06, GEO-07, GEO-10, SCP-01, SCP-02
6	ADM-4, ADM-14, ADM-43, ADM-52, ADM-53, ADM-54, QAD-03, QAD-04, GEO-09, SCP-06
7	CP-2, PMP-16, QAD-06, EAO-03, SYS-13
8	CUR-02
9	SAO-02, SAO-03, SAO-04, ENG-02
10	GEO-08
11	ENG-19
12	—
13	CUR-01, CUR-03
14	—
15	PMP-08, PMP-10, QAD-09
16	PMP-09, PMP-13
17	PMP-02, PMP-04, C&P-1, QAD-10, ADM-6, ADM-8, ADM-9, ADM-10, ADM-11, ADM-12, ADM-13, ADM-20, ADM-44, EAO-02, EAO-04, ENG-04, ENG-05, ENG-07, ENG-10, ENG-18, GEO-04, SCP-08, SYS-12
18	QAD-01, QAD-02, QAD-12

PLANNED QA ADMINISTRATIVE PROCEDURES BY 10CFR50, APPENDIX B CRITERIA

Criteria	Procedure Number
1	—
2	—
3	PMP-12, PMP-20, PMP-24, PMP-25, PMP-26, PMP-28, PMP-29, PMP-31, PMP-33, PMP-38
4	PMP-22, C&P-03, C&P-04, C&P-05
5	PMP-30, PMP-35
6	PMP-27
7	IMS-01, C&P-06, C&P-07, C&P-08, C&P-09, C&P-10, C&P-11
8	—
9	—
10	—
11	—
12	PMP-36
13	PMP-37
14	—
15	—
16	—
17	—
18	—

FUTURE QA PROGRAM ACTIONS

- UPGRADING OF ONWI PROJECT QA PLAN AND QA ADMINISTRATIVE PROCEDURES TO FULLY MEET NRC REVIEW PLAN
- TRAINING FOR REVISED AND NEW PROCEDURES
- UPGRADING OF CONTRACTOR QA SPECIFICATIONS TO FULLY MEET NRC REVIEW PLAN
- IN-HOUSE SURVEILLANCE PROGRAM TO BE FORMALIZED AND STRENGTHENED.

VI. DISCUSS SEVERAL EXAMPLES OF QA ADMINISTRATIVE PROCEDURES

PMP-04—QUALITY RECORDS FOR EXTERNAL PROJECTS

Purpose: Provides Detailed Requirements for the Identification, Maintenance, and Turnover of Quality Records for External BPMD Projects

Key Provisions:

- Inclusion of QA Records Requirements in BPMD Procurement/Agreement Documents
- Review of External Project Records List (PRL)
- Monitoring of Contractor's Records System
- Submittal of Contractor Records Turnover Package (RTPs)
- BPMD Review of RTPs for Acceptability
- RTP Sent to Information Systems Services (ISS) for Entry Into ONWI Files

PMP-04 KEY PROVISIONS

Inclusion of QA Records Requirements in BPMD Procurement/Agreement Documents

- QA Records Requirements Are Included in the QA Specification for Each Project. The QA Specification Is Prepared by the Project Manager/QA Specialist and Then Approved by the QAD Manager.

- Submittal Requirements for the PRL, Interim and Final RTPs, and QA Program Documents (QA Manual, Plan, Procedures) Appear on the Deliverable Data and Reporting Requirements (DD&RR) Form in the BPMD Procurement/Agreement Documents.

PMP-04 KEY PROVISIONS

Review of External Project Records List (PRL)

- PRL Is a Subject-Oriented Listing of Types of Project Records To Be Generated and Maintained Throughout Duration of the Project.
- A Master File Index Specifying the Location of the Records Is Maintained by the Contractor.
- Initial PRL and any Updates Are Submitted to BPMD for Review and Approval in Accordance With Procedure PMP-16.

PMP-04 KEY PROVISIONS

Monitoring of Contractor's Records System

- QA Specification Requires Contractor To Establish Controlled Filing System Ensuring That Records Are Legible, Identifiable, Retrievable, Authentic, and Preserved/Safeguarded To Preclude Damage, Loss or Deterioration.

- System is Formally Evaluated During BPMD QA Audits/ Surveillances

- System is Informally Evaluated During Visits From BPMD Technical and QA Personnel

PMP-04 KEY PROVISIONS

Submittal of Contractor Records Turnover Packages (RTPs)

- BPMD Project Manager Provides Contractor With "Declaration of Authenticity" Form To Be Completed and Guidelines for Packing, Handling and Shipping the RTP to BPMD.

- Contractor is Required to Submit an RTP at the Completion of a Project or at Specified Intervals (Not to Exceed 2 Years).

- The RTP is to Include the PRL, File Index, Completed "Declaration of Authenticity" Form, and the Project Records.

PMP-04 KEY PROVISIONS

BPMD Review for Acceptability

- Upon Receipt of the RTP, the Project Manager
  - Reviews the RTP for Completeness, Order, Correctness, and Clarity
  - Adds Any Internal Records Pertaining to the Project That Have Not Previously Been Sent to ONWI Files
  - Requests QA to Review the RTP for Concurrence
- The QA Specialist
  - Reviews a Sample of the RTP as Above
  - Adds Any Internal QA Records Pertaining to the Project That Have Not Previously Been Sent to ONWI Files
  - Documents Concurrence
- When an RTP is Deficient, Project Manager Transmits Letter Identifying Deficiency and Requiring Contractor to Take Corrective Action

PMP-04 KEY PROVISIONS

RTP Sent to Information Systems Services (ISS) for Entry Into ONWI Files

- After RTP Has Been Found To Be Acceptable, the QA Specialist Forwards it to ISS

- All of the Contained Records Can Be Retrieved by BPMD Personnel After the RTP Has Been Entered Into ONWI Files

PMP-05 DESIGN REVIEW

TYPE OF REVIEW

- Project Manager (Manager Approval)
  - responsible to determine type of review
  - PMP-16 review of contractor technical submittals
- Design Review Application
  - conceptual
  - preliminary (Title I)
  - detail design (Title II)
  - construction (Title III)

PURPOSE OF DESIGN REVIEWS

- Review and Verify
  - criteria, specification, requirements, etc.
  - design conformance to criteria
  - interim stage

PMP-05 DESIGN REVIEW
(Continued)

REVIEW PROCESS

- Design Review Plan (Project Manager/ EFM Approval/QAD Concur)
  - scope
  - objectives
  - documents
- Design Review Committee (EFM)
  - adequate representation
  - QA participation
  - excluded members
- Meeting Notice (Chairman/EFM Approval)
  - plan
  - committee membership
  - agenda
  - technical checklist
  - QA concurrence
- Meeting Preparation
  - review design report
  - prepare technical checklist

PMP-05 DESIGN REVIEW
(Continued)

REVIEW PROCESS (Continued)

- Review Meeting (Chairman)
  - presentations
  - deliberations
- Findings Report (Chairman/EFM Approval)
  - minutes
  - recommendations
  - member reviews
- Completion Report (Chairman/DM, FM, QAD, Approval/Legal Review)
  - resolutions
  - documentation
  - closing statement
  - reviews and concurrence

PMP-05 DESIGN REVIEW
(Continued)

REVIEW PROCESS (Continued)

- Review Documentation
  - review plan, meeting notice, findings, and completion reports
  - file PM, QAD, ONWI, others
  - process monitored by QAD

PMP-06 PEER REVIEW

PURPOSE

- Establishes Requirements for Performing Peer Review to Assure:
  - completeness
  - adequacy
  - accuracy
  - traceability of data and information

PMP-06 PEER REVIEW
(Continued)

DETERMINATION OF NEED

- Responsible Manager Determines When a Peer Review Is Required
- Occasions When Need for Peer Review May Be Determined
  - planning of internal work or procurements
  - receipt of contractor technical submittal
  - completion of internally developed technical document

PMP-06 PEER REVIEW
(Continued)

PLANNING, SCHEDULING, AND SELECTION OF PERSONNEL

- Responsible Manager Prepares Peer Review Request Form That Identifies:
  - review chairman
  - document to be reviewed
  - type of review
  - objectives, requirements, and guidelines of review
  - schedule of review
  - qualified review personnel
  - specific sections of document to be reviewed by participants

PMP-06 PEER REVIEW
(Continued)

PERFORMANCE OF PEER REVIEW

- Reviewers Document Comments
  - comment/resolution form
- Comments Are Resolved by Review Chairperson
  - agreement on disposition of comments reached between reviewer and chairperson
    - accepted comments
    - modified comments
  - comments that cannot be resolved are elevated to responsible manager for decision
  - disposition of comments and rationale are documented
- Chairperson Assures That All Accepted Comments Are Incorporated Into Final Version of Document

PMP-06 PEER REVIEW
(Continued)

PERFORMANCE OF PEER REVIEW (Continued)

- Peer Review Report
  - peer review request form
  - completed comment/resolution forms
  - completed checklist
  - meeting minutes
  - personnel qualifications
  - other supporting material
  - submitted to responsible manager for review and approval
- Participation in Review Process by QA Staff
  - participates in reviews
  - evaluates and approves peer review process for adequacy and compliance with ONWI QA program requirements

PMP-16 REVIEW OF CONTRACTOR TECHNICAL SUBMITTALS

Purpose: Establishes Methods for Reviewing Contractor Technical Submittals

Key Provisions:

- Receipt of Contractor Technical Submittals
  - Performance of Management Review Upon Receipt of Technical Submittal
    - Project Manager to Review for Completeness, Correctness, Availability/Appropriateness of References, and Conformance With Contractual Requirements
    - Project Manager to Document Determination of Acceptability on Review Form
    - Project Manager to Determine Need for Additional Review (Peer, Design, Independent Technical), List Proposed Reviewers, and Obtain Approval of Responsible Manager for Type of Review Selected
    - Contractor Submittal and Review Form Forwarded to QAD for Review and Concurrence
  - Types of Additional Review
    - PMP-05 to Perform Design Review
    - PMP-06 to Perform Peer Review
    - PMP-16 to Perform Independent Technical Review

PMP-16 REVIEW OF CONTRACTOR TECHNICAL SUBMITTALS
(Continued)

Key Provisions: (Continued)

- Independent Technical Review
  - — Project Manager Responsible for Planning, Scheduling, and Selecting Qualified Personnel to Perform Technical Review
    - Initiate Review Process by Preparing Review Package—Contractor Technical Submittal, Review/Comment Forms, and Review Instructions
    - Review Package Transmitted to Designated Review Personnel
  - — Review Performance and Documentation of Results
    - Designated Reviewers to Perform Technical Review in Accordance With Review Instructions and PMP-16 Requirements
    - Review Comments and Rationale Documented on Review/ Comment Form
    - Review Results Returned to Project Manager
  - — Evaluation and Resolution of Technical Review Comments
    - Project Manager to Evaluate Review Comments and Provide Disposition
    - Comments Designated as Mandatory Required to Be Incorporated or Resolved Between Project Manager and Reviewer, and Reviewer's Concurrence for Comment Resolution Documented
    - When Mandatory Review Comments Cannot Be Resolved, the Unresolved Comment to Be Transmitted to the ONWI Program Manager for Resolution
  - — Upon Resolution of All Comments, Project Manager to Complete and Submit Completed Review Forms to the Responsible Manager for Review and Concurrence

PMP-16 REVIEW OF CONTRACTOR TECHNICAL SUBMITTALS
(Continued)

Key Provisions: (Continued)

- Monitoring the Review Process
  - QA Specialist to Review Completed Review Package to Assure Disposition and Resolution of All Comments, and Document Concurrence
- Technical Review Results
  - Project Manager to Notify Contractor of Actions to Be Taken for Revision and Resubmittal of the Document Resulting From the Technical Review
  - Upon Resubmittal of the Revised Document, Project Manager to Perform Review to Assure Incorporation/Compliance With Review Comments and to Document This Determination (e.g., Requires Additional Review/Return to Contractor, Final Acceptance)
  - Project Manager to Transmit Completed Review Package and Review Forms to CDMS (Contractor Data Management System) to Input Into the ONWI Records File

VII. REVIEW EXAMPLES OF TECHNICAL PROCEDURE PREPARATION AND IMPLEMENTATION CONTROLS

GEOLOGIC PROJECT MANAGER – PERMIAN BASIN PROJECT

OFFICE OF NUCLEAR WASTE ISOLATION

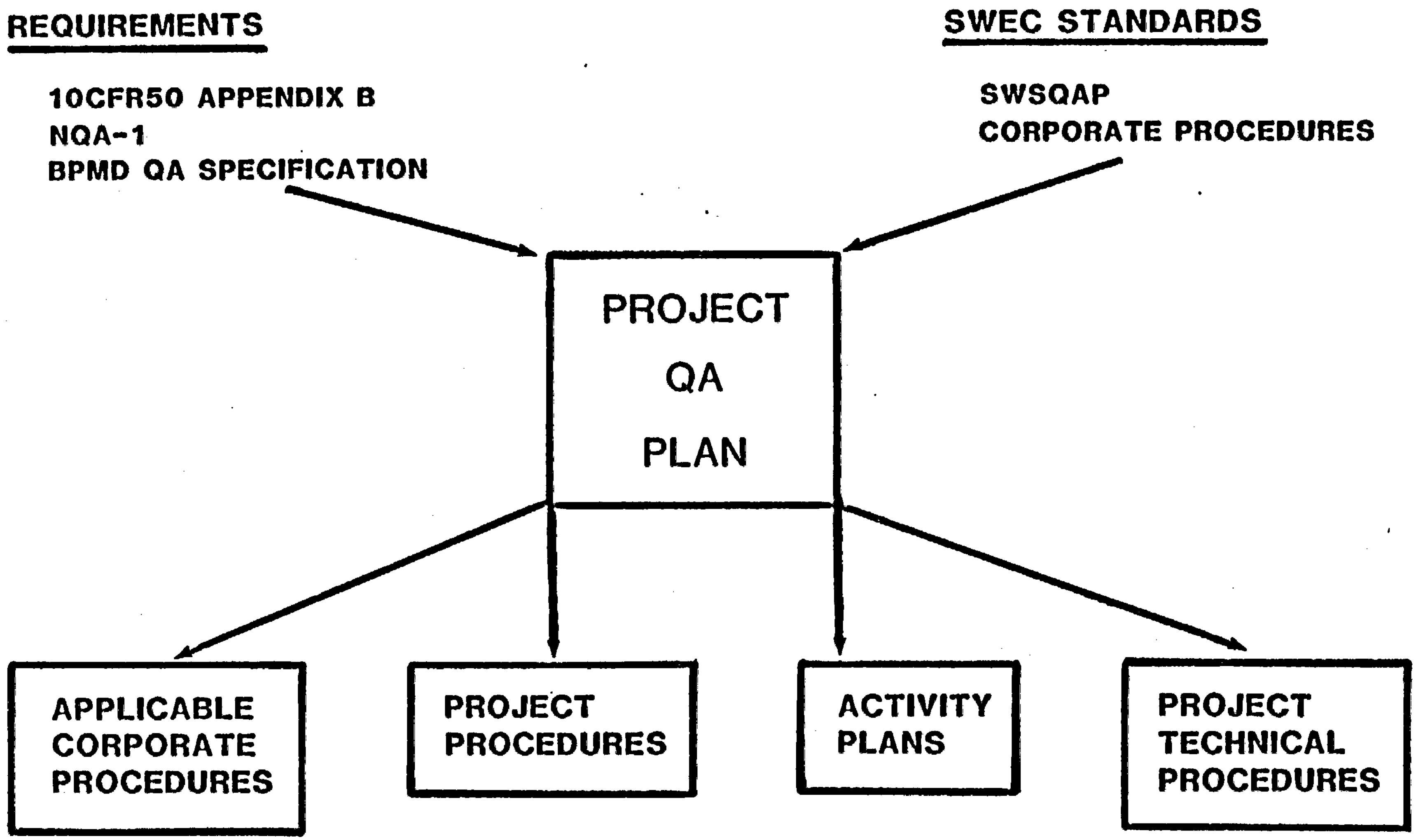
BATTELLE MEMORIAL INSTITUTE, PROJECT MANAGEMENT DIVISION

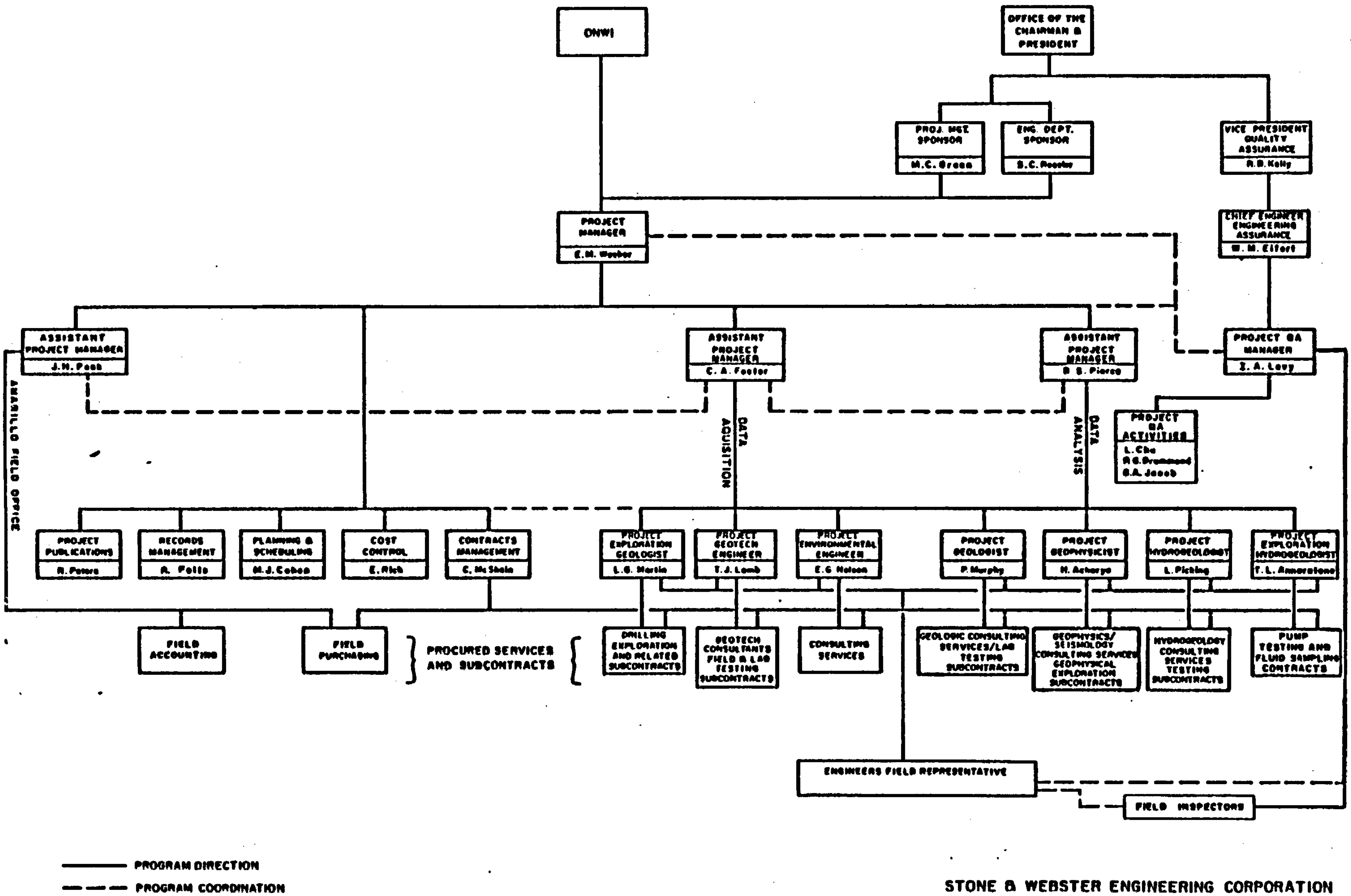
STONE & WEBSTER ENGINEERING CORPORATION

PRESENTATION

• PROJECT QUALITY ASSURANCE PROGRAM OVERVIEW	I.A. LEVY – PROJECT QUALITY ASSURANCE MANAGER
• CORING SERVICES AND CORE LOGGING AT THE J. FRIEMEL NO. 1 WELL	C.A. FOSTER – ASST. PROJECT MANAGER
• PUMP TESTING AND FLUID SAMPLING AT THE J. FRIEMEL NO. 1 WELL	C.A. FOSTER – ASST. PROJECT MANAGER

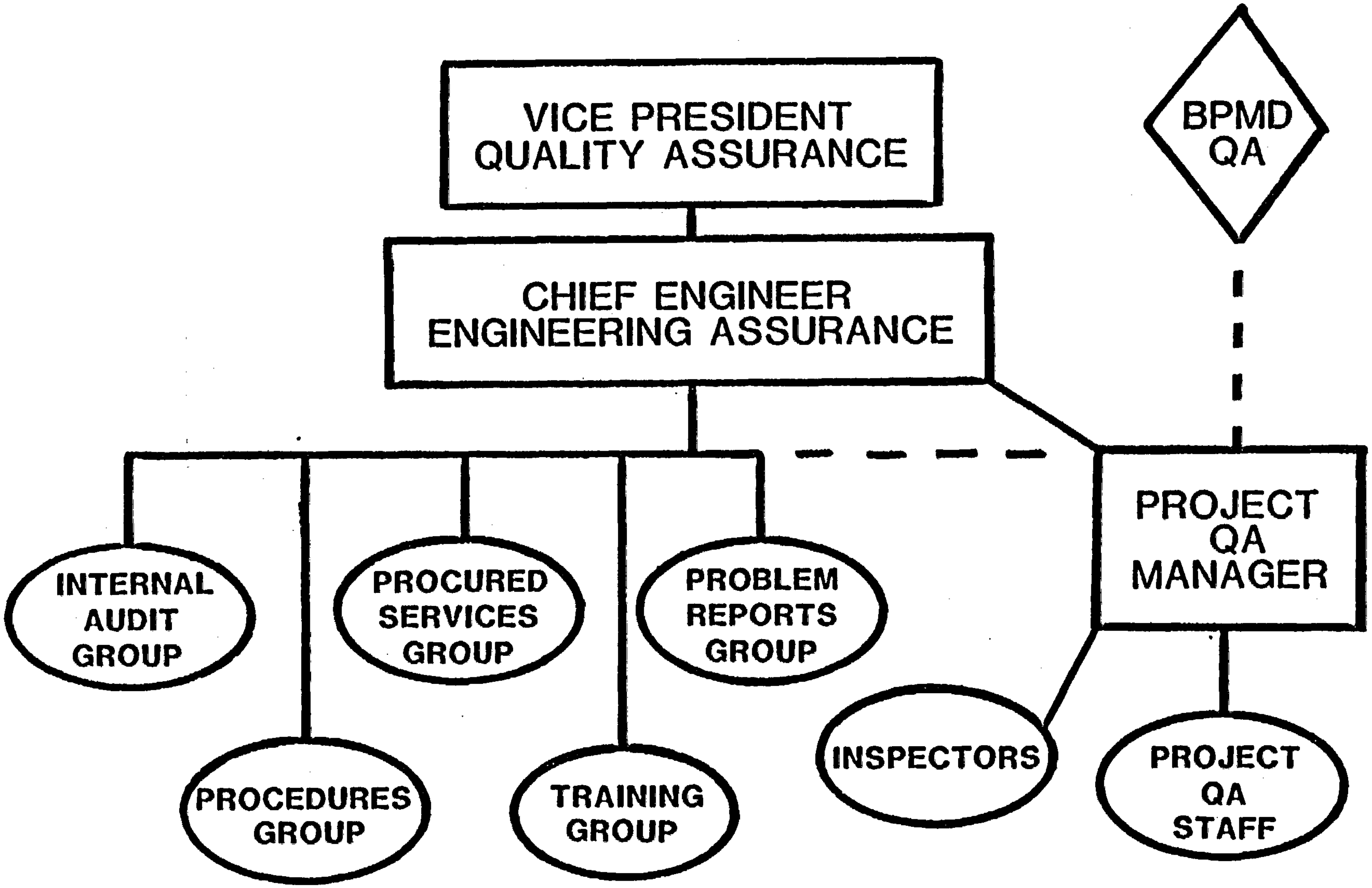
QA PROGRAM


REQUIREMENTS
10CFR50 APPENDIX B
NQA-1
BPMD QA SPECIFICATION
SWEC STANDARDS
SWSQAP
CORPORATE PROCEDURES
PROJECT QA PLAN
APPLICABLE CORPORATE PROCEDURES
PROJECT PROCEDURES
ACTIVITY PLANS
PROJECT TECHNICAL PROCEDURES

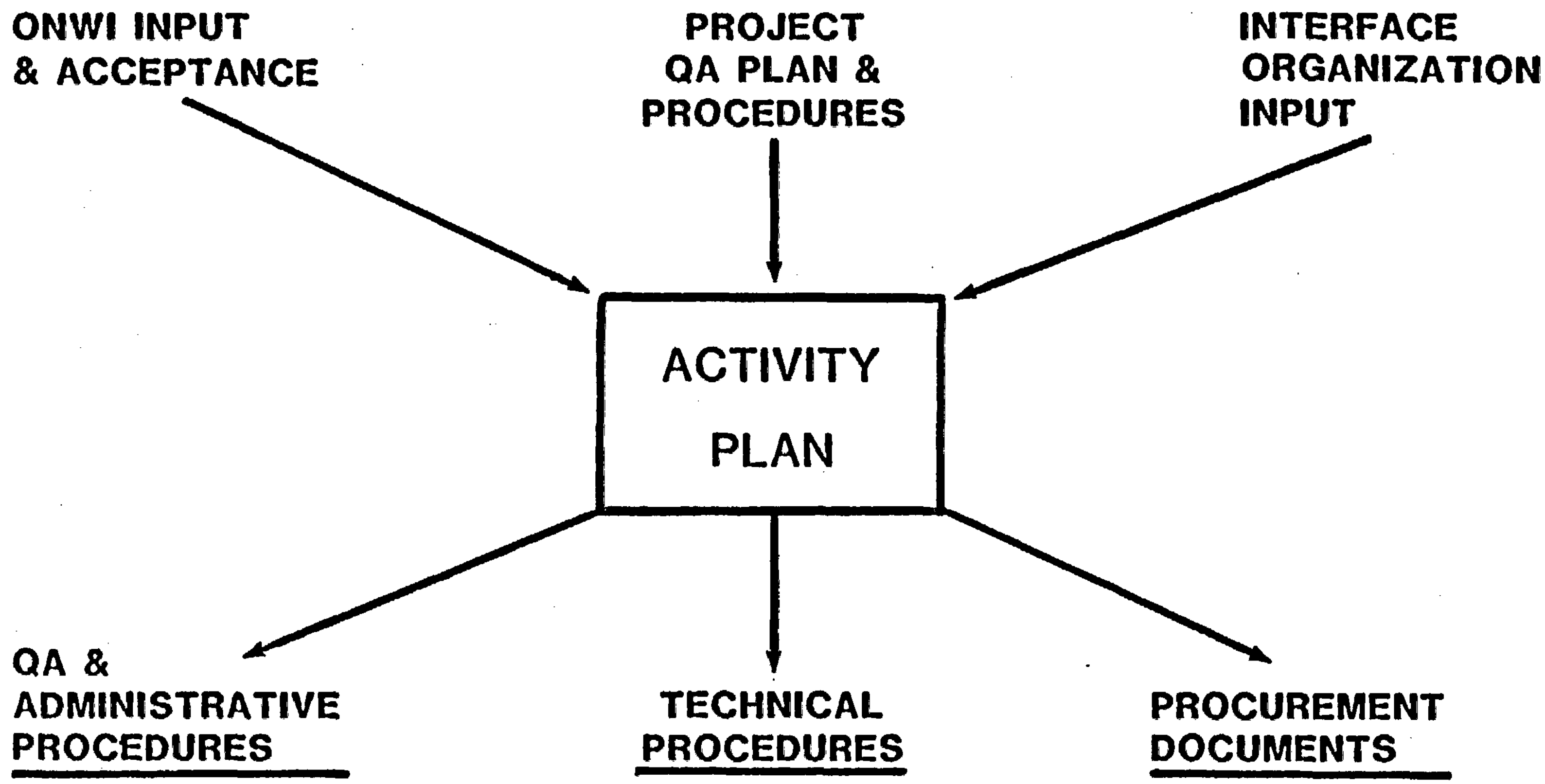


STONE & WEBSTER ENGINEERING CORPORATION
PROJECT ORGANIZATION
PERMIAN BASIN GPM
JUNE 1984

QA ORGANIZATION



ACTIVITY CONTROL DOCUMENTS



QA & ADMINISTRATIVE PROCEDURES

ENGINEERING ASSURANCE (EAP)

ENGINEERING DEPARTMENT (EDPP)

PROJECT (PP)

TECHNICAL PROCEDURES

GEOTECHNICAL DIVISION (GTP)

ENVIRONMENTAL DIVISION (ETP)

PROJECT (PTP)

PROCUREMENT DOCUMENTS

ENGINEERING SERVICE SCOPE OF WORK (ESSOW)

PURCHASE REQUISITION (PR)

IMPLEMENTING DOCUMENTS [1]

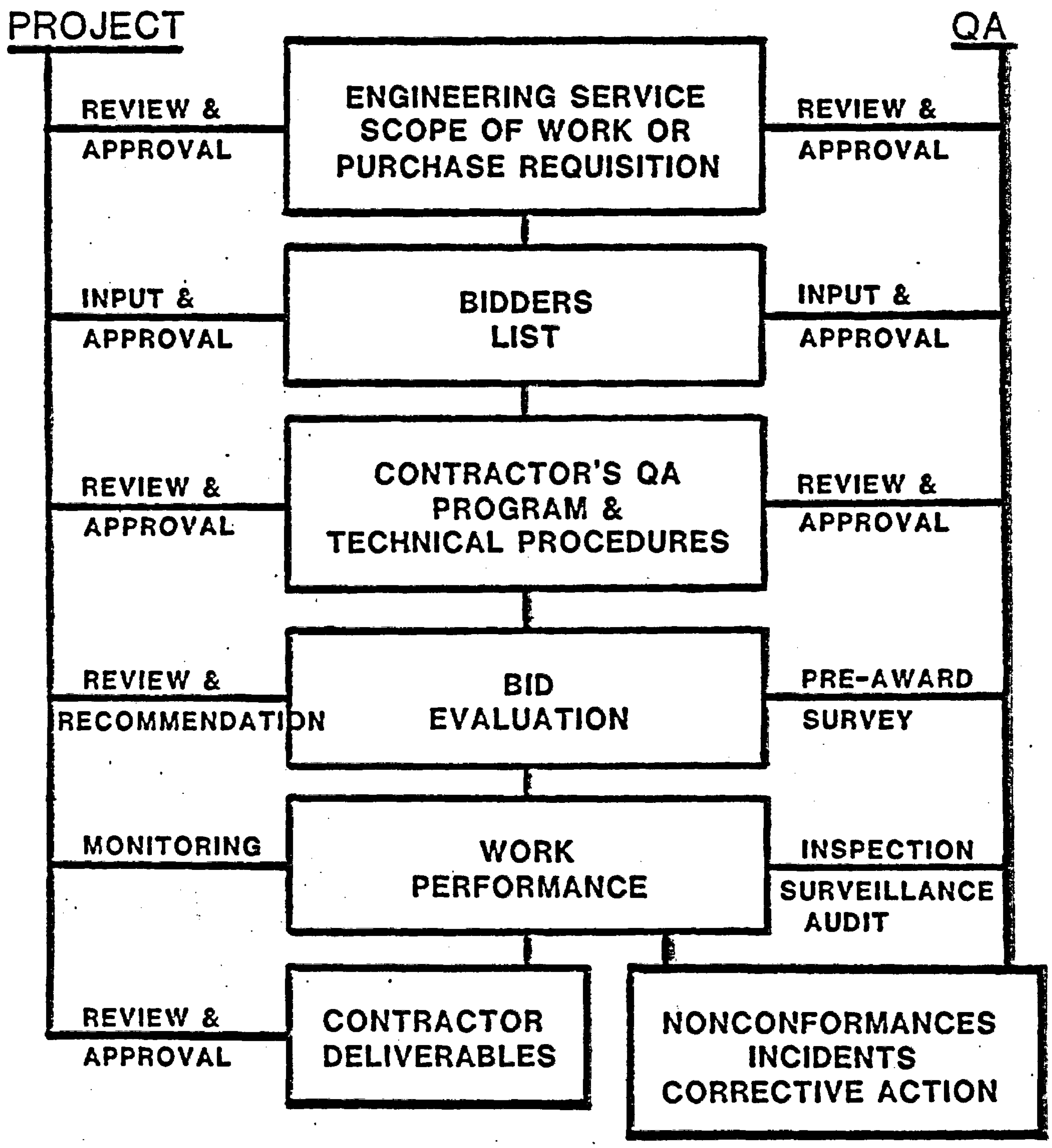
	REVIEW AND APPROVAL			
DOCUMENT	TECHNICAL	QA	INDEPENDENT TECHNICAL	PROJECT MANAGEMENT
QA PLAN (3)		X		X
PROJECT PROCEDURE (PP)		X (2)		X
ACTIVITY PLAN (AP)	X	X	X	X
PROJECT TECHNICAL PROCEDURE (PTP)	X	X	X	X
ENGINEERING SERVICE SCOPE OF WORK (ESSOW)	X	X	X	X
PURCHASE REQUISITION (PR)	X	X	X	X

(1) INVOKES APPLICABLE SWEC STANDARD PROCEDURES AND REQUIREMENTS.

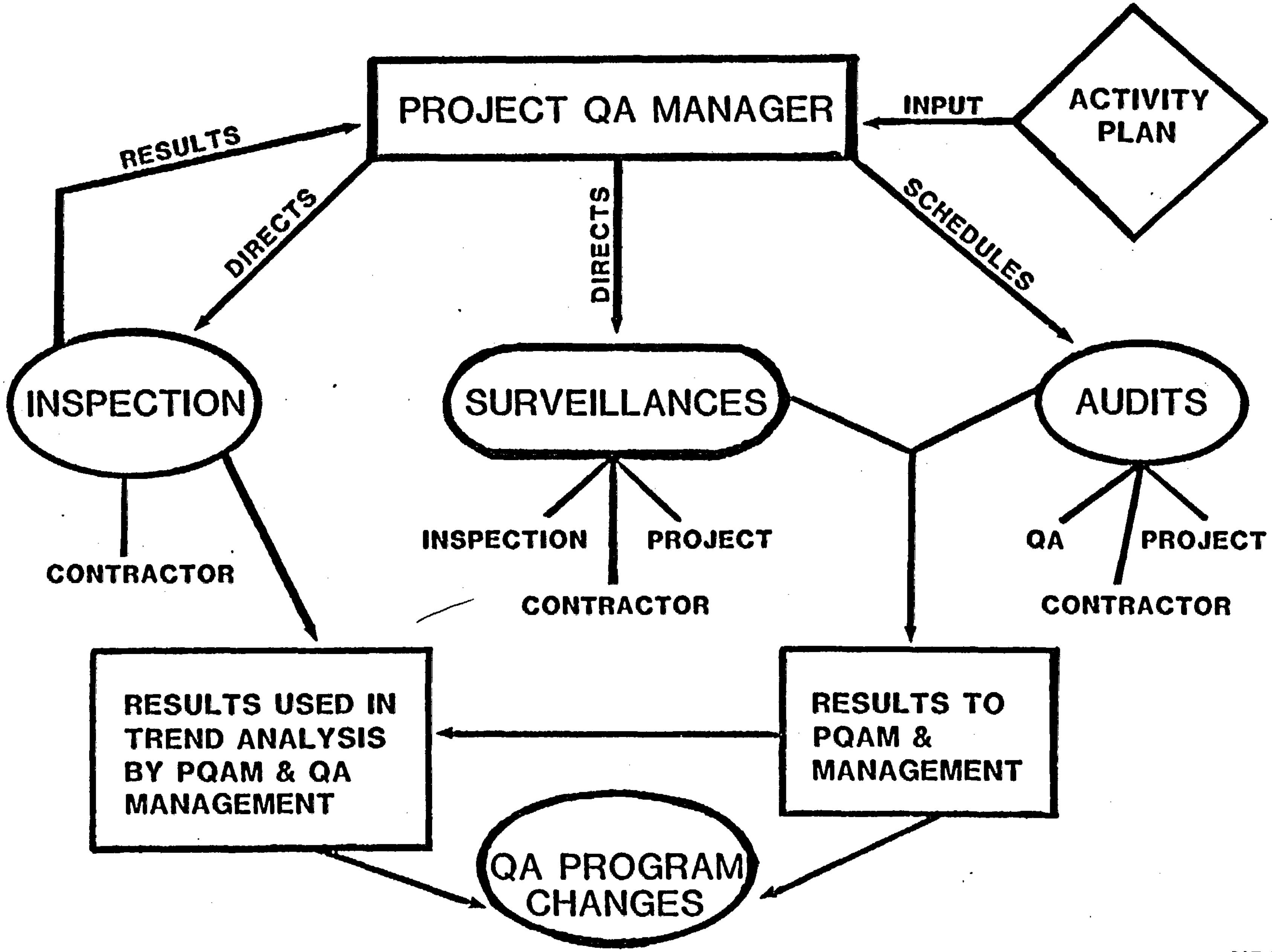
(2) FOR THOSE PROCEDURES AFFECTING QUALITY.

(3) ALSO REVIEWED/APPROVED BY EA CHIEF ENGINEER AND QA VICE PRESIDENT.

PROCUREMENT CONTROL



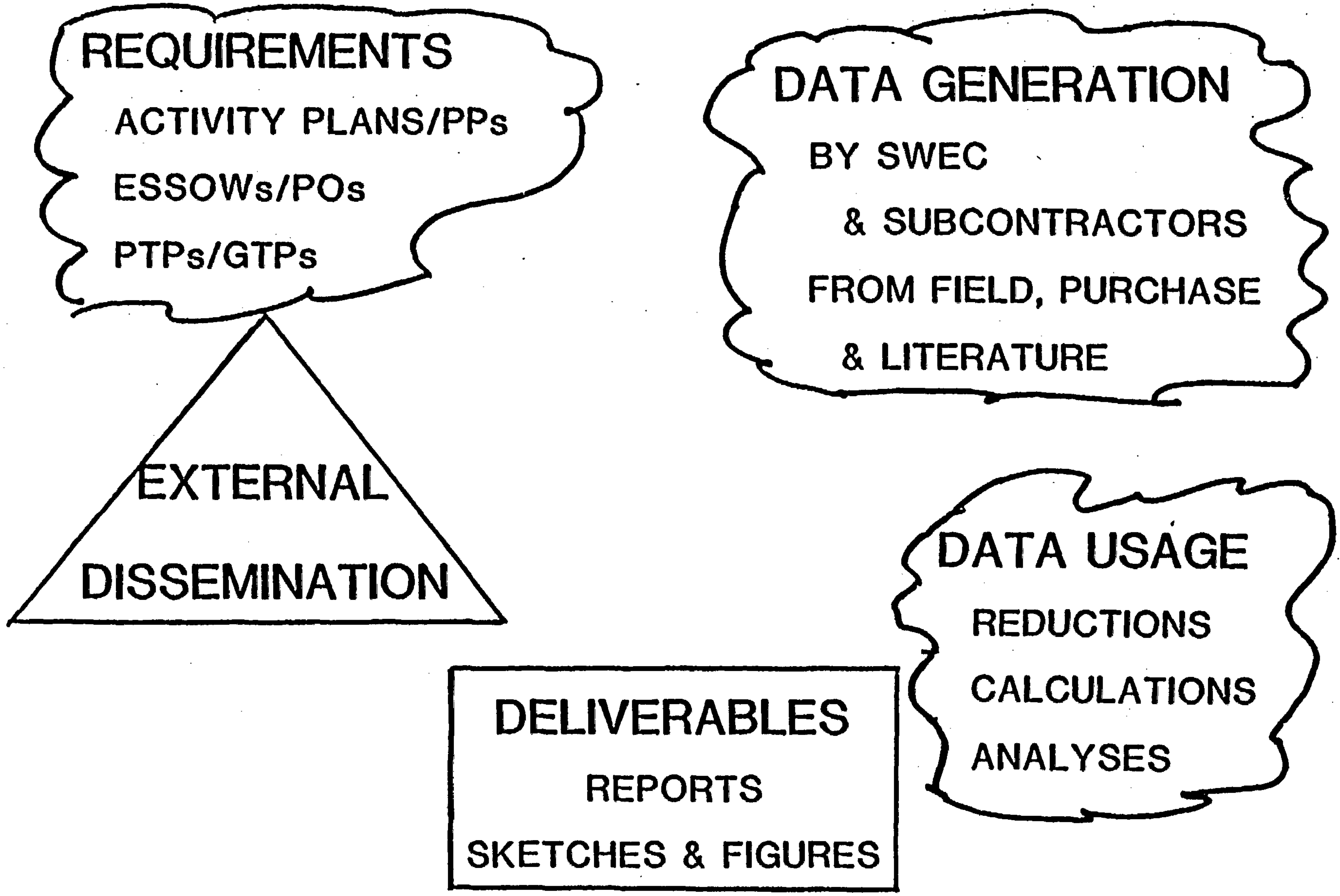
QA MONITORING



INSPECTION FUNCTIONS

INSPECTOR	PROJECT QA MANAGER
PERFORM INSPECTIONS DESIGNATED IN ESSOWs & POs	DIRECTS INSPECTION FUNCTION
DOCUMENTS INSPECTION	
o TEST, INSPECTION AND DOCUMENTATION REPORT (TID)	REVIEWS AND CLOSES TIDs
o MATERIAL AND EQUIPMENT RECEIVING REPORT (MRR)	MONITORS MRRs
INITIATES NONCONFORMANCE AND DISPOSITION REPORTS (N&D)	APPROVES INITIATION
REINSPECTS TO VERIFY N&D CORRECTIVE ACTION	CLOSES N&Ds
INITIATES INCIDENT REPORTS	ISSUES INCIDENT REPORTS
REPORTS OCCURRENCES TO PQAM THAT MAY RESULT IN A N&D, INCIDENT REPORT AND/OR STOP WORK ORDER.	EVALUATES OCCURRENCES AND DIRECTS INSPECTOR TO ISSUE N&D, INCIDENT REPORT OR STOP WORK.
PARTICIPATES IN EVALUATION MEETINGS	PARTICIPATES IN EVALUATION MEETINGS
QUALIFIED TO ANSI N45.2.6 FROM GEOTECHNICAL DIVISION	

DELIVERABLE DOCUMENT RELATIONSHIPS



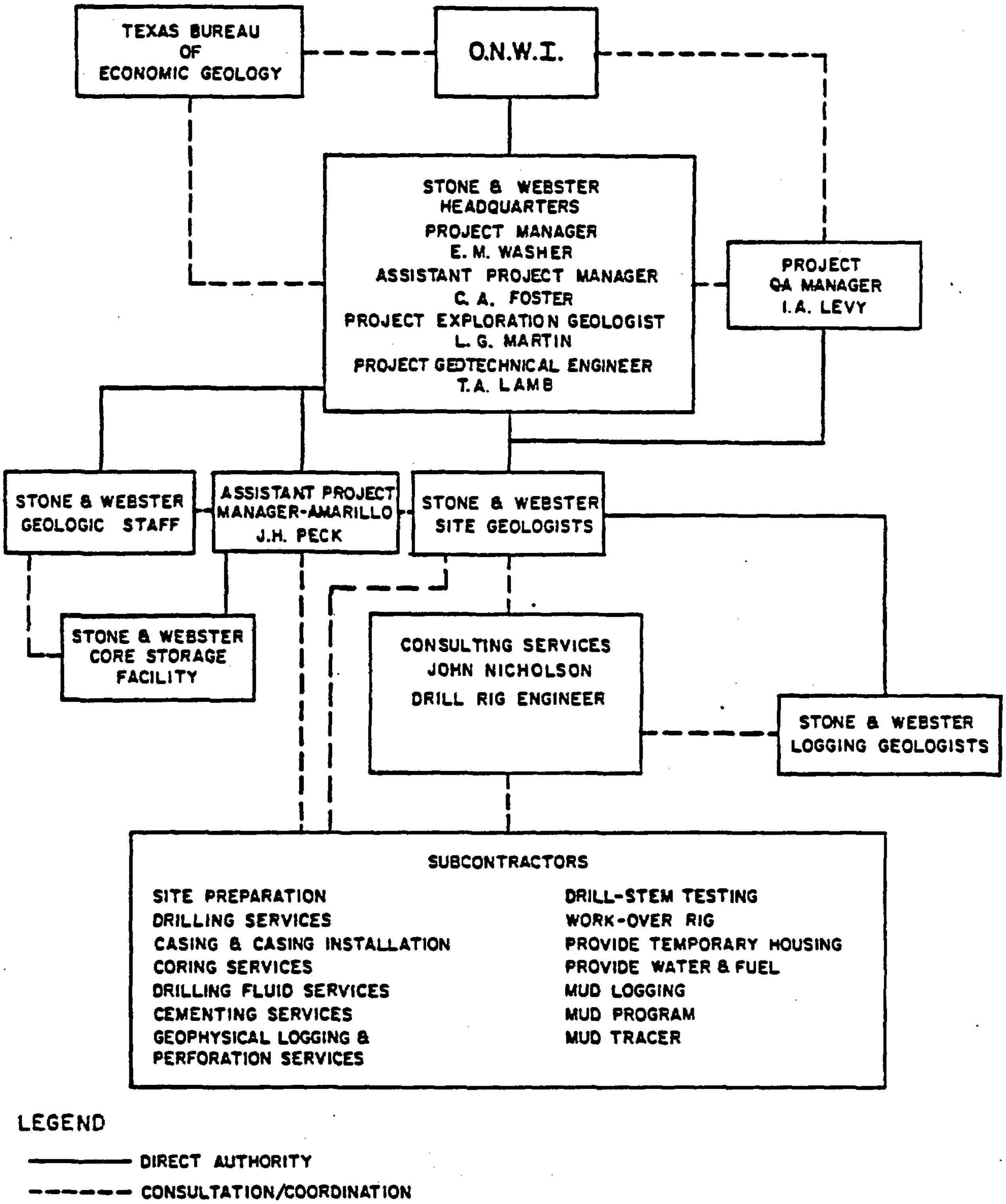
ONWI – PERMIAN BASIN PROJECT
GEOLOGIC PROJECT MANAGER

FIELD TESTING PROGRAM – DATA ACQUISITION

TYPICAL EXAMPLES:

J. FRIEMEL NO. 1 WELL

- CORING SERVICES AND CORE LOGGING
- PUMP TESTING AND FLUID SAMPLING



NOTE:

FOR MORE DETAIL ON HEADQUARTERS ORGANIZATION SEE PROJECT QUALITY ASSURANCE PLAN APPENDIX A

FIELD ORGANIZATION CHART

STONE & WEBSTER ENGINEERING CORPORATION

PROJECT CONTROL DOCUMENTS

CORING SERVICES & CORE LOGGING

AP-9- HYDROLOGIC TEST WELL - J. FRIEMEL NO. 1

- WELL LOCATION, DEPTH & DESIGN
- SEQUENCE OF CORING ACTIVITIES
- INTERVALS TO BE CORED & CORE SIZE

(CORING SERVICES)

SWEC SUBCONTRACTOR
ESSOW - G103C - ROCK CORING EQUIP. & SERVICES

- TECHNICAL & QA SECTION OF CONTRACT
- DETAILED REQUIREMENTS FOR EQUIP. & SERVICES
- PROCEDURES
- DOCUMENTATION
- INSPECTION

(CORE LOGGING)

SWEC GEOLOGISTS
PTP - 8 - FIELD LOGGING, PACKAGE, TRANSPORT OF CORE
PTP - 11 - TRANSPORT, LOGGING PHOTO, STORAGE OF CORE - AFO

- LOGGING PERSONNEL
- EQUIPMENT
- PROCEDURES & FORMS
- DOCUMENTATION
- DATA DISTRIBUTION
- INSPECTION

AP - 9 HYDROLOGIC TEST WELL - J. FRIEMEL NO. 1

TABLE OF CONTENTS

AP - 9 HYDROLOGIC TEST WELL J. FRIEMEL NO. 1

ATTACHMENT 4-0
HYDROLOGIC TEST WELL

SWEC SUBCONTRACTORS

Name	General Description	Contract ESSOW or P.O. No.
Baker & Taylor	Drill Rig & Crew	G103A
Schlumberger	Geophysical Logging & Perforating Services	G103B
Hycalog	Rock Coring Equipment & Coring Engineer	G103C
Dresser-Magcobar	Mud Program - Drilling Fluids & Mud Engineer	G103D
Field Call-out	Cementing Supplies & Services	*
Field Call-out	Casing and Tubing	
Johnston - Macco	Drill Stem Testing	G103G
FMC	Well Head Assembly	G103H
Field Call-out	Casing Installation Crew	*
Field Call-out	Fuel-Drill Rig, Other Onsite Equipment	*
Field Call-out	Water for Drilling	*
Exploration Logging	Mud Logging Services	G103Q
John Nicholson Amarillo, Texas	Drilling Consultant Petroleum Geologist	G112A
P. Cameron, Jr, Inc.	Consultant-Petroleum Engineer. Drill Rig Engineers	G112F
Glen Thompson Tucson, Arizona	Mud Tracer Consultant	G112D

*Field Purchase Orders

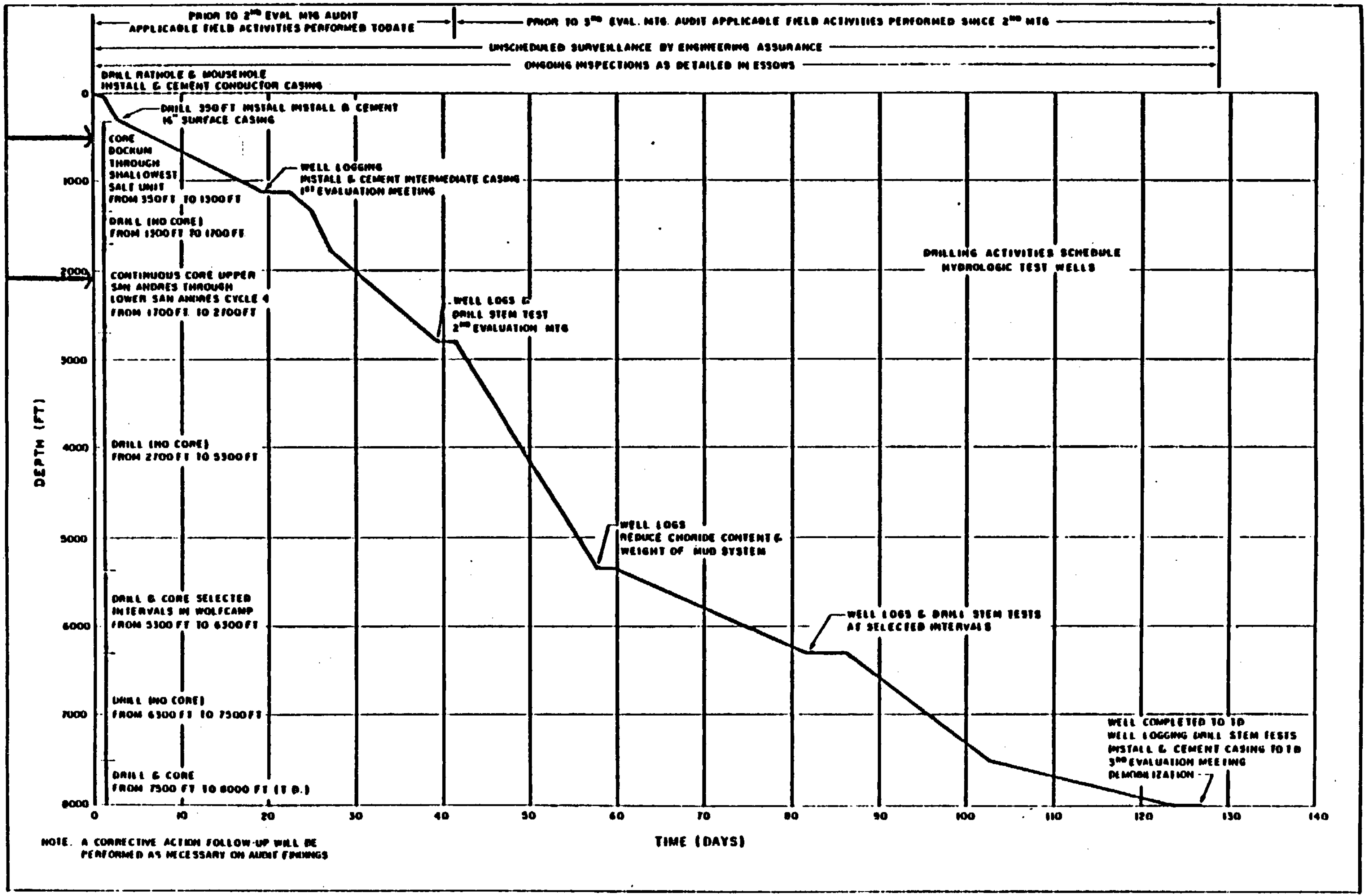
AP - 9 HYDROLOGIC TEST WELL - J. FRIEMEL NO. 1

ATTACHMENT 5-0
HYDROLOGIC TEST WELLS

SWEC PROJECT TECHNICAL PROCEDURES (PTPs)
AND PROJECT PROCEDURES (PPs)

Number	Title/Description
PTP 13697-7	Cementing and Casing Installation
PTP 13697-8	Logging, Packaging, and Transport of Core
PTP 13697-11	Transport, Logging, Photographing, and Storage of Core at SWEC Field Office
PP 9-1	Responsibilities of SWEC Site Geologist
PP 9-2	Receiving Equipment and Materials

AP - 9 - HYDROLOGIC TEST WELL - J. FRIEMEL NO. 1
ACTIVITIES SCHEDULE



ESSOW G103C - ROCK CORING EQUIPMENT & SERVICES

TABLE OF CONTENTS

STONE & WEBSTER ENGINEERING CORPORATION

SHOP
FIELD
T.I.D. REPORT FOR Rock Coring Equipment and Services

5040.48B (QCD-101) ☐ REPORT NO. ______ ☐ FINAL REPORT SHEET ______ OF ______

CLIENT Battelle Memorial Institute	J.O. NO. 13697 / MARK NO
PROJECT National Waste Storage Program	ORDER NO G103C / ITEM NO.
SELLER OR CONTRACTOR	SHOP ORDER NO
SUBSUPPLIER OR SUBCONTRACTOR	SHOP NO.
DESCRIPTION	SELLER OR CONTRACTOR'S IDENTIFICATION
REFERENCE DRAWING(S)	
S & W SPECIFICATION NAME ESSOW G103C - Rock Coring Equip. & Services	SPECIFICATION DATE / ADDENDA THRU NO

	TEST, INSPECTION, AND DOCUMENTATION RECORD	*	VERIFIED**	WITNESSED**	PERFORMED**	CERTIFIED*** BY (Signature)	CERTIFIED*** DATE	DEVIATION AUTHORIZATION TYPE	DEVIATION AUTHORIZATION NUMBER OR NAME	DEVIATION AUTHORIZATION DATE
1	Equipment & Materials (at start)	1								
2	Equipment (Primary)	1	x							
3	Equipment (Backup)	1	x							
4	Materials	1	x							
5	Daily Progress Report (Format)	1	x							
6	Equipment & Materials (ongoing)	1								
7	Equipment	1		x						
8	Materials	1		x						
9	Procedures	1		x						
10	Documentation									
11	Daily Progress Reports	2	x							
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

*FOR INSTRUCTIONS, SEE THIS NUMBER IN THE INSPECTION SUBSECTION.
**BY S & W INSPECTOR IF FILLED IN "X" (Purchaser's Field Representative)
VERIFIED — PERSONAL OBSERVATION OF DATA APPLICABLE TO THE WORK.
WITNESSED — PERSONAL OBSERVATION WHILE THE MANUFACTURER PERFORMS THE TASK.
PERFORMED — PERSONAL PERFORMANCE OF THE TASK
***AS IN CONFORMANCE WITH THE SPECIFICATION OR WITH THE DEVIATION AUTHORIZATION INDICATED.

REMARKS

OFFICE | REPORTED BY | DATE

CONTENTS

The Logging Geologist is responsible for distributing data as indicated below:

Item	SWEC Project Exploration Geologist	TBEG Project Manager	ONWI Project Manager	SWEC Field Office Manager
Rock Core		X (Permanent)		X (Temporary)
Rock Core Logs				
Original	X			
Copies	X	X	X	X
Photographs				
Negatives	X			
Prints	X (2 sets)	X	X	X
Slides	X		X	

In addition, complete sets of prints will be sent to the following persons:

M.E. Steiner
Parsons Brinkerhoff/PB-KBB
11767 Katy Freeway
Houston, TX 77079

G.P. Callahan
RE/Spec, Inc.
P.O. Box 725
Rapid City, S.D. 57709

The remaining three sets will be kept at the Amarillo Field Office

ONWI - BATTELLE MEMORIAL INSTITUTE - PERMIAN BASIN PROJECT

WELL NAME AND No. ____________ J.O. No. 13697 SHEET 1 OF ____

LOCATION ____________

ELEVATION: KELLY BUSHING ________ FT. PLATFORM ELEVATION ________ FT.

GROUND SURFACE ________ FT.

LOGGED BY ____________

DATE: START/FINISH ____ / ____ CONTRACTOR/TOOL PUSHER ____ / ____

DRILL RIG TYPE ____________

DRILLING METHOD ____________

MUD PROGRAM ____________

DEPTH TO BEDROCK ________ FT. TOTAL DEPTH DRILLED ________ FT.

HOLE SIZE ____________

CORE SIZE ____________

CASING RECORD ____________

SPECIAL TESTING OR INSTRUMENTATION ____________

REMARKS ____________

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE		RECOVERY FT RQD %	GRAPHIC LOG	SAMPLE DESCRIPTION
		RUN NO	BOX NO			
						NOTE: SEE SWEC "SOIL & ROCK IDENTIFICATION MANUAL"

STONE & WEBSTER ENG. CORP	APPROVED	DATE	SHEET OF

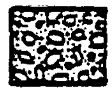
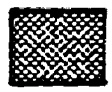
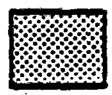
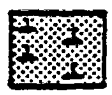
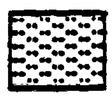
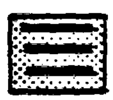
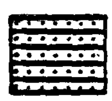
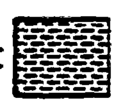
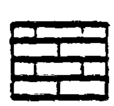
CORE STORAGE LOG - AMARILLO FIELD OFFICE
STONE & WEBSTER ENGINEERING CORPORATION

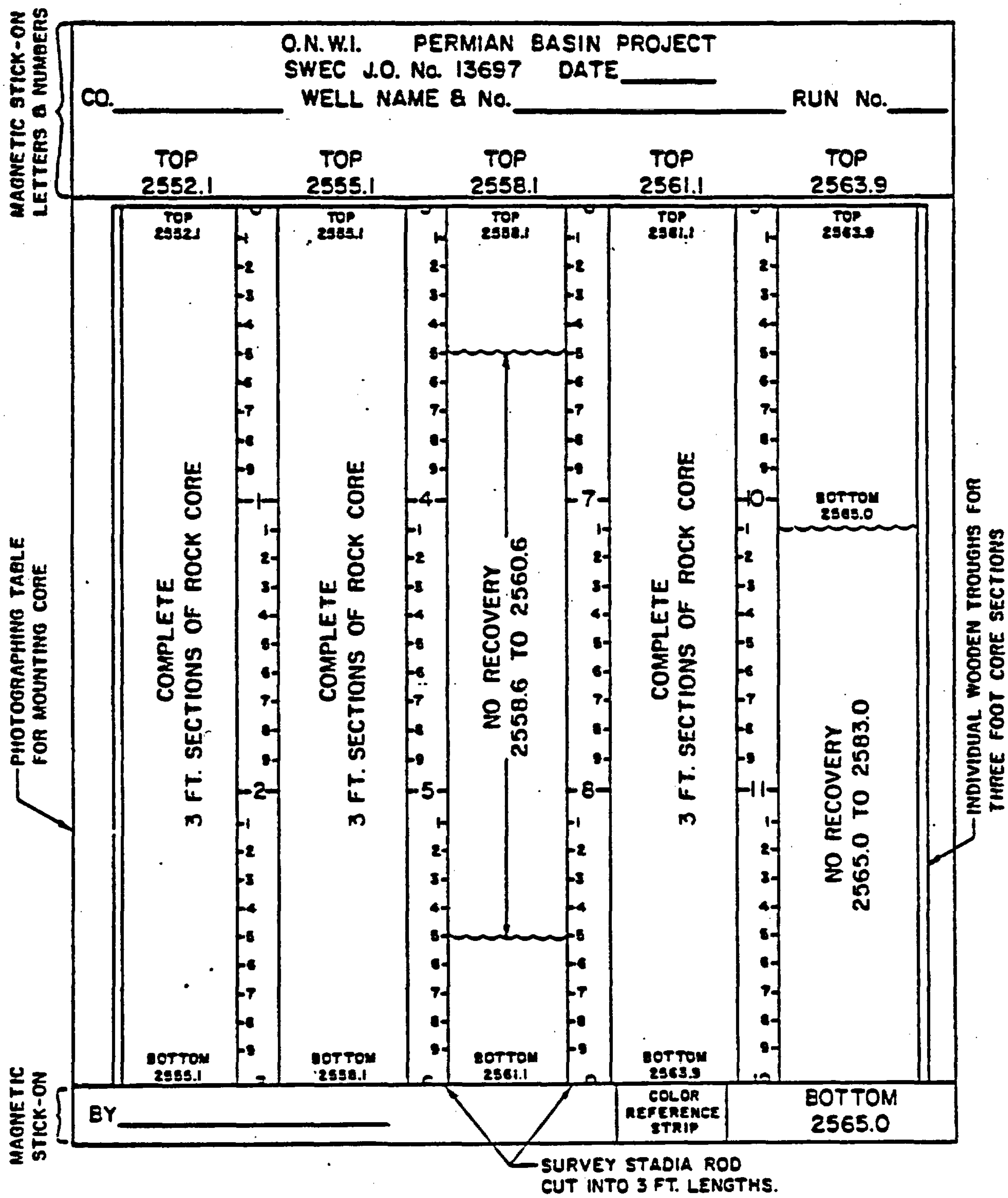
ATTACHMENT - 3
PTP 13697-11-2

WELL NAME & NO. J.O NO. 13697 SHEET ____ OF ____

BOX	DEPTH (FT)		ELEVATION		DATE	LOGGED		TEMPORARY	CORE REMOVED			CORE RETURNED	
NO.	TOP	BOT.	TOP	BOT.	REC.	DATE	BY	STORAGE LOCATION	DATE	BY	INTERVAL	DATE	BY

GRAPHIC SYMBOL SHEET STONE & WEBSTER ENGINEERING CORP.

ROCK TYPE	GRAPHIC SYMBOL	LETRATONE No. (OR EQUIVALENT)	REMARKS
CONGLOMERATE		LT 182	
SANDSTONE			
MASSIVE-COARSE GRAINED		LT 11	
MASSIVE-FINE GRAINED		LT 8	
CALCAREOUS		LT 8	ADD LINES BY HAND (SIMILARLY FOR DOLOMITIC S.S.)
BEDDED		LT 145	
CROSS BEDDED		LT 89	
W/SHALE PARTINGS		LT 8	ADD LINES BY HAND
SANDSTONE & SHALE (EQUAL)		LT 164	
SILTSTONE		LT 120	ADD DOTS BY HAND
MUDSTONE OR CLAYSTONE		LT 121	
SHALE		LT 169	
OIL SHALE		LT 169	ADD DARK LINES BY HAND
CALCAREOUS SHALE		LT 169	ADD LINES BY HAND
LIMESTONE		LT 123	
DOLOMITIC		LT 242	



NOTE:
TOP & BOTTOM DEPTHS PAINTED ON 3FT. SECTIONS OF ROCK CORE

SKETCH FOR SET-UP FOR PHOTOGRAPHING CORE
STONE & WEBSTER ENGINEERING CORP.

ONWI – BATTELLE MEMORIAL INSTITUTE – PERMIAN BASIN PROJECT

WELL NAME AND No. J. Friemel No. 1 J.O. No. 13697 SHEET 1 OF 49

LOCATION Deaf Smith County, J. Friemel Lease, Block K-7, Section 3, 2778' from S.L., 221' from E.L.

ELEVATION: KELLY BUSHING 4024.3 FT. PLATFORM ELEVATION 4024.2 FT.
GROUND SURFACE 4015.9 FT.

LOGGED BY A.O. Sinisalo, D.A. Grover, K.W. Maxwell, S.D. Boyd

DATE: START/FINISH 10-15-82 / 3-18-83 CONTRACTOR/TOOL PUSHER Baker & Taylor / Eiseman

DRILL RIG TYPE Baker and Taylor – Rig #18

DRILLING METHOD Conventional rotary drilling
Diamond and stratopax coring

MUD PROGRAM Fresh base to 1210 ft, salt base from 1210 ft to 4695 ft, fresh base from 4695 ft to TD (8283 ft).

DEPTH TO BEDROCK Unknown FT. TOTAL DEPTH DRILLED 8283 FT.

HOLE SIZE 30" to 59'; 20" to 1210'; 14 3/4" to 4698'; 8 3/4" to 8283'.

CORE SIZE 4" dia. cored. intervals: 352' to 1216'; 1239' to 1464'; 1846' to 2830'; 5519' to 6032'; 6421' to 6536.5'; 7698' to 7780'; 8047' to 8283'.

CASING RECORD
22"(2DSALO) to 57 ft; 16"(H-40 65#/ft) to 1210 ft; 10 3/4"(40.5#/ft, J-55) to 4698 ft;
5 1/2"(17 & 15.5#/ft, K-55) to 8282 ft.

SPECIAL TESTING OR INSTRUMENTATION DSTs : successful – 1279' to 1464', 2753'-2830', 5630'-5909'; unsuccessful – 787' to 850', 958' to 1216', 7692' to 7781'. Geophysical Logs: complete suites – 60'-1216', 1000'-4649', 4695'-8282'; partial suites – 1201'-1450', 1201'-2825', 4698'-5908', 5700'-6535', 6300'-7780'.

REMARKS Box numbers refer to shipment from SWEC, Amarillo, Texas to TBEG, Austin, Texas, where core was reboxed. All depths measured from Kelly Bushing. Depths not normalized to geophysical logs.
Note: All box numbers from J. Friemel core have the identifying letter prefix "JF".

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE RUN NO.	SAMPLE BOX NO.	RECOVERY (FT) RQD %	GRAPHIC LOG	SAMPLE DESCRIPTION
						Conventional drilling to 352.0'.
3675	350					
			1			352.0-353.4 Lt Brown SANDSTONE. No apparent bdg. Soft to v soft, fine-grained, rounded to subrounded grains in calcareous matrix. Bottom half: putty like.
3670						353.4-382.0 No recovery.
			NR			
		1				
	360					

STONE & WEBSTER ENG. CORP. | APPROVED CA Foster | DATE 11/30/83 | SHEET 1 OF 49

WELL NAME AND No. J. Friemel No. 1 J.O. No. 13897 SHEET 19 OF 49

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE RUN NO.	SAMPLE BOX NO.	RECOVERY (FT) RQD %	GRAPHIC LOG
			321		
	1850		322		
			323		
2170			324		
			325		
	1860		326		
2160			327		
			328		
	1870	28	329	58.8 / 98	
			330		
2150			331		
	1880		332		
			333		
2140			334		
			335		
	1890		336		
2130			337		
			338		
	1900		339		
			340		
2120			NR		
		29	341	59.1 / 98	

SAMPLE DESCRIPTION

1846.0- 1864.0 Dk Red-Brown SILTSTONE. No app bdg. Widely-spaced drilling breaks. Fresh, mod hard; numerous green-gray reduction spots often with carbonaceous nuclei. Occasional thin anhydrite stringers.

@1863.3 & 1863.8: Irregular thin anhydrite stringers.

1864.0- 1870.4 Med Red-Brown CLAYSTONE. Slightly silty, no app bdg, no joints; mod close drilling breaks at 0°; fresh, med hard; numerous green-gray reduction spots; occasional vertical, thin, crystalline salt intergrowths; occ small white anhydrite pods and thin stringers.
@1865.3 - 1866.5 & 1869.3 - 1870.5: Vertical salt stringers.

1870.4- 1872.7 Med to Dk Red-Brown Arg SILTSTONE. No app bdg; no joints; mod close 0° drilling breaks; med hard; thin closely-spaced salt stringers. Occasional anhydrite stringers.
@1871.8: Thin white anhydrite stringers.

1872.7- 1877.9 Med Red-Brown CLAYSTONE, 10 to 50% salt; med hard; mod close drilling breaks at 0°. Salt is med to coarse crystalline and translucent to transparent.
1872.7 - 1873.5: 20 to 30% salt.
1873.5 - 1875.8: 40 to 50% salt.
1875.8 - 1877.9: 10 to 20% salt.

1877.9- 1901.4 Translucent SALT. 5 to 30% red-brown ST/CS in pockets and stringers, occ up to 1/2" thick. Widely-spaced drilling breaks, no joints, med to coarsely crystalline. Occ v thin anhydrite stringers.
1877.9 - 1979.7: 15 to 30% siltstone with some claystone.
1879.7 - 1881.7: 5 to 10% claystone.
1881.7 - 1901.4: 5 to 8% v dk brown ST. Occ zones of nearly white pure salt.
1898.4 - 1899.6: Near vertical fracture with light orange salt filling approximately 2 to 2 1/2" thick.

1901.4- 1904.8 Med Red-Brown CLAYSTONE. Sl silty, no bdg, no joints. Mod close, fresh drilling breaks. Fresh surface, med hard; occ v thin salt-filled cracks, reduction spots. Occasional sand-sized anhydrite bodies.

1904.8- 1906.0 No recovery.

1906.0- 1940.1 Translucent SALT. Generally 5 to 20% red-brown ST bodies; ST med to mod hard, as irr ang pods, and ang elongate stringers; close to mod close cone breaks; scattered wispy stringers and patches of anhydrite to 1". Occasional green siltstone bodies.

NOTE: FOR BORING SUMMARY AND LEGEND INFO. SEE SHEET 1.

STONE & WEBSTER ENG. CORP. | APPROVED C A Foster | DATE 11/30/83 | SHEET 19 OF 49

PROJECT CONTROL DOCUMENTS

PUMP TESTING AND FLUID SAMPLING

AP-9 HYDROLOGIC TEST WELL - J.FRIEMEL NO 1

- WELL DESIGN TO ACCOMMODATE PUMP TESTING
- OBTAIN DATA TO SELECT TEST ZONES

AP-17 PUMP TESTING AND FLUID SAMPLING

- IDENTIFIES TESTING ZONES
- SEQUENCE OF TESTING ACTIVITIES

SWEC SUBCONTRACTOR - ESSOW G103L - PUMP TESTS AND FLUID SAMPLING

- TECHNICAL & QA SECTION OF CONTRACT
- DETAILED EQUIP. & SERVICE REQUIREMENTS
- DOCUMENTATION
- CALIBRATION
- INSPECTION

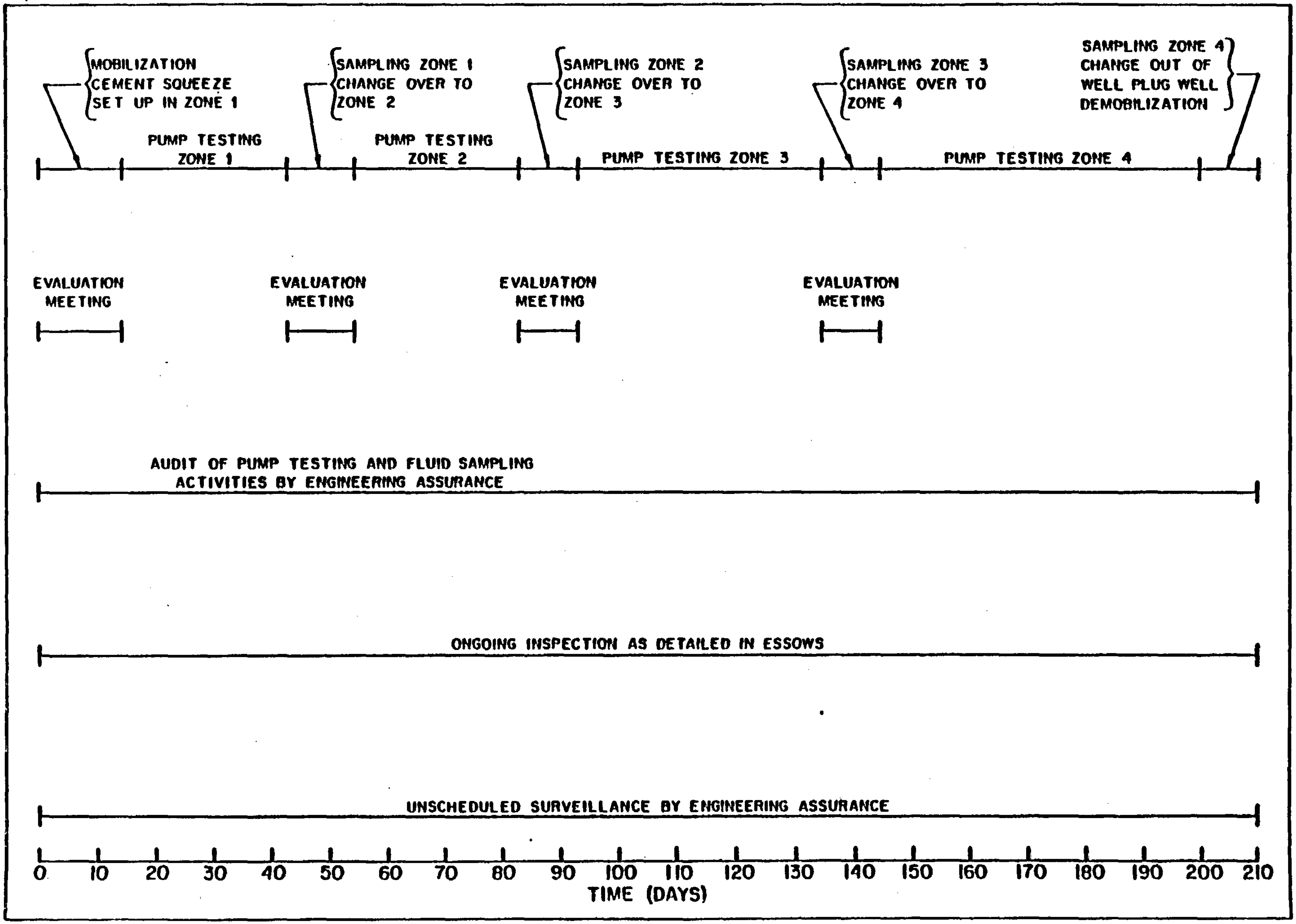
SWEC HYDROGEOLOGISTS PTP-13 - PUMP TESTS AND FLUID SAMPLING

- DETAILED TESTING PROCEDURES
- RECORDING DATA
- DATA DISTRIBUTION

OTHER SWEC, ONWI, & DOE SUBCONTRACTOR TESTING PROGRAMS

AP - 17 PUMP TESTING & FLUID SAMPLING

CONTENTS


MOBILIZATION
CEMENT SQUEEZE
SET UP IN ZONE 1
SAMPLING ZONE 1
CHANGE OVER TO
ZONE 2
SAMPLING ZONE 2
CHANGE OVER TO
ZONE 3
SAMPLING ZONE 3
CHANGE OVER TO
ZONE 4
SAMPLING ZONE 4
CHANGE OUT OF
WELL PLUG WELL
DEMOBILIZATION
PUMP TESTING ZONE 1
PUMP TESTING ZONE 2
PUMP TESTING ZONE 3
PUMP TESTING ZONE 4
EVALUATION MEETING
EVALUATION MEETING
EVALUATION MEETING
EVALUATION MEETING
AUDIT OF PUMP TESTING AND FLUID SAMPLING ACTIVITIES BY ENGINEERING ASSURANCE
ONGOING INSPECTION AS DETAILED IN ESSOWS
UNSCHEDULED SURVEILLANCE BY ENGINEERING ASSURANCE
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210
TIME (DAYS)

ESSOW G103L - PUMP TESTING AND FLUID SAMPLING

CONTENTS

ESSOW G103L - PUMP TESTING AND FLUID SAMPLING

DOCUMENTATION BY CONTRACTOR

Title	Copies	Submit to	6.17
Daily Progress Report including:	1	Purchaser's Field Representative	6.20 6.21
(1) Description of work performed during the day including any incidents			6.24 6.25 6.26 6.27
(2) Water samples obtained, depth, time and number of containers			6.29 6.30 6.31
(3) Break down of charges as outlined in the Contract and a listing of the personnel working on-site			6.44 6.45 6.46 6.47 6.48
Discs copies	1	Purchaser	6.51
Hard copy computer output of data listings and plots of drawdown and recovery data. A minimum of 2 complete sets of data and plots, per day, as required.	1	Purchaser's Field Representative	6.54 6.55 6.56 6.57 6.58 7.1 7.2
Final report describing test results for each zone	10	Purchaser	7.5 7.6
Calibration Reports for the pressure/ temperature transducers flowmeter	1	Purchaser	7.11 7.12 7.13 7.14
Procedure for downhole sampling and transfer of fluids.	1	Purchaser	7.16 7.17 7.18
API Subsurface Pump Classification	1	Purchaser	7.22 7.23

Each document submitted by the Contractor shall be clearly identified with the Purchaser's name, well number, the job title, the job order number, and a descriptive title. 7.33 7.34

STONE & WEBSTER ENGINEERING CORPORATION	T.I.D. REPORT

CLIENT BATTELLE MEMORIAL INSTITUTE	PROJECT ONWI PERMIAN BASIN		J.O. NO. 13697
ESSOW/PO TITLE Pump Testing and Fluid Sampling	NO. G103L	DATE	ADDENDA THRU Revision 2
CONTRACTOR Baker Productions	SUBCONTRACTOR		
WORK LOCATION	REFERENCE DOCUMENTS PTP 13697-13		

TEST, INSPECTION, AND DOCUMENTATION RECORD	*	VERIFIED**	WITNESSED**	PERFORMED**	CERTIFIED*** BY (Signature)	CERTIFIED*** DATE(S)****	DEVIATION AUTHORIZATION TYPE	DEVIATION AUTHORIZATION NUMBER OR NAME	DEVIATION AUTHORIZATION DATE	REMARKS
Equipment and Material	1									
at start		X								
ongoing		X								
Testing Procedures	2									
at start		X								
ongoing		X								
Pump Test Data Records	3									
at start		X								
ongoing		X								
Recovery Test Data Rec.	4									
at start		X								
ongoing		X								
Vertical Test Data Rec.	5									
at start		X								
ongoing		X								
Fluid Sampling	6		X							
Documentation	7			X						

*FOR INSTRUCTIONS, SEE THIS NUMBER IN THE INSPECTION SUBSECTION.
**BY S & W INSPECTOR IF FILLED IN "X"
VERIFIED — PERSONAL OBSERVATION OF DATA APPLICABLE TO THE WORK.
WITNESSED — PERSONAL OBSERVATION WHILE THE MANUFACTURER PERFORMS THE TASK.
PERFORMED — PERSONAL PERFORMANCE OF THE TASK.
***AS IN CONFORMANCE WITH THE SPECIFICATION OR WITH THE DEVIATION AUTHORIZATION INDICATED.
****SPECIFIC DATE(S) OR PERIOD OF INSPECTION, AS APPLICABLE.

TID REVIEWED & CLOSED BY ________________ DATE __________

SHEET ______ OF ______

PTP 13 PUMP TESTING & FLUID SAMPLING

PTP 13697-13-1

CONTENTS

ATTACHMENT 2
PTP 13697-13-2

FLUID SAMPLE LOG
STONE & WEBSTER ENGINEERING CORP.

J.O. NO.	DATE

WELL NAME & NO.	ZONE NO.	FORMATION NAME	SITE REP.	PAGE NO.

SAMPLE NO.	DATE	SAMPLE DEPTH	SAMPLE TEMP. °F*	SAMPLE PRESS. PSI*	DATE SHIPPED	COMMENTS

*RECORDED AT TUBING TRANSDUCER DEPTH ______ FT. BELOW WELL DATUM AT KELLY BUSHING

ATTACHMENT 3
PTP 13697-13-2

FLOW METER RECORD
STONE & WEBSTER ENGINEERING CORP.

WELL NAME AND NO.	SITE REP.	CLIENT ONWI	J.O. No.
		PAGE OF	

DATE	TIME	READING	Δ READING	Δ TIME	Q GAL/MIN	Q BBL/DAY

ATTACHMENT 4 1.10

FLUID SAMPLING REQUIREMENTS 1.12

Sample Type	Sample Volume	Recipient	Sample Disposition	
				1.16
				1.17
Surface, Tracer	0.51	Dr. Glenn Thompson	Box and Ship to	1.19
			Dept. of Hydrology	1.20
			and Water Resources	1.21
			Att. Marc Malcomson	1.22
			A.E. Douglas Bldg.	1.23
			University of	1.24
			Arizona	1.25
			Tuscon, AZ 85721	1.26
Downhole	1 l. or as required by ONWI	Dr. Glenn Thompson	Crate and Ship to	1.40
			Dept. of Hydrology	1.41
			and Water Resources	1.42
			A.E. Douglas Bldg.	1.43
			University of	1.44
			Arizona	1.45
			Tucson, AZ 85721	1.46
Downhole	0.6 l. or as required by ONWI	Dr. Anthony Zaikowski	Crate and Ship to	1.48
			Bendix Field Engrng.	1.49
			2599B 3/4 Road	1.50
			Grand Junction, CO	1.51
Surface	1 gal	Dr. Paul Knauth	Crate and Ship to	1.54
			Dept. of Geology	1.55
			Arizona State	1.56
			University	1.57
			Tempe, AZ 85287	1.58
Surface	1 gal	Dr. Harold Bentley	Crate and Ship to	2.4
			Hydro-Geology Chem.	2.5
			744 North Country	2.6
			Club Road	2.7
			Tucson, AZ 85716	2.8
Surface	1 gal	Dr. Jeffrey Means	Crate and Ship to	2.12
			Battelle Columbus	2.13
			Laboratories	2.14
			505 King Avenue	2.15
			Columbus, OH 43201	2.16

Sample Type	Sample Volume	Recipient	Sample Disposition
Surface	1 gal	Dr. Anthony Zaikowski	Crate and Ship to Bendix Field Engineering 2599 B3/4 Road Grand Junction, CO
Surface	50 gal or as required by ONWI	Dr. J.C. Laul	To be collected and held at the well site or in the Amarillo field ofc. or as otherwise di- rected by ONWI
Downhole	1.01 or as required by ONWI	TBEG	Crate and Ship to University of Texas at Austin Bureau of Economic Geology University Station, Box X Austin, Texas, 78712-7508 Att. Steve Fisher

ATTACHMENT 5
FLUID SAMPLE TRANSMITTAL LETTER

PTP -13 - PUMP TESTING AND FLUID SAMPLING

STONE & WEBSTER ENGINEERING CORPORATION

245 SUMMER STREET. BOSTON. MASSACHUSETTS

ADDRESS ALL CORRESPONDENCE TO P.O. BOX 2325. BOSTON. MASS. 02107
W U TELEX 94-0001
94-0977

BOSTON
NEW YORK
CHERRY HILL. N.J.
DENVER
CHICAGO
HOUSTON
PORTLAND. OREGON
WASHINGTON. D.C.

DESIGN
CONSTRUCTION
REPORTS
EXAMINATIONS
CONSULTING
ENGINEERING

Date

Name and
Address of
Recipient

Please be aware that No., (Size) container(s) of (surface or downhole) formation fluid sampled from the (No.) production zone at (Name) Well No. ___. will be shipped to your office. The production zone was perforated between depths of ______ and _____ feet. This fluid sample was collected on (Date) at (Time). Following receipt of this shipment, please notify:

Mr. T. Annaratone 245/12
STONE & WEBSTER ENGINEERING CORPORATION
P. O. Box 2325
Boston, MA 02107

at you earliest convenience.

Very truly yours,

(SWEC Site Representative)

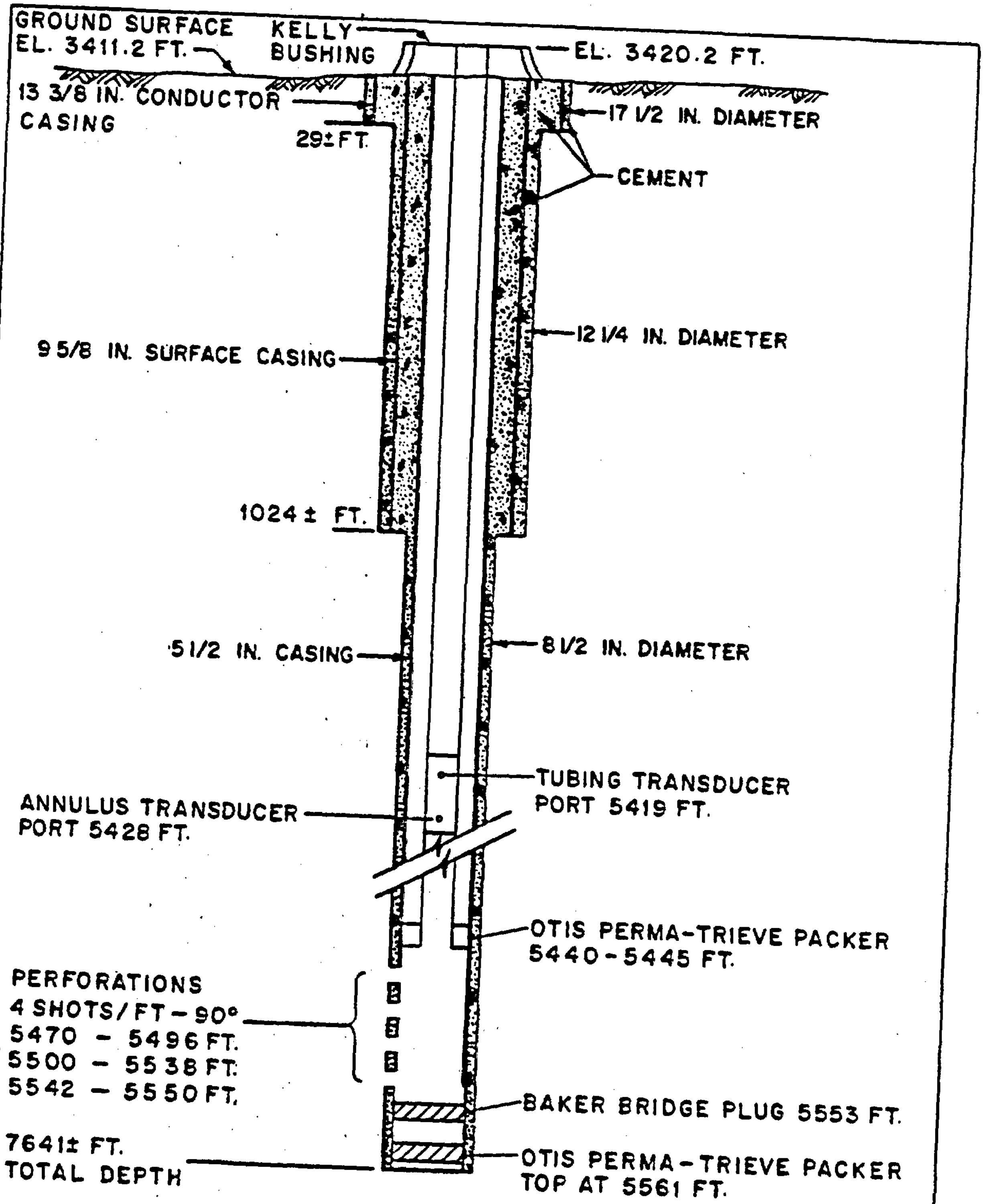
DAILY REPORT FORM
STONE & WEBSTER ENGINEERING CORP.

REPORT NO.	

CLIENT		J.O. NO.	DATE
ONWI-BATTELLE MEMORIAL INSTITUTE		13697	
WELL NAME & NO.	ZONE	FORMATION NAME	SITE REPRESENTATIVE
TEST TYPE	TEST NO.	TEST SAMPLING	

TIME LOG	DETAILS OF OPERATIONS

MEASUREMENTS	N	TIME	DATE	COMMENTS
TEST START				
TEST STOP				
TEST ZONE PRESSURE				
ANNULAR PRESSURE				
TEST ZONE TEMP				
DISCHARGE RATE				
DISCHARGE RATE CHECK				
TOTAL ZONE PRODUCTION				
PUMP STROKE RATE				
TRACER CONCENTRATION				



Explanation:

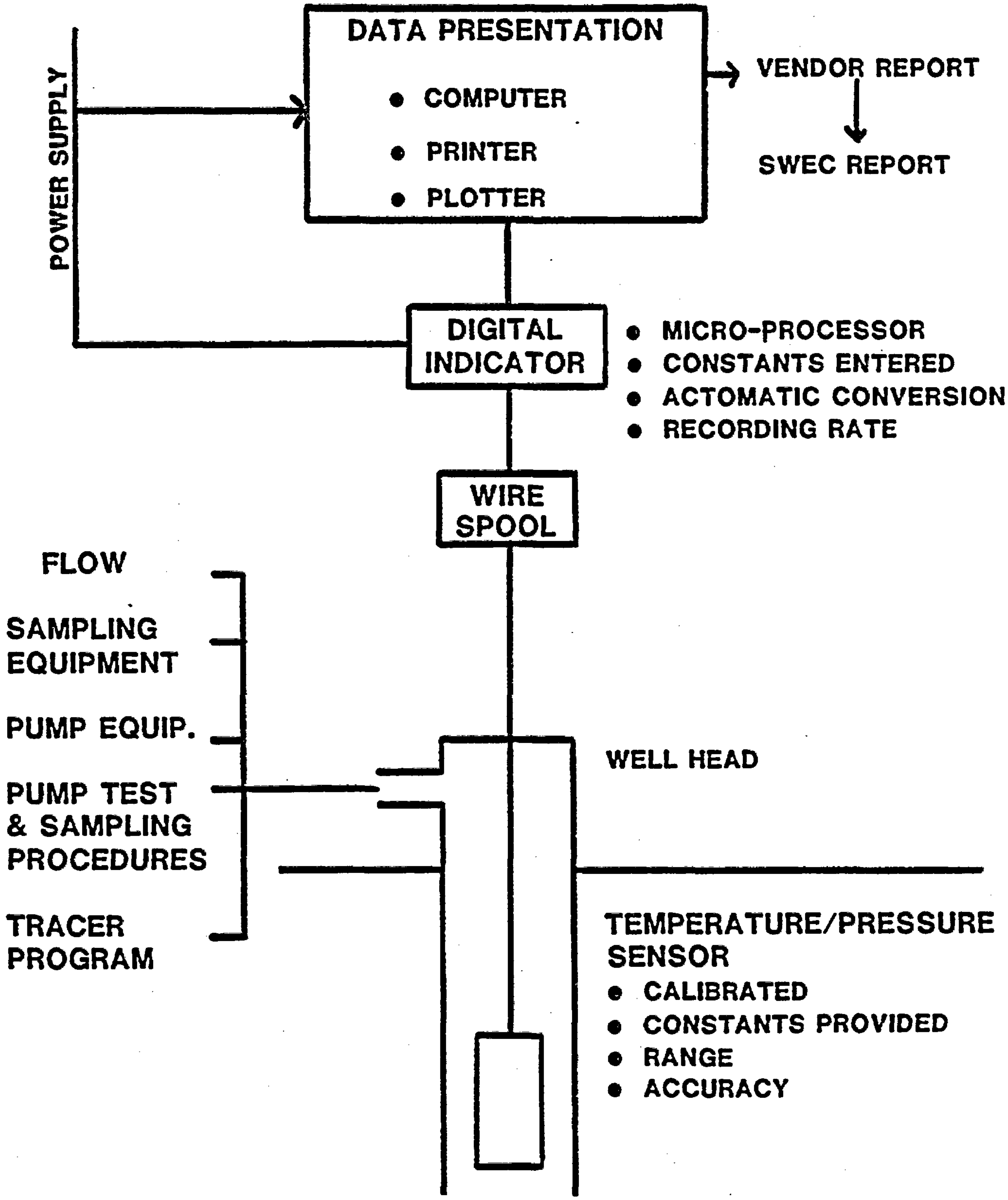
All Depths Measured
From the Kelly Bushing

Not to Scale

As-Built Drawing of
Test Zone No. 3, Upper Permian Wolfcamp
Zeeck No. 1 Well

Figure D-10

PUMP TESTING
INSTRUMENTATION & DATA RECORDING

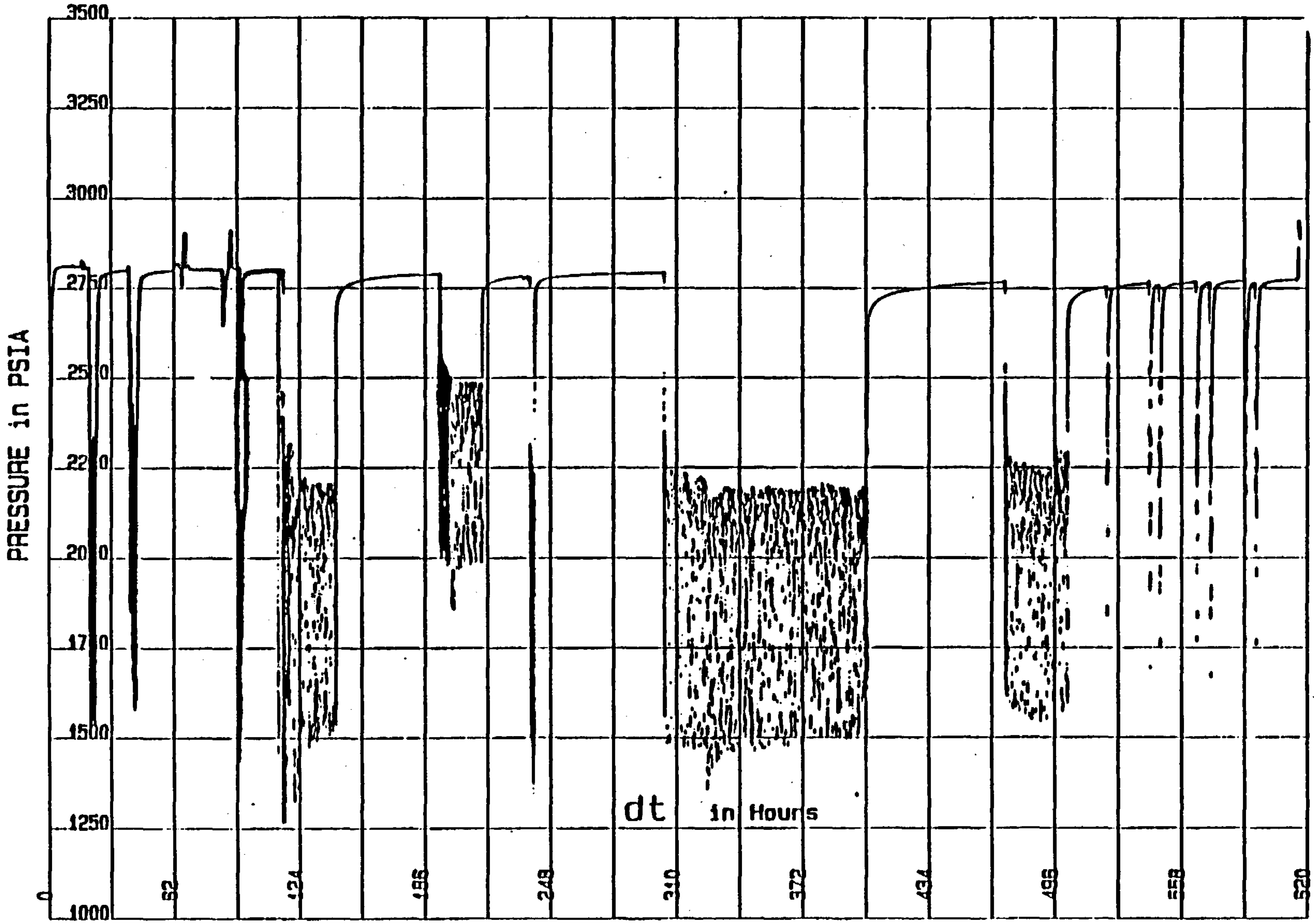


COMPANY: Stone & Webster
by BAKER Engineer: B.H. REAGAN
TEST DATE : 6/26/83 DISC: 404 FILE: 20

WELL: J. Friemel #1
COMMENTS: WILDCAT

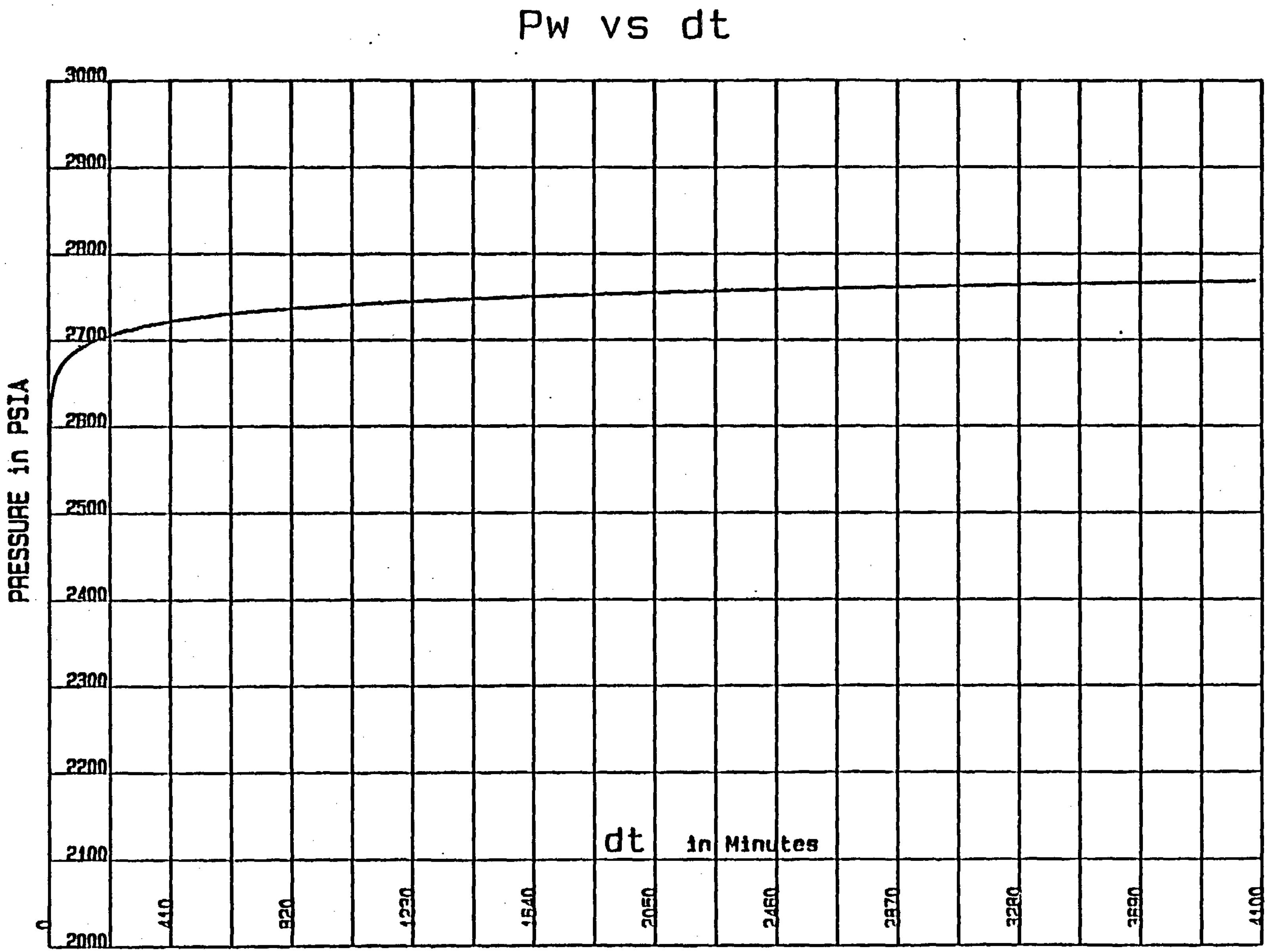
		************* TUBING	*************			************* ANNULUS	*************			
REAL TIME	ELAPSED TIME	PRESSURE psia	dPRESSURE psia	TEMP 'F	dTEMP 'F	PRESSURE psia	dPRESSURE psia	TEMP 'F	dTEMP 'F	R#
18:23:28	47:39:22	2791.12	0.12	130.1	0.0	3064.19	-0.45	129.9	-0.1	1
18:33:28	47:49:22	2791.34	0.22	130.1	0.0	3064.69	0.50	129.9	0.0	2
18:43:27	47:59:21	2791.22	-0.12	130.1	0.0	3064.48	-0.21	130.0	0.1	3
18:53:27	48:09:21	2791.46	0.24	130.1	0.0	3064.60	0.12	130.0	0.0	4
19:03:27	48:19:21	2791.47	0.01	130.1	0.0	3064.24	-0.36	130.0	0.0	5
19:13:27	48:29:21	2791.38	-0.09	130.1	0.0	3064.17	-0.07	130.0	0.0	6
19:23:27	48:39:21	2791.46	0.08	130.1	0.0	3064.26	0.09	129.9	-0.1	7
19:33:27	48:49:21	2791.64	0.18	130.1	0.0	3064.62	0.36	129.9	0.0	8
19:43:27	48:59:21	2791.86	0.22	130.1	0.0	3064.50	-0.12	129.9	0.0	9
19:53:27	49:09:21	2791.85	-0.01	130.1	0.0	3064.41	-0.09	129.9	0.0	10
20:03:27	49:19:21	2791.49	0.44	130.1	0.0	3064.58	0.17	130.0	0.1	11
20:13:27	49:29:21	2791.44	-0.05	130.1	0.0	3063.95	-0.63	129.9	-0.1	12
20:23:27	49:39:21	2791.54	0.10	130.1	0.0	3064.27	0.32	130.0	0.1	13
20:33:27	49:49:21	2791.28	-0.26	130.1	0.0	3064.04	-0.23	130.0	0.0	14
20:43:27	49:59:21	2791.61	0.33	130.1	0.0	3064.25	0.21	129.9	-0.1	15
20:53:27	50:09:21	2791.45	-0.16	130.1	0.0	3064.61	0.36	130.0	0.1	16
21:03:26	50:19:20	2791.71	0.26	130.1	0.0	3064.02	-0.59	129.9	-0.1	17
21:13:26	50:29:20	2792.13	0.42	130.1	0.0	3064.65	0.63	129.9	0.0	18
21:23:26	50:39:20	2791.90	-0.23	130.1	0.0	3064.15	-0.50	129.9	0.0	19
21:33:26	50:49:20	2791.71	-0.19	130.1	0.0	3063.92	-0.23	129.9	0.0	20
21:43:26	50:59:20	2791.91	0.20	130.1	0.0	3063.97	0.05	130.0	0.1	21
21:53:26	51:09:20	2791.90	-0.01	130.1	0.0	3063.64	-0.33	129.9	-0.1	22
22:03:26	51:19:20	2791.70	-0.20	130.1	0.0	3064.22	0.58	129.9	0.0	23
22:13:26	51:29:20	2791.79	0.09	130.1	0.0	3063.72	-0.50	130.0	0.1	24
22:23:26	51:39:20	2791.93	0.14	130.1	0.0	3063.82	0.10	129.9	-0.1	25
22:33:26	51:49:20	2791.64	-0.29	130.1	0.0	3063.97	0.15	129.9	0.0	26
22:43:26	51:59:20	2791.60	-0.04	130.1	0.0	3064.01	0.04	129.9	0.0	27
22:53:26	52:09:20	2791.68	0.08	130.1	0.0	3063.83	-0.18	130.0	0.1	28
23:03:26	52:19:20	2791.93	0.25	130.0	0.1	3063.84	0.01	129.9	-0.1	29
23:13:26	52:29:20	2791.63	-0.30	130.1	0.1	3064.18	0.34	130.0	0.1	30
23:23:26	52:39:20	2792.04	0.41	130.0	0.1	3063.56	-0.62	130.0	0.0	31
23:33:25	52:49:19	2792.25	0.21	130.1	0.1	3063.27	-0.29	129.9	-0.1	32
23:43:25	52:59:19	2792.26	0.01	130.1	0.0	3063.86	0.59	129.9	0.0	33
23:53:25	53:09:19	2791.77	-0.49	130.1	0.0	3063.47	-0.39	130.0	0.1	34
0:03:25	53:19:19	2791.89	0.12	130.1	0.0	3063.31	-0.16	130.0	0.0	35
0:13:25	53:29:19	2792.22	0.33	130.1	0.0	3063.43	0.12	129.9	-0.1	36
0:23:25	53:39:19	2791.83	-0.39	130.0	-0.1	3063.60	0.17	129.9	0.0	37
0:33:25	53:49:19	2791.69	-0.14	130.1	0.1	3063.63	0.03	129.9	0.0	38
0:43:25	53:59:19	2792.04	0.35	130.1	0.0	3063.23	-0.40	129.9	0.0	39
0:53:25	54:09:19	2792.09	0.05	130.1	0.0	3063.44	0.21	129.9	0.0	40
1:03:25	54:19:19	2792.35	0.26	130.1	0.0	3063.54	0.10	129.7	0.0	41
1:13:25	54:29:19	2792.20	-0.15	130.1	0.0	3063.31	-0.23	129.9	0.0	42
1:23:25	54:39:19	2792.05	-0.15	130.1	0.0	3063.32	0.01	129.9	0.0	43
1:33:25	54:49:19	2792.19	0.14	130.1	0.0	3063.30	-0.02	129.9	0.0	44
1:43:25	54:59:19	2791.73	-0.46	130.1	0.0	3063.84	0.54	129.9	0.0	45
1:53:24	55:09:18	2792.16	0.43	130.0	-0.1	3063.54	-0.30	129.9	0.0	46
2:03:24	55:19:18	2792.23	0.07	130.0	0.0	3063.06	-0.48	130.0	0.1	47
2:13:24	55:29:18	2792.20	-0.03	130.1	0.1	3063.54	0.48	130.0	0.0	48
2:23:24	55:39:18	2792.33	0.13	130.1	0.0	3063.24	-0.30	129.9	-0.1	49
2:33:24	55:49:18	2792.22	-0.11	130.1	0.0	3063.09	-0.15	129.9	0.0	50
2:43:24	55:59:18	2792.68	0.46	130.1	0.0	3062.93	-0.16	129.7	0.0	51
2:53:24	56:09:18	2792.38	-0.30	130.1	0.0	3063.16	0.23	129.9	0.0	52

Pw vs dt



BAKER Production Services - 4105 Hwy. 521, Fresno, Tx., 77545, (713) 431-2514

COMPANY: Stone & Webster WELL: J. Friemel #1 PLOT INTERVAL:
by BAKER Engineer: B.H. REAGAN START: 6 / 14 / 83 - 18 : 42 : 10
PROGRAM SERIAL NUMBER: TXP80083CU343F1 STOP : 7 / 10 / 83 - 10 : 54 : 48
GAUGE SERIAL NUMBER: 3.1077
COMMENTS: HISTORY - ZONE #1 ZONE #1 8188-8204'



BAKER Production Services - 4185 Hwy. 521, Fresno, Tx., 77545, (713) 431-2514

COMPANY: Stone & Webster WELL: J. Friemel #1 PLOT INTERVAL:
by BAKER Engineer: B.H. REAGAN START: 7 / 1 / 83 - 14 : 15 : 52
PROGRAM SERIAL NUMBER: TXP80883CU343F1 STOP : 7 / 4 / 83 - 10 : 13 : 4
GAUGE SERIAL NUMBER: 3.1077
COMMENTS: SHUT-IN RECOVERY #4 ZONE #1 8188-8204'

BAKER PRESSURE TESTING SYSTEM

FLUID SAMPLING AND TRACER PROGRAM

AP - 17 J. FRIEMEL WELL - PUMP TESTING & FLUID SAMPLING

- SCOPE
- OBJECTIVES
- GENERAL PROCEDURES
- PARTICIPANTS

PTP - 13 PUMPING TEST AND FLUID SAMPLING

- SEQUENCE
- FREQUENCY
- TRACER LIMITS
- DISTRIBUTION
- SAMPLE SIZE
- SHIPMENT

(SWEC SUBCONTRACTORS)

ESSOW-G103L
PUMPING CONTRACTOR

- FORMATION FLUID SAMPLING EQUIP.
- PROCEDURES FOR SAMPLING
- PERFORMS SAMPLING
- INSPECTION
- DOCUMENTATION

ESSOW G103D
MUD ENGINEER DURING DRILLING OPERATIONS ONLY

- TAKES SAMPLE
- PERFORMS TRACER CONCENTRATION TESTS ACCORDING TO PROCEDURES IN ESSOW G112D

ESSOW G112D
TRACER AND GAS ANALYSIS

- DETAILED FIELD & LAB TEST PROCEDURES
- TRACER LIMITS
- TEST EQUIP.
- CALIBRATION
- DOCUMENTATION

FORM 4F

LOG OF SAMPLES AND FIELD MEASUREMENTS OF TRACER CONCENTRATIONS IN DRILLING FLUID - J. FRIEMAL #1

Site	Depth	Collection Date	Type of Sample	Concen-tration	Comments	Performed By

**This form can be applied to other future wells which require a tracer metering system as approved by Glenn Thompson

Log reviewed by Program Director