Oklahoma
Geological
Survey
1982

Special Publication 82-5

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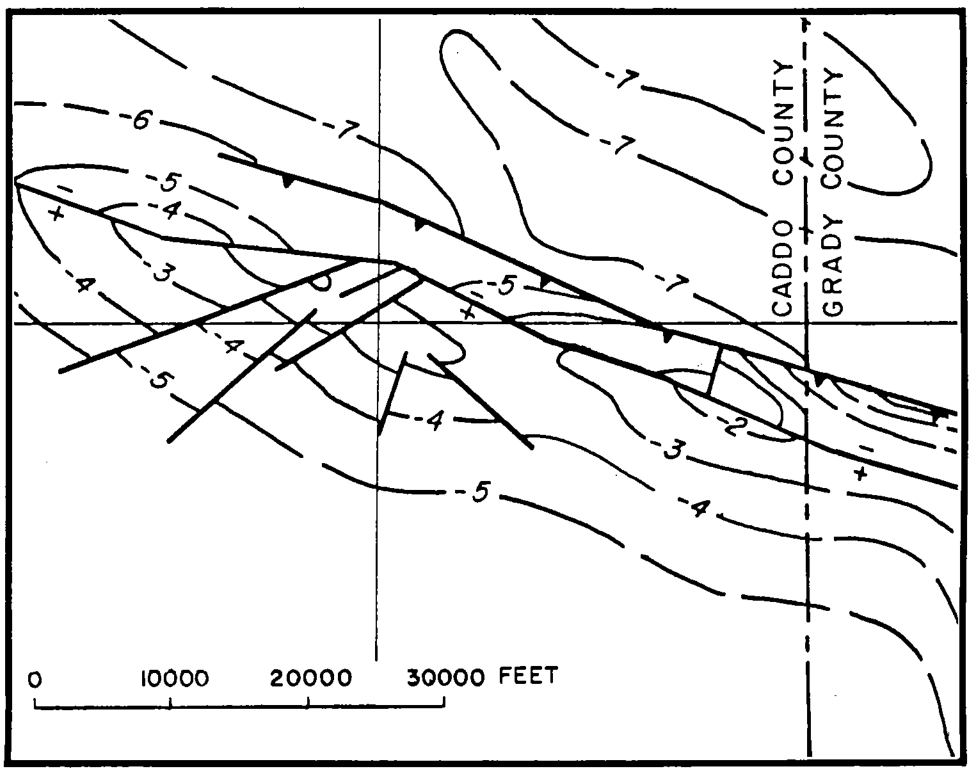

Special Publication 82-5
ISSN 9275-0929

AN EVALUATION OF WATER RESOURCES FOR ENHANCED OIL-RECOVERY OPERATIONS CEMENT FIELD, CADDO AND GRADY COUNTIES, OKLAHOMA

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April 1981

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Prepared for
Bartlesville Energy Technology Center
U.S. Department of Energy
Under Contract No. DE-AC19-79BC10115

Published in 1982 by
Oklahoma Geological Survey
Charles J. Mankin, Director

Special Publication Series

The Oklahoma Geological Survey's Special Publication series is designed to bring new geologic information to the public in a manner efficient in both time and cost. The material undergoes a minimum of editing and is published for the most part as a final, author-prepared report.

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[1] The plates are included in the envelope at the back of this publication.

INTRODUCTION

This report is based on the results of an investigation of the water resources local to the Cement Oil Field in Caddo and Grady Counties, southwestern Oklahoma (fig. 1).

The intent of the report is to present at least a semi-quantitative estimate of the volume, deliverability, and chemistry of the water potentially available for enhanced oil recovery in one or more Oklahoma oil fields. Subsequent to a review of several oil fields, the Cement Field was chosen for study because of its large size (25,000 acres), its extensive subsurface control (over 1,850 wells), and its long history of production (since 1952) from several producing formations, some of which are already undergoing extensive waterflood operations.

A preliminary review of the available data for this study suggested a threefold categorization of water resources, since the data for each category are distinctly different in nature, and, to some extent, different in source. The three categories are arbitrarily defined as follows.

Surface Water This category includes both streams and surface impoundments within a 25-mile radius from the field. The principal data sources for the surface-water inventory are the hydrologic atlases, the water-resource studies, and the U.S. Geological Survey water-data files that encompass the area of interest. Streamflow measurements, estimated volumes of impounded waters, and chemical analyses of the surface waters have been extracted from these data sources.

Ground Water Ground water is here defined as the water resident in shallow aquifers, those generally penetrated by water wells and amenable to geometric resolution from water well and surface geological data. The chemistry, deliverability, and volume of ground water local to the Cement Field have been estimated from essentially the same data sources that were used for surface water.

Subsurface Water This category is defined as water in reservoirs that are below the usual depth range of water wells where the required data source is mainly from well logs, published subsurface field studies, and oil company records. Correlation and petrophysical analyses of the well logs have afforded, for the most part, the estimates of volume, deliverability, and chemistry of the subsurface water in the field, although some actual measurements of porosity, permeability, and chemical components in the water have been obtained from reports and company records.

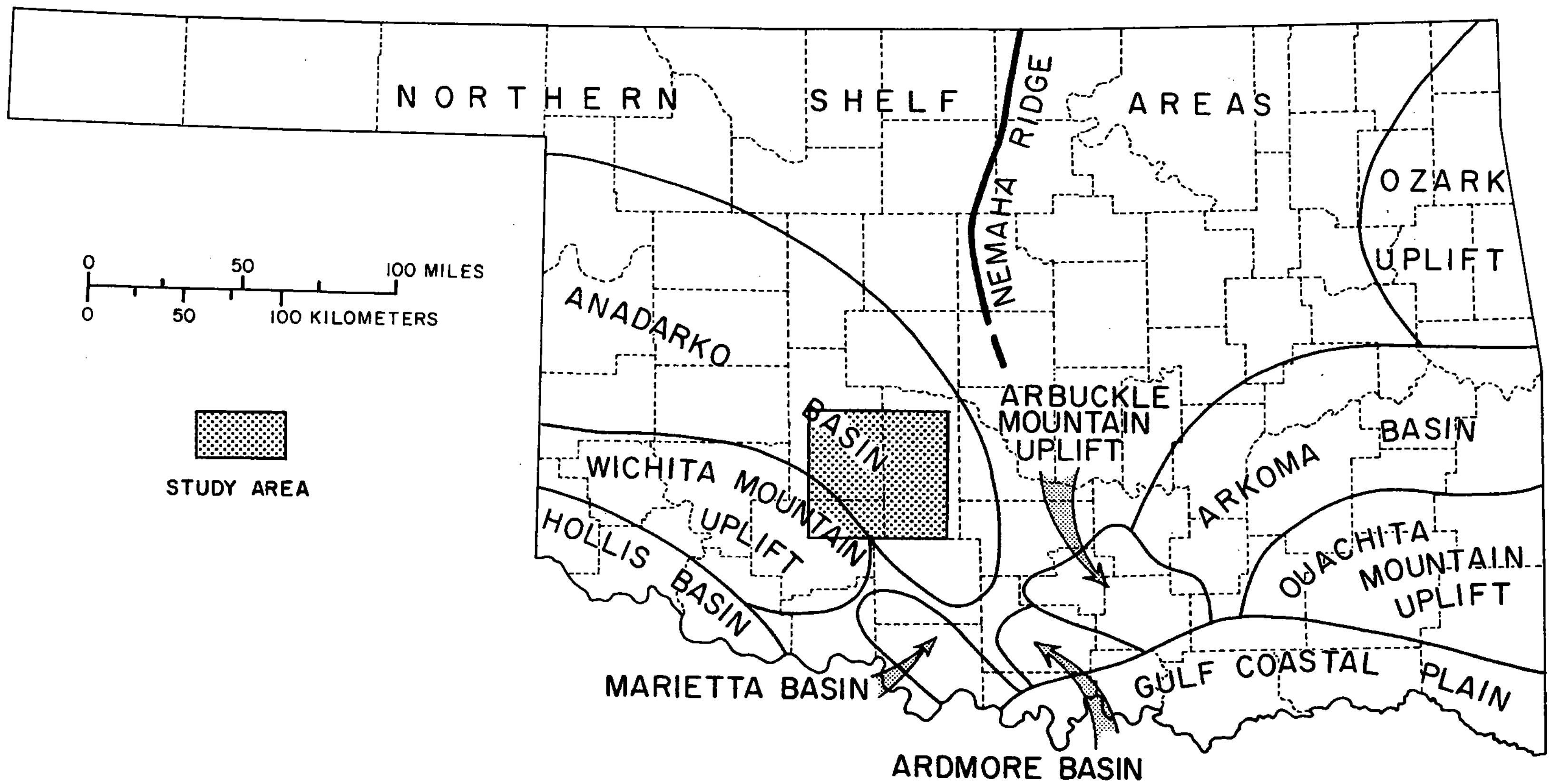

Figure 1. Index map of Cement area.

SUMMARY OF RESULTS

Surface Water The total storage capacity of impounded water in the reservoirs, lakes, and ponds that lie within the area of study surrounding the Cement Field is 362,000 acre-feet or approximately 2.8 billion barrels. Of this total, 338,500 acre-feet, or 93.5 percent of this capacity, is contained in just four reservoirs: Fort Cobb, Ellsworth, Lawtonka, and Spring Creek (table 1-1). The total dissolved solids in the waters impounded in the four reservoirs range from 245 mg/L to 1,948 mg/L, averaging 330 mg/L.

The principal recharging agent for the impounded water is runoff. In the area of investigation the runoff is about 12 percent of the precipitation which averages about 32 inches per year. The runoff is fed to the reservoirs by tributary streams of the Washita River.

The Washita River flows through the area with no impoundments, owing to the poor quality of its water with respect to its use for domestic or irrigational purposes. The flow of the Washita varies markedly with the season from about 5.4 cubic feet per second (cfs) or 83,000 barrels per day during the dry season to about 380 cfs (5,852,000 bpd) during the wet season. Total dissolved solids carried in the river water vary from 1,700 mg/L to 150 mg/L respectively. The quantity and quality of water in the tributary creeks reflect the same seasonal behavior, although with a greater variability in range.

Ground Water Ground water aquifers included in this report are only those that yield 25 gallons per minute (gpm) or more. The four major aquifers are the Rush Springs Sandstone, the El Reno Group, the Arbuckle-Timbered Hills (Cambrian-Ordovician), and the Quaternary deposits (fig. 2). The aquifers yield from 60 to 150 gpm from the Quaternary to an average of 500 gpm from parts of the Rush Springs, the principal aquifer in the area. Eliminating consideration of water containing above 5,000 mg/L total dissolved solids, the volume of water producible from all aquifers is estimated at approximately 131 billion barrels. The estimate is based on an average porosity of 10 percent and a recoverability of 35 percent, assuming no recharge of the aquifers. The amount of water in place totals about 373 billion barrels.

Subsurface Water The amount of subsurface water accessible from the formations penetrated by wells drilled within the Cement Field is estimated to be approximately 41-1/3 billion barrels; 16½ billion from the Permian reservoirs, 25 billion from the pre-Permian reservoirs. This total is the water in place; the amount producible depends principally on the withdrawal and recharge rates. Because of the erratic well penetration and discontinuity of many of the pre-Permian reservoirs, individual estimates were made for the water volumes in four of the pre-Permian reservoirs that are penetrated almost everywhere and that have good lateral persistence. The water

SYSTEM	SERIES	GROUP	FORMATION	MEMBER
PERMIAN	CUSTERIAN		CLOUD CHIEF	CYRIL GYPSUM
		WHITEHORSE	RUSH SPRINGS	
			MARLOW	
	GUADALUPIAN	EL RENO	CHICKASHA	
			DUNCAN	
	LEONARDIAN	CLEARFORK	HENNESSEY	
			GARBER	FORTUNA SANDSTONE
			WICHITA	NOBLE OLSON SANDSTONE
	WOLFCAMPIAN		PONTOTOC	
PENNSYLVANIAN	VIRGILIAN	CISCO	THRIFTY	
			GRAHAM	UPPER GREGORY LIMESTONE
				GARNER SANDSTONE
				LOWER GREGORY LIMESTONE
				GRIFFIN SANDSTONE
				ROWE LIMESTONE
				ROWE SANDSTONE
				NILES LIMESTONE
				NILES SANDSTONE
				UPPER OOLITIC LIMESTONE
				YULE SANDSTONE
	MISSOURIAN		HOXBAR	UNNAMED
				WADE SANDSTONE
				DAUBE
				ADAMS BRANCH
				MEDRANO LIMESTONE
				MEDRANO CONGLOMERATE
				UNNAMED
				MARCHAND SANDSTONE
	DESMOINESIAN		WEST ARM	CULP-MELTON
			DEESE	
	ATOKAN	"ATOKA"	LAKE MURRAY	
	MORROWAN	"MORROW"	GOLF COURSE	
MISS.	CHESTERIAN		SPRINGER	
			GODDARD	

Figure 2. Upper Paleozoic stratigraphic chart for Cement Field.

volumes accessible in the four reservoirs are: Rowe sand, 3.3 billion barrels; Niles sand, 2.7 billion barrels; Wade sand, 1.5 billion barrels; Marchand sand, 2.4 billion barrels (see fig. 2).

Since deliverability is dependent on project-specified factors, this report provides only a nomograph from which initial open-flow potentials can be estimated after a set of producing parameters is given. As an example, however, a 2-square-mile area of the field (secs. 9 and 10, T. 5 N., R. 9 W.) has a calculated initial open-flow of water from the pre-Permian reservoirs of 710,000 to 1,410,000 barrels per day.

The chemistry of subsurface formation waters is, predictably, highly variable within the Cement Field. The total dissolved solids carried by the original formation water range from 17,000 mg/L to 200,000 mg/L, whereas the actual analyses of existing make-up water in the reservoirs undergoing waterflood operations show a variation between 96,000 mg/L and 217,000 mg/L.

GEOLOGIC SETTING

Structure

Permian The Cement Oil Field is on the northwesterly trending Cement Anticline, which is expressed at the surface by exposures of the Rush Springs Formation (Permian). The structure has an area of closure about 11 miles long and 2 miles wide. At the surface the anticline is gently folded with closure of about 60 feet over most of the structure. Two separate domes along the crest locally increase the surface structural relief up to 200 feet. The structural configuration is also clearly reflected by the topographic surface. Intensity of folding in the Permian strata gradually increases with depth until the relief at the Pennsylvanian-Permian unconformity reaches as much as 500 feet. No significant faulting has been identified within the gently folded Permian section even though considerable subsurface information is afforded by the intensive drilling within the strata.

Pre-Permian Pennsylvanian strata below the unconformity are sharply folded into a strongly asymmetric structure, the northeast flank dipping more steeply than the other (fig. 3). The folding is complicated by major faulting more or less parallel to and north of the fold axis. One major fault, a south-dipping reverse fault, is probably responsible for the asymmetry of the structure. The anticline extends at depth to at least that part of the Mississippian strata that has been drilled densely enough to resolve a structural configuration (fig. 4).

Considerable thinning of the Pennsylvanian beds over the crest of the anticline, and an obvious influence by the major faulting on deposition, imply active tectonism during Pennsylvanian deposition, a tectonism sharply subdued during and after the Permian as manifested by the mild deformation

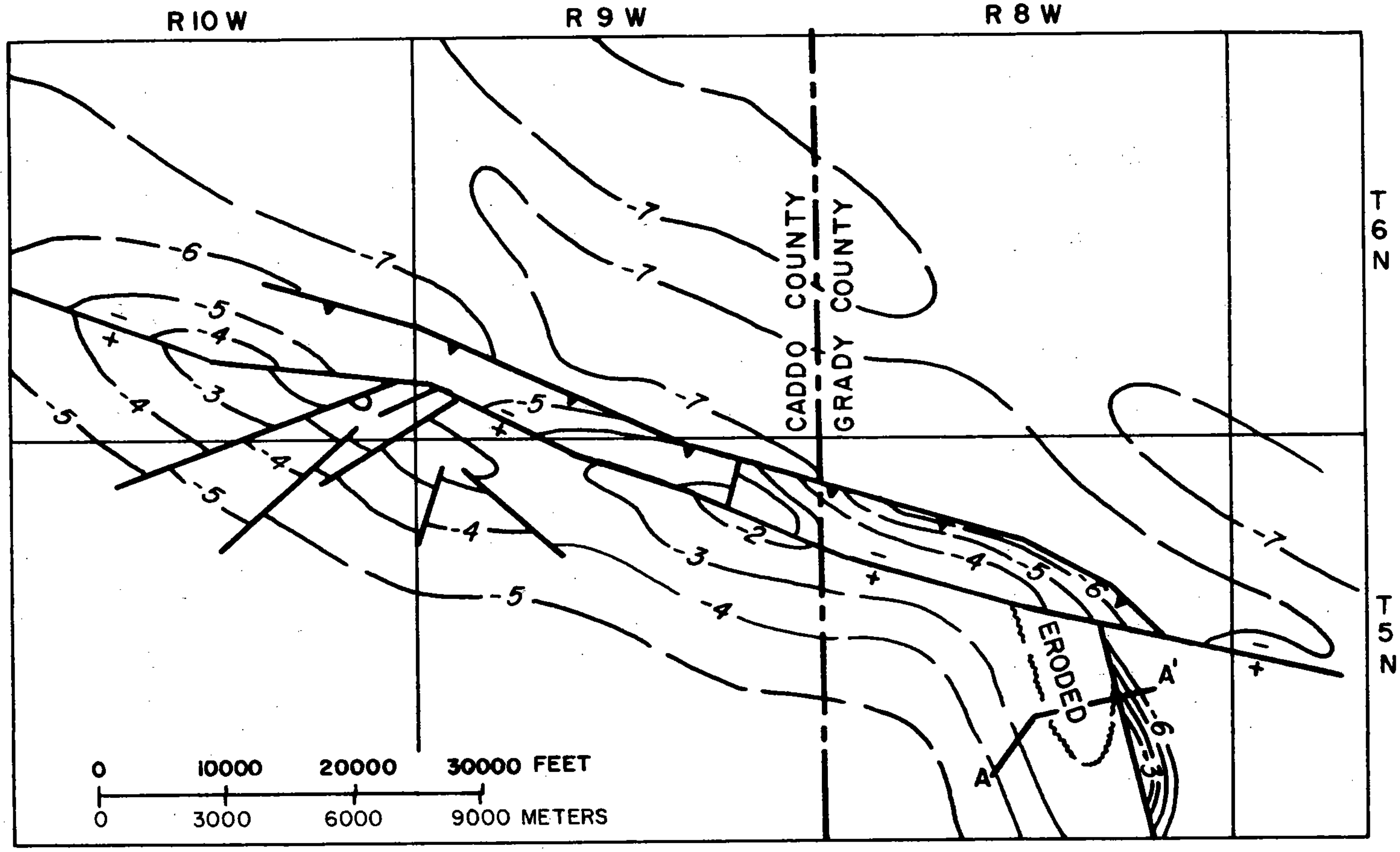

Figure 3. Map of Cement Field showing structure of top of Hoxbar Formation. Structure contours shown in thousands of feet; contour interval, 1,000 feet. After Herrmann (1961, figure 9).

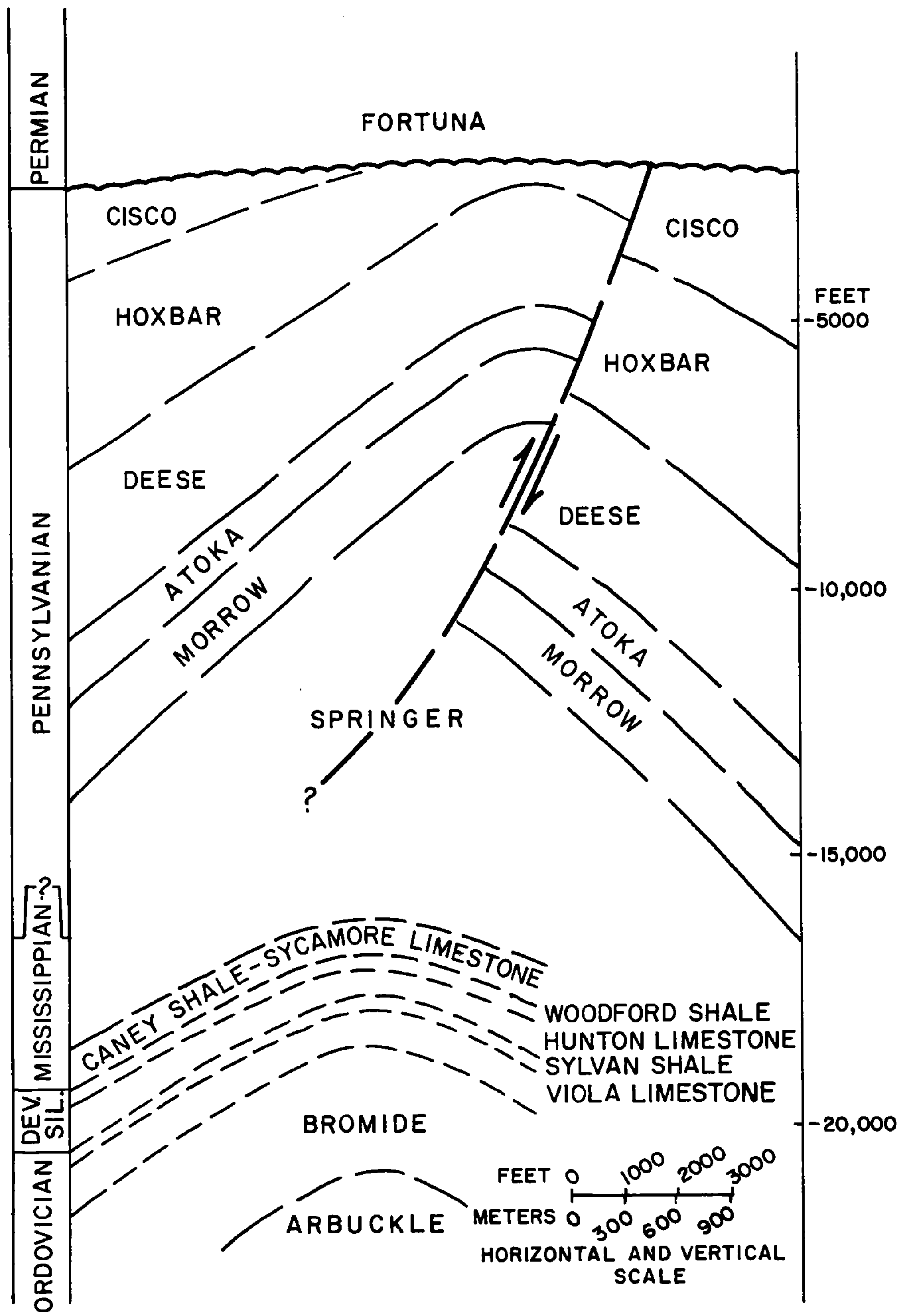

Figure 4. Cross section A-A' through Cement Field. After Herrmann (1961, figure 6).

and minor thinning of the Permian strata over the structure. There has been little deeper drilling at Cement since a detailed structural study of the field was done by Herrmann in 1961. Thus, there is little additional subsurface information with which to further resolve the configuration of the Cement Anticline. Therefore, Herrmann's report has provided the structural framework that has been used for this study. Readers with a further interest in the structural aspects of the Cement Field are referred to his paper.

Stratigraphy

Permian Although the Rush Springs Sandstone is the shallowest aquifer in the Cement Field, essentially all wells in the field are surface cased into the underlying Marlow Shale (Custerian). The Marlow Shale is principally a fluviatile red-shale sequence with scattered stringers of sand and carbonate and contains few reservoir beds. It is underlain by the El Reno Group, composed of the Chickasha Formation and the Duncan Sandstone (fig. 2).

The Chickasha is a maroon mudstone and shale with a few erratically distributed interlayers of fine-grained sands. The formation varies from 200 to 300 feet in thickness. The base of the Chickasha rests on the Duncan Sandstone, which varies from 300 to 400 feet in thickness. The Duncan is characteristically a very fine- to medium-fine-grained dolomitic and gypsiferous sand, and should serve as a significant potential water source in the Permian.

Disconformably underlying the Duncan Sandstone is the Leonardian Hennessey Formation. The Hennessey ranges from 1,600 to 2,000 feet in thickness and consists mostly of dark maroon shale. Gypsiferous siltstones and fibrous gypsum beds make up a 250-foot unit near the top of the formation. The Fortuna Sandstone (Garber equivalent), at the base of this sequence, provides the shallowest production in the field and may afford a good water resource. The Wichita Group, about 700 to 1,000 feet of dark-gray to brown fissile shale, is the oldest Leonardian unit in the Cement Field. The Noble Olson sandstone, a fine-grained sand 50 to 100 feet above the base of the Wichita, is a prolific oil-producing unit in the field.

The Wolfcampian is represented in the Cement Field by a highly heterogeneous sedimentary unit, the Pontotoc Formation, that consists mainly of fragmental limestone conglomerate, with subordinate amounts of maroon shale, arkosic gray shale, and coarse-grained sandstones. The beds within the Pontotoc exhibit a marked variability both laterally and vertically. The formation lies unconformably on truncated beds of the Pennsylvanian Cisco and Hoxbar Groups in a distinct overlap relationship.

The Permian-age reservoirs in the Cement Field are generally sandstones that were deposited in a fluviatile environment. As a consequence the individual sands are erratically distributed and discontinuous; subsurface correlation of the sands over any distance is impossible, often even between wells no more than one-quarter mile apart. The areal drainage efficiency of reservoir fluids within the Permian is undoubtedly impaired. Therefore, in determining the volume of available water from the Permian we have arbitrarily restricted water drainage from these reservoirs to within one-fourth of a mile from the borehole.

Pre-Permian The youngest beds below the pre-Permian unconformity are in the Pennsylvanian (Virgilian) Cisco Group. From south to north the Cisco beds are successively truncated by erosion and have been completely removed along much of the culmination of the Cement anticlinal structure. A down-to-the-north normal fault, which parallels the axis of the structure and lies slightly to the north of the axis, has enough stratigraphic throw to have preserved the entire Cisco section north of the fault.

In the down-flank wells, where the Cisco is complete, the upper section comprises the Thrifty Formation, a unit characterized by a dominance of dark-maroon shales. Thin sandstone beds and nodular limestone beds are common. The maximum thickness is 300 feet.

The Graham Formation makes up the lower part of the Cisco Group and is characterized by its lack of variability. The several members of this formation, shown on the stratigraphic chart (fig. 2), are laterally persistent regionally and exhibit uniformity of lithology. The limestone members are generally very fine grained to cryptocrystalline and contain abundant fusulinids. Except where they are oolitic they do not constitute major reservoirs. The sandy members, on the other hand--the Garner, the Rowe, the Niles, and the Yule--are fair to excellent reservoirs, affording a good water-production potential. Two of these, the Niles and the Rowe, were treated individually in our study of pre-Permian water resources in order to provide a clearer understanding of the characteristics of single reservoirs, particularly as to their lateral persistence and uniformity. The sands are fine to medium grained in texture.

The Hoxbar Group underlies the Cisco strata. The members in the Hoxbar, unlike those in the Cisco, reflect active tectonism exhibiting considerable intertonguing and abrupt lateral facies changes that range from carbonates to shales, sands, or coarse conglomerates. These changes may be so abrupt as to make correlation between even contiguous wells impossible, especially since well penetration is erratic at these depths. This is the principal reason for the decision to consider the accessibility of pre-Permian water on the basis of well penetration rather than to attempt to delineate the lateral boundaries of every potential reservoir.

Two of the most persistent reservoirs in the Hoxbar Group are the Wade sand and the Marchand sand and conglomerate. The Wade is commonly fine to medium grained and calcareous with isolated stringers of sandy and oolitic limestone. The Marchand is a prolific producer of oil in parts of the Cement Field and varies from fine- to medium-grained sand to cherty conglomerates. The thickness of both the sand and conglomerate facies varies considerably across the Cement structure. These two members of the Hoxbar have also been treated individually in this study.

Many other sandstone and limestone reservoirs occur stratigraphically deeper through the lower Pennsylvanian well into the Mississippian rocks. The deepest penetration in the field is into the Viola Formation (Ordovician). However, because of the increasingly rare penetration with depth, any reservoirs within these deeper strata are considered to be potential contributors to the total available water only from within an arbitrary drainage area of one-quarter mile from where they have been penetrated. Accordingly, no attempt was made to correlate these reservoirs throughout the field, and their arbitrarily limited contributions are combined into the total available water from the pre-Permian rocks.

PART I: SURFACE AND GROUND WATER

Most techniques currently used for enhanced-oil-recovery (EOR) operations require water with low concentrations of calcium and magnesium and a total dissolved-solids content of less than 5,000 mg/L. As much as one pore volume of water may be needed to sustain an enhanced-oil-recovery operation. Thus, when an oil field becomes a candidate for enhanced oil recovery, an appraisal of the fresh-water resources should be conducted in order to determine the potential for an adequate supply. Fortunately, there is considerable information on the water resources of Oklahoma. Much of this information is contained in publications issued by the Oklahoma Water Resources Board, Oklahoma Geological Survey, and U.S. Geological Survey.

The area within an arbitrarily chosen 25-mile radius of the center of the Cement Field was selected for a detailed study of the surface- and ground-water resources. The area extends from T. 3 N. to T. 9 N. and from R. 6 W. to R. 12 W., or approximately 1,750 square miles (pl. 1, fig. A). No cost estimates were made on delivery systems, so it may be that an economically feasible transportation distance away from the field may be more than or less than 25 miles.

Regional Surface Geology

The surface rocks of the Cement area consist mainly of Permian red beds of the Anadarko Basin, with dips of less than 90 feet per mile toward the axis of the basin (pl. 1, fig. C). A part of the Wichita Mountains is included in the southwest part of the area, where Cambrian igneous rocks are exposed.

The oldest rocks exposed in this area are those in the Wichita Mountains. They consist of rhyolite flows, tuffs, conglomerate beds, and granites of various textures. These rocks are unconformably overlain by the Timbered Hills Group (Cambrian), which consists of several hundred feet of intercalated beds of sandstone and limestone. The Arbuckle Group (Cambrian and Ordovician), mostly limestone, dolomite, and sandstone, overlies the Timbered Hills Group. These sedimentary units are exposed in the study area only on the north flank of the Wichita Mountains where the units have been uplifted and erosion has removed much of the overlying strata. The erosional debris from the Wichita Mountains forms limestone conglomerate beds near limestone outcrops and arkosic gravel near igneous outcrops in the vicinity of the Wichita Mountains. These rock types, which are interbedded with sand, silt, clay, and shale, are as much as 500 feet thick at the surface and thicken toward the Anadarko Basin, where they are as much as 10,000 feet thick in the subsurface.

North of the Wichita Mountains are nearly flat-lying Permian beds that are mapped as the El Reno and Whitehorse Groups. Exposures of the El Reno Group, which is composed of the Chickasha Formation, Duncan Sandstone, Flowerpot Shale, Blaine Formation, and Dog Creek Shale, occur in both the southwest and northwest regions of the study area (pl. 1, fig. C). The Chickasha Formation and Duncan Sandstone are exposed on the eastern side of the study area. These formations grade northward and westward into fine-grained clastics and evaporite beds of gypsum and dolomite that belong to the Flowerpot Shale, Blaine Formation, and Dog Creek Shale (pl. 1, fig. C).

The overlying Whitehorse Group is mainly orange-brown, fine- to medium-grained, moderately indurated sandstone. The Marlow and Rush Springs Formations are the principal units that compose the Whitehorse Group. These units form an outcrop pattern approximately 18 miles wide extending northwest-southeast across the central part of the study area. The Marlow Formation is an even-bedded, orange-brown, fine-grained sandstone about 100 feet thick, containing much gypsum cement. A few thin gypsum or dolomite beds occur near the top. Above the Marlow Formation is the Rush Springs Formation, which is composed of about 300 feet of fine-grained, orange-brown, cross-bedded sandstone. Both of these formations are important fresh-water aquifers in west-central Oklahoma.

The Cloud Chief Formation overlies the Whitehorse Group. This formation is principally a reddish-brown to orange-brown shale, interbedded with siltstone and sandstone in the middle part and some dolomite and gypsum in the lower part. The basal Moccasin Creek Gypsum Member of the Cloud Chief Formation, about 30 feet thick, is also represented in this area. Limited and isolated exposures of this formation occur in the central and northwest parts of the study area.

Pleistocene deposits are represented by 50 to 100 feet of gravel, sand, silt, and clay, which occur as terraces adjacent to the Washita River and surrounding regions. Alluvium, present only within the stream channels, was deposited as lenticular beds of intercalated sand, silt, clay, and gravel. Deposits are as thick as 120 feet but probably average about 25 feet along major streams. Along minor streams, thickness ranges from a few to about 50 feet but also averages only about 25 feet. Ground water is locally withdrawn from alluvium and terrace deposits for domestic use.

Principal references for the surface geologic information include Davis (1955), Fay (1968a), Fay (1968b), Fay (1969), Hart (1974), Bingham and Moore (1975), Carr and Bergman (1976), and Havens (1977).

Surface Water

Mean annual precipitation in the study area ranges from about 28 inches in the northwest to about 33 inches in the southeast (fig. 5). The wettest period generally occurs during May and June, whereas the driest generally coincides with the late fall and winter months.

Most precipitation is utilized by vegetation or is lost by evaporation. Any excess, which becomes runoff, is stored temporarily in local farm ponds and reservoirs. Storm intensity and frequency influence the amount of runoff from a given storm. Average annual runoff in the Cement area ranges from about 1.5 inches per year in the northwest to about 4 inches per year in the southeast (fig. 6). This represents only 12 percent or less of the average annual rainfall for the Cement area.

Some of the precipitation percolates downward to recharge the various ground-water aquifers in the Cement area. The amount of this recharge varies with the composition of the rocks. Recharge to alluvium and terrace deposits may be as much as 12 percent of annual precipitation, whereas recharge amounts are only 6 percent of annual precipitation, or about 1.8 inches, for formations that belong to the El Reno Group (Barclay and Burton, 1953; Steele and Barclay, 1965). Tanaka and Davis (1963) estimated recharge to the Rush Springs Sandstone to be about 10 percent of annual precipitation. The Arbuckle-Timbered Hills aquifer, primarily limestone, probably recharges at a rate that utilizes less than 1 percent of mean annual precipitation (Havens, 1977).

More detailed information is included in the following references: Oklahoma Water Resources Board Publications 19, 23, and 24; Hart (1974); Bingham and Moore (1975); Carr and Bergman (1976); and Havens (1977).

Estimate of Volume Surface storage has been developed in the Cement area because of the limited availability of potable ground water, the high variability of stream flow, and the lack of sustained flow in streams. There are approximately 145 lakes and ponds in the Cement area (Oklahoma Water Resources Board, 1976 Oklahoma Water Atlas). The distribution of surface storage impoundments is shown in plate 1, figure B, and the tabulated data arranged by surface area are shown in table 1-1.

Nine bodies of water in the Cement area have in excess of 100 surface acres (table 1-1). Three major reservoirs, Fort Cobb, Ellsworth, and Lawtonka, which have a combined storage capacity of about 349,000 acre-feet, have been constructed within the Cement area. Fort Cobb was built by the U.S. Bureau of Reclamation to provide storage for irrigation, recreation, municipal, and flood-control. It has a storage capacity of 146,600 acre-feet (1,137,300,000 barrels). Two other large reservoirs, Ellsworth and Lawtonka, which have a combined storage capacity of about 157,000 acre-feet (1,218,000,000 barrels), supply water for municipal and industrial use to Lawton and Fort Sill. The

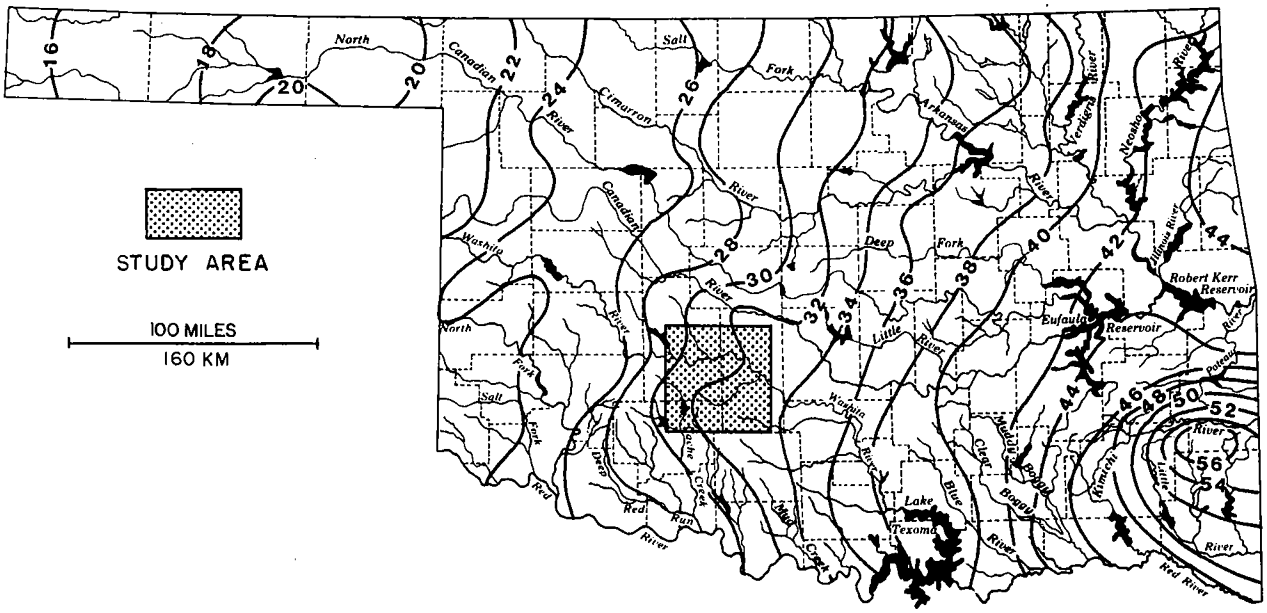

Figure 5. Average annual precipitation, in inches, for Oklahoma; 1931-60.

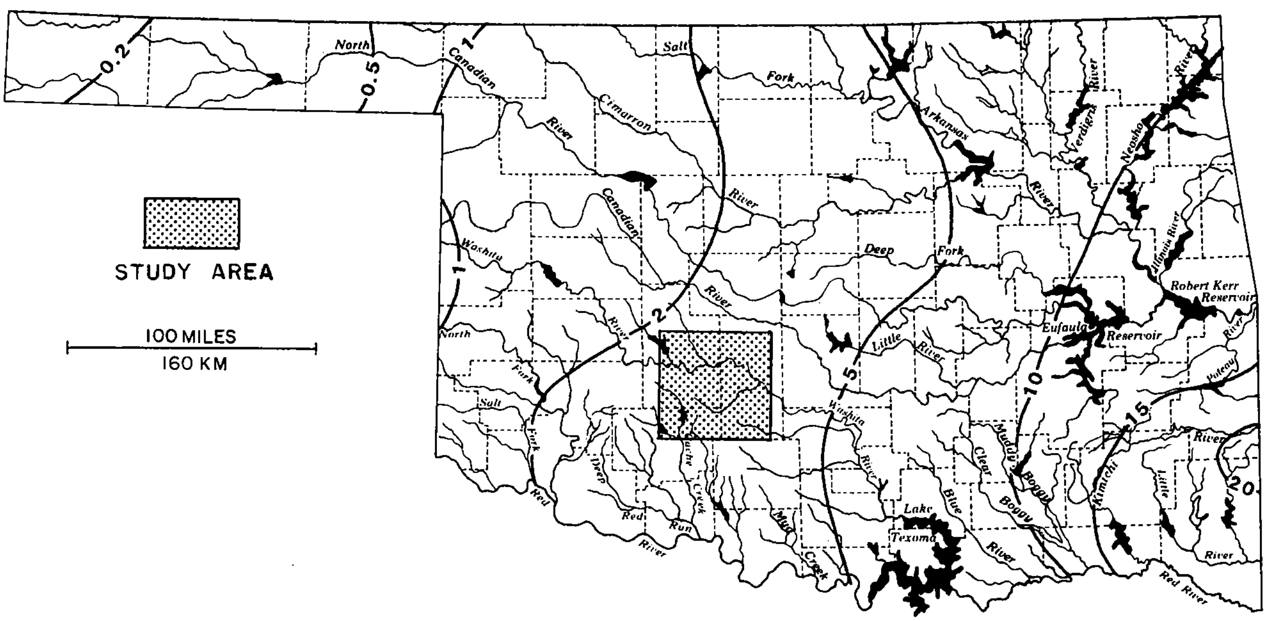

Figure 6. Average annual runoff, in inches, for Oklahoma; 1931-60.

remaining six reservoirs in this category provide water for irrigation, municipal supply, and flood-control for nearby communities; their capacity is about 356,000,000 barrels. There are 81 lakes and ponds that have surface areas between 10 and 100 acres. They have a combined storage capacity of 10,526 acre-feet (81,700,000 barrels). There are 55 lakes and ponds that have surface areas of less than 10 acres. The combined storage capacity of these lakes is only 1,949 acre-feet (15,120,000 barrels). A majority of the lakes with surface areas of 100 acres or less are used for flood control. These reservoirs are used to regulate surface runoff, to control flooding, and to reduce sediment loads in stream waters. In addition to flood control, many of these man-made ponds and small lakes provide water for stock and other farm uses as well as for individual domestic use.

The total water capacity of all of the impounded surface water within the area of investigation is approximately 2.8 billion barrels. How much of this capacity is realized throughout the year, or is available for private or industrial use, is unknown.

Deliverability Streamflow Data The Washita River and its tributaries as well as several Red River tributaries are the principal sources of surface water in the Cement area (pl. 1, fig. A). The principal Washita River tributaries in the Cement area include Sugar Creek, Salt Creek, Bitter Creek, Cobb Creek, Little Washita River, and Rush Creek. In the southwest part of the study area, drainage is southward toward the Red River. Major drainage ways in this region include Cache Creek, Medicine Creek, and Beaver Creek.

Streamflow discharge and water-quality data are highly dependent upon precipitation distribution. Streamflow data are summarized for 10 gauging-station sites in the Cement area (pl. 1, fig. A). Prior to 1961, streamflow records were published in an annual series of U.S. Geological Survey Water Supply Papers, "Surface Water Supply of the United States." The Oklahoma records are contained in part 7 of that series. The records for the 5-year period, 1961-65, are contained in a two-volume publication of the same series. Beginning with water year 1961, the U.S. Geological Survey began to publish streamflow records separately for each state and released the reports through its district offices, primarily for local use. Selected streamflow data, such as average number of days per year with no flow, are depicted for each gauging station (pl. 1, fig. A). Except for the Washita River, most streams and creeks in this region have several days of no flow. Average daily discharge ranges from a low of 5.4 cubic feet per second (cfs) to about 380 cfs on the Washita River. Variations in streamflow coincide with annual precipitation fluctuations. Generally, high streamflows occur during the months of April, May, and June, whereas low discharge values are usually associated with the winter months of December, January, and February and the summer months of July and August.

The availability of shallow ground water (generally less than 1,000 feet) in the Cement area depends on the saturated thickness, permeability, and storage capacity of the underlying strata. There are several aquifers in the Cement area that will yield significant amounts of water to wells. For this report, aquifers are considered to yield more than 25 gpm (gallons per minute).

Information used to evaluate the ground-water conditions in the Cement area was obtained from the U.S. Geological Survey's hydrologic-atlas studies published by the Oklahoma Geological Survey. Part of this information included a 227-well inventory for the Cement area. The location and reference number for each well is shown in plate 2, figure A. Selected ground-water data, such as well depth, water depth, and yield information, where available, are summarized for each well in table 1-2.

There are four major aquifers: the alluvium-terrace deposits, the Marlow-Rush Springs, the El Reno Group, and that portion of the Arbuckle-Timbered Hills that lies within the Cement area. Their locations are shown in plate 2, figure A. The alluvium and terrace deposits are combined and shown as a single aquifer because both of these units have similar water-bearing properties. Alluvium and terrace deposits, which crop out along the Washita River and some of its major tributary streams, provide a source of water for irrigation, industrial, and municipal use.

The Rush Springs Sandstone is the principal ground-water aquifer in the Cement area as well as west-central Oklahoma. It supplies water for irrigation, municipal, and industrial use. The Rush Springs Formation has a maximum thickness of about 300 feet in Caddo County, north of the Washita River, and thins northward to about 200 feet in Dewey County as well as southward in Stephens County.

The Marlow Formation, which underlies the Rush Springs Sandstone, has a maximum thickness of about 100 feet. For this report, the Marlow Formation and Rush Springs Sandstone were grouped into a single aquifer because many wells are completed in both formations.

The Chickasha Formation and Duncan Sandstone of the El Reno Group may locally provide water for any combination of domestic, industrial, or irrigational uses.

The limestone and dolomite aquifers of the Arbuckle-Timbered Hills Group are exposed at the surface in the Limestone Hills area of Comanche and Caddo Counties in the Cement area.

Additional information about ground-water availability can be obtained by contacting either the Oklahoma Water Resources Board and/or the U.S. Geological Survey Water Resources Division, both in Oklahoma City.

Estimate of Volume Total dissolved solids in a water sample include all solid material in solution whether ionized or not. Natural waters range from less than 10 mg/L of dissolved solids for rain and snow to more than 300,000 mg/L for some brines. Water for most domestic and industrial uses should be less than 1,000 mg/L, and water for most agricultural uses should be below 3,000 mg/L (Davis and DeWiest, 1966).

At this time, most chemicals used in conjunction with enhanced-oil-recovery techniques are incompatible with water that has total-dissolved-solids concentrations in excess of 5,000 mg/L (Haddenhorst, 1976). An attempt was made to determine the volume of rock in the Cement area that contains water with a total dissolved-solids content of 5,000 mg/L or less.

Most of the potable water in the Cement area occurs in the upper 1,000 feet. Therefore, very little information, such as water chemistry, from conventional water wells exists below this depth. However, total-dissolved-solids concentrations can be estimated from electric-log interpretations.

A map showing the base of the "fresh" ground water (5,000 mg/L or less dissolved solids) was prepared for southern Oklahoma by Hart (1966). Oil-well electric logs were the principal source of information used to prepare the maps. The interpretations of the electric logs were based on the comparative values of the following three curves: 1) spontaneous-potential curve, 2) short-normal resistivity curve, and 3) long-normal resistivity curve. The data were contoured using mean sea level as a datum. A contour map of the base of fresh ground water for the Cement area is shown on plate 2, figure C. The wells used to construct the maps are also shown. There are only 64 wells for approximately 1,750 square miles in the Cement area. Furthermore, most of the wells occur in the central and southern parts of the Cement area. Therefore, the contour map and the following data derived from this map provide only regional, generalized assessment of the ground-water conditions in the Cement area. Detailed on-site investigations would have to be conducted to assess ground-water quality and quantity conditions.

An isopach map, showing the thickness of fresh ground water, was constructed for the Cement area (pl. 2, fig. D). The base of the fresh-ground-water contour map was overlaid on a topographic map. The elevation differences at the intersection between the ground-water contours and the topographic contours were recorded. These elevation differences, which represent the thickness of the fresh-ground-water zone, were then contoured to produce plate 2, figure D.

An attempt was made to estimate the total volume of saturated rock in the Cement area that may provide fresh ground water for enhanced oil recovery. The map area was subdivided into 16 domains. An area (in acres) and an average thickness (in feet) within the area were determined. The volume for each domain was determined by multiplying the average thickness by the area. These data are summarized in table 5-1 associated with plate 2, figure D. The total volume of rock that may possibly contain fresh ground water (less than 5,000 mg/L) for the Cement area is 481,412,700 acre-feet. This represents an area of about 980,000 acres with an average thickness of 491 feet.

The amount of water in storage is estimated to be 48,141,270 acre-feet, or approximately 374 billion barrels. This figure was calculated using a storage coefficient of 0.1 and an average saturated thickness value of 491 feet. Assuming 35 percent recoverability, the estimated total available water would be 16,849,444 acre-feet (Roles, 1976). This would be equivalent to about 131 billion barrels of water.

Deliverability Most wells in the alluvium along the Washita River yield between 60 and 150 gpm. Along most tributary streams in the Cement area, the alluvium generally is thin and contains a high proportion of silt and clay; therefore, it yields only small amounts of water, except possibly in a few local areas.

In Caddo County, north of the Washita River, a few irrigation wells in the Rush Springs Sandstone are reported to yield as much as 1,000 gpm; but the average well yield is 400 to 500 gpm. South of the Washita River, the saturated thickness and permeability of the Rush Springs generally are less, and well yields range between 25 and 150 gpm. Although the Rush Springs Sandstone contains a large supply of ground water, high-yield wells concentrated in small areas can result in local overproduction. Such overproduction causes a steady decline of the water level and a decrease in saturated thickness, which result in smaller well yields and increased pumping costs (Carr and Bergman, 1976; Roles, 1976; Oklahoma Water Resources Board, 1976).

The Marlow Formation has low to moderate permeability, locally high salinities where gypsum is present, and well yields ranging from 25 to 150 gpm. The high variability in lithologic character, mudstone conglomerate to shale, is responsible for a wide variation in well yields in the Chickasha and Duncan Sandstones. Well yields generally range from 25 to 150 gpm. However, there are numerous locations where yields are less than 25 gpm.

In this area wells and springs in the Arbuckle-Timbered Hills Groups provide water for domestic use and rural water districts. Average well yields for this region range from 25 to 150 gpm.

PART II: SUBSURFACE WATER

The principal source of data used for determining the characteristics of the subsurface water resources in Cement Field is a selected set of well logs assembled from the extensive well-log files maintained by Riley's Reproduction, Inc., in Oklahoma City. From 1,850 wells, a representative data-base was compiled by obtaining logs from the deepest well in each quarter section having the most comprehensive log coverage. Logs from almost 200 wells were required to cover the extensive area encompassed by the field.

The first step in processing the logs was to identify in each well the major formation contacts as well as the boundary between the Permian and pre-Permian rocks. The initial identifications were made from scout and completion tickets contained in the files compiled by the Petroleum Information Corporation and the Oklahoma Corporation Commission. After the contacts were marked on the logs, a log-to-log correlation was made to ensure consistency in their identification. The logs were adjusted where necessary and then annotated.

Next, the fluid reservoirs were defined from the self-potential and resistivity curves on the resistivity logs. The thicknesses of the reservoirs in each well were separately totaled for the Permian and pre-Permian rocks that were penetrated by the well. Isopach maps were then constructed from the thickness measurements (pl. 3, figs. A and C).

The Permian strata were treated separately, since almost all of the wells completely penetrate the Permian. The isopach map therefore provides stratigraphic information relevant to depositional patterns. Penetration of the pre-Permian rocks, on the other hand, varies so greatly in completeness that most of the depositional information is lost. However, to partially mitigate this loss four of the major pre-Permian reservoirs that are laterally persistent and usually penetrated were treated individually. Isopach maps were constructed for each of these reservoirs (pl. 4).

In doing this study it was necessary to make several simplifying assumptions. These are discussed below.

1) The reservoirs are defined from electric logs by the relationships between the self-potential curve and the resistivity curves. The long developmental history of the field, however, has necessitated the use of several technological generations of logs run by several logging services. Consequently, the variation in curve response prohibits a fixed-parameter definition of reservoirs. Their determination from log to log is, therefore, partially subjective.

2) Producible water is available only from strata defined as reservoirs.

3) All reservoirs are considered to be 100 percent water saturated. This assumption overestimates the water volume and flow rate from those reservoirs retaining a significant remaining oil saturation.

4) The effective drainage area per well is one-fourth of a square mile. The lateral extent of reservoir contribution beyond edge wells is consequently set at one-eighth of a mile.

Although each of these assumptions contributes a degree of error, we believe that the volume estimate nevertheless falls within the proper order of magnitude.

The amount of subsurface water available for enhanced-oil-recovery operations in Cement Field cannot be determined without first defining the operations for which it is needed. For any proposed operation it would be necessary to specify the number of wells involved, the total water-production rate required from these wells, the allowable levels of total dissolved solids in the water, and in the case of sustained withdrawal, the recharge rate of water into the reservoirs being produced. In a gas-depletion-drive field such as Cement, the short-term water-recharge rate is effectively zero.

Because all of these parameters are set by specific operations, the estimates here are confined to (a) the total volume of water accessible from all the reservoirs that have been penetrated by wells within the field, (b) the initial open-flow potential of water from the wells, and (c) the amount of total dissolved solids in the water.

Volume Estimate In the highly complex structural-stratigraphic system that makes up the Cement Field, any estimates of the volume of subsurface water based on inferences of reservoir thickness and continuity away from well control are likely to be grossly inaccurate. Moreover, the desired end result of this study is an estimate of the total accessible water rather than the total water present in the field. Accessible water implies water that will flow into a well within a limited time: hence, it is unrealistic to include reservoir water that is distant from the well. Consequently, the volume estimates in this report are based on only the reservoir thicknesses penetrated by each well and a presumed quarter section drainage area around each well.

The total volume of Permian reservoirs was derived from an isopach map of those reservoirs (pl. 3, fig. A). First, the area of drainage was outlined at approximately one-eighth of a mile beyond the edge wells penetrating the Permian. Since almost all wells used for this study fully penetrate the Permian, most of the 200 fall within the outlined area. Next, within this effective drainage boundary, the map areas between every pair of isopach contours were partitioned and then measured by planimeter. The reservoir volume for each of the partitioned areas was then calculated by multiplying that area by the corresponding midpoint thickness value. Thus, a planimetrically measured area falling between the 200- and 300-foot isopach would be multiplied by the mid-value thickness of 250 feet to obtain the reservoir volume (in acre-feet). The volumes (in acre-feet) for each measured area were subsequently added together to yield the total penetrated reservoir volume.

An average porosity of 21 percent was determined for the Permian reservoirs on the basis of company reports and numerous determinations from porosity logs. An example of the log-derived porosities for the Fortuna sand is shown in table 3-6.

Assuming 100 percent water saturation, the water volume is simply equivalent to pore volume, so that the total pore volume of the Permian reservoirs was calculated by multiplying the total reservoir volume by 21 percent, the average porosity.

Finally, the calculated water volume, which at this stage is expressed in acre-feet, was converted to barrels by the relationship:

Volume (bbl) = volume (acre-feet) x 43,560 (ft^2/acre) ÷ 5.615 (ft^3/bbl)

The total water volume estimate for the Permian reservoirs within the effective drainage boundary required partitioning of the isopach map (pl. 3A) into 39 areas for planimetric resolution. The total reservoir volume was calculated to be 78,572,714,290 barrels. The pore volume within the reservoirs is estimated at 16,500,270,000 barrels, which, assuming 100 percent water saturation, is equivalent to the in-situ water within the reservoirs.

The general distribution of Permian reservoirs is strongly oriented at about N 80° W, or roughly parallel to the axis of the Cement Anticline. This orientation is evident on both the isopach map (pl. 3, fig. A) and the reservoir-to-penetrated-thickness ratio map (pl. 3, fig. B), which in the case of the Permian is essentially a sand-shale ratio map. The parallelism between the Cement structure and the depositional trend of the fluviatile Permian sands reflects a strong structural influence on deposition even though folding during the Permian was gentle. This orientation will have a marked directional effect on the drainage and flow patterns within the Permian reservoirs. The discontinuous nature inherent in fluviatile sands will further complicate the production of water from the sands.

Even though the pre-Permian reservoirs were deposited under widely varying environmental conditions ranging from quiet marine to high-energy fluviatile, the reservoirs have been given some directionality owing to the strong structural growth of the Cement Anticline during their deposition. The pre-Permian-reservoir isopach map (pl. 3, fig. C) shows a northwesterly trend to the reservoirs, although this effect is somewhat masked, particularly on the eastern end of the field, by the erratic penetration on which the reservoir thicknesses are based. Plate 3, figure D, where the effect of penetration-depth variation is largely subdued by using the ratio of reservoir to total penetration, shows the directionality more clearly. In the pre-Permian the trend is mostly due to erosion from and onlap onto the structure, so that although the distribution of the individual reservoirs may be directional (pl. 4, figs. A-D), the flow patterns within a reservoir, unlike the Permian, are probably relatively uniform.

The total subsurface water-volume estimate for the penetrated pre-Permian rocks was determined like that of the Permian reservoirs. The total pore fluid is estimated at 25,115,713,000 barrels. It is likely to be advantageous to produce water from only the best and most laterally persistent reservoirs. Accordingly, individual isopach maps have been prepared for the four pre-Permian reservoirs that are thick, permeable, laterally persistent, and most often penetrated (pl. 4, figs. A-D). The in-situ water-volume estimates for these reservoirs, all of which are sands, vary from about 1.5 billion barrels in the Wade sand to 3.3 billion barrels in the Rowe sand.

Flow Potential The initial open-flow potential of wells in the Cement Field can be determined by a form of Darcy's Law that expresses radial liquid flow into a borehole in units of barrels of liquid per day:

$$Q = \frac{7.07\ kh\ (P_e - P_w)}{\mu\ \ln r_e/r_w}$$

- Q = barrels per day
- k = permeability in darcies
- h = interval thickness in feet
- P_e = 1 atmosphere in psi
- P_w = formation pressure in psi
- μ = viscosity (1.0)
- r_e = distance from well bore (660 feet)
- r_w = radius of well bore in feet

A nomograph (fig. 7) has been constructed for the open-flow potential of the Cement wells on the basis of this equation. The interval thickness is set at 25 feet, P_e is set at 1 atmosphere or 14 psi, viscosity is set at 1.0, r_e is set at 660 feet (which is standard practice), and the well-bore radius is set at 5 inches, since most of the Cement Field wells have a well bore of about 10 inches.

Consequently, the only variables in the equation are permeability, which is dependent on the particular reservoir considered, and the formation pressures, which are presumed as hydrostatic and hence, are a function of depth. The permeabilities for several of the reservoirs in Cement Field were determined from resistivity logs. The calculations are based on a set of empirical petrophysical relationships developed by Schlumberger Well Services. A sample calculation is shown in the Appendix. This procedure is considered acceptable as a first approximation.

A normal hydrostatic gradient of 0.443 psi per foot has been used for calculating the formation-pressure increase with depth, although the actual pressures are somewhat higher in accordance with the high salinities of the formation waters.

The nomograph can provide a good first approximation of initial flow for any project where the number of wells involved, the depths to the reservoirs producing water, the permeability of the reservoirs, and the thickness of the reservoirs have been defined. For example, it can be seen on the nomograph that a single well will initially flow 17,500 barrels of water per day from each 25 feet of reservoir having 200-millidarcies permeability at 8,500-feet well depth.

Some of the wells in Cement Field have well bores with as little as a 7-inch diameter. A plot of the flow potential at 100-millidarcies permeability for a 7-inch well bore is shown on the nomograph for comparison with a 10-inch well bore: the differences in flow rate between the two diameters is minor.

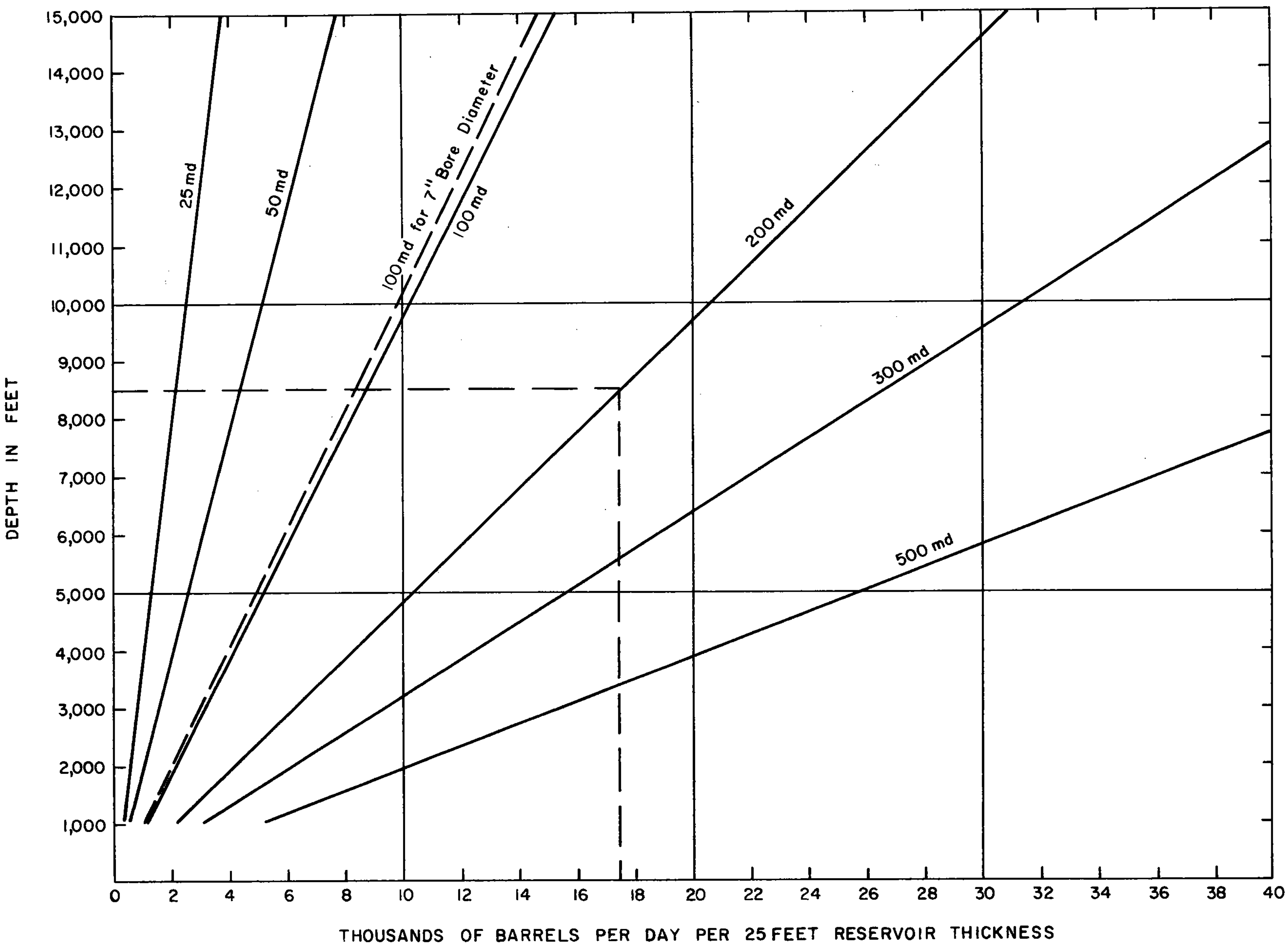

Figure 7. Nomograph for determining initial open-flow potential for reservoirs in Cement Field.

An example is presented here of finding the initial open-flow potential within a specific area of the Cement Field. The area is arbitrarily chosen as Secs. 9 and 10 in T. 5 N., R. 9 W. To find the flow from the Niles sand, it can be seen on plate 4, figure B, that seven wells penetrate the Niles in these two sections. The total thickness of the Niles penetrated by the seven boreholes is: 70 + 70 + 65 + 120 + 70 + 50 + 50 = 495 feet.

From table 3-6 the permeabilities in the Niles range from 40 to 90 millidarcies.

The average depth to the Niles within secs. 9 and 10 as determined from the electric logs is 4,750 feet.

Entering the nomograph (fig. 7) at 4,750 feet, and then moving right to approximately 40 md, indicates an initial open-flow potential of about 2,000 barrels of water per day for each 25 feet of reservoir thickness. The total flow, then, would be:

$$2{,}000 \times 495 \div 25 = 39{,}600 \approx 40{,}000 \text{ BW/D.}$$

With a permeability of 90 md, the total flow would be:

$$4{,}600 \times 495 \div 25 = 91{,}080 \approx 90{,}000 \text{ BW/D.}$$

As a first estimate, therefore, the initial flow from the seven wells should fall within the range of 40,000 to 90,000 barrels per day. The ensuing flow, of course, would depend on the withdrawal rate, and on many other factors that would be project specified.

A similar exercise was done in the same area for the Marchand sand (pl. 4, fig. D) and for the total penetrated pre-Permian reservoirs (pl. 3, fig. C). The initial open-flow estimates are 220,000 to 930,000 BW/D for the Marchand, and 710,000 to 1,410,000 BW/D for the pre-Permian reservoirs.

Using the isopach maps it is also possible to derive a rough estimate of water volume within a given area. Within the area covered by secs. 9 and 10, for example, there is an approximate average reservoir-thickness penetration of 800 feet in the pre-Permian sediments (pl. 3, fig. C). Assuming an average porosity of 20 percent as reasonable for these reservoirs, the total volume of reservoir water in secs. 9 and 10 would be:

$$800 \text{ feet} \times 640 \text{ acres} \times 2 \approx 1{,}000{,}000 \text{ acre-feet}$$

of bulk reservoir volume. Then:

$$1{,}000{,}000 \times 0.20 = 200{,}000 \text{ acre-feet}$$

of water in the reservoirs, assuming 100 percent water saturation. Finally, converting acre-feet to barrels:

$$200{,}000 \text{ acre-feet} \times 43{,}560 \text{ ft}^2 \div 5.615 \text{ ft}^3 \approx 1.55 \times 10^9$$

or 1½ billion barrels of water.

PART III: WATER CHEMISTRY

Introduction All EOR applications require detailed study of several site-specific characteristics (i.e., petrophysics, temperature and pressure conditions, and fluid chemistry) before such programs are implemented. Micellar-polymer flooding, which appears to be the most promising technique for Midcontinent sandstone reservoirs, is somewhat dependent on the chemical characteristics of both formation and injection water. Table 3-1 lists preferred characteristics for this particular EOR method. Although salinity conditions and concentration of divalent cations (mainly calcium and magnesium) are generally considered important screening criteria for micellar-polymer flooding, there is some evidence that certain surfactants have a high salinity tolerance (Murtada and Marx, 1980). These workers conducted bench-scale experiments on brines which contained nearly 200,000 mg/L TDS with encouraging results. If this technology can be fully developed, perhaps the chemical characteristics of formation and injection water will become less critical for micellar-polymer applications.

Chemical Characteristics of Surface- and Ground-Water Samples

Surface Water Surface-water quality in this region is dependent upon streamflow characteristics, erodibility, the lithology of geologic formations traversed by a stream, and the addition of dissolved minerals from man's activities such as the discharge of sewage and industrial wastes. Geologic deposits, such as salt, gypsum, and to some extent dolomite, in this region dissolve easily and contribute large quantities of dissolved solids to local streams. Maximum concentrations of dissolved solids occur during periods of low flow; minimum concentrations usually occur during periods of heavy precipitation and high runoff.

Data collected and published by the U.S. Geological Survey and the Oklahoma Water Resources Board have provided information on the chemical quality of surface water at 24 sites in the Cement area. These data are summarized in table 3-2, and the sample sites are shown on plate 1, figure A. Maximum and minimum values for calcium, magnesium, sodium, total dissolved solids, sodium-adsorption ratio, and specific conductance are shown for each sample site. Generally, the maximum and minimum values correspond to low and high streamflows respectively. At almost all locations, the water quality, especially at high streamflows, is within the limits established for enhanced oil recovery. However, the water at sampling site 20 on McCardo Creek near Cement, has very high concentrations of sodium, in excess of 2,000 mg/L, as well as total dissolved solids of 8,000 mg/L. The water at this location would not be compatible with chemicals presently being used for enhanced oil recovery.

Ground Water Water samples from 52 wells and 3 springs, which were analyzed by the U.S. Geological Survey, provide data on the chemical characteristics of ground water in the Cement area. Water-quality diagrams are used to portray the concentrations of selected chemical constituents for each well (pl. 2, fig. B). The chemical data are also listed in table 3-3.

The water-quality diagrams show the general chemical character of ground water at each well location. The size of the diagram indicates the dissolved-solids concentration in the water. The larger the area within the diagram, the more dissolved solids are present. Therefore, the shape of the diagram is a general indication of the chemical quality. Cation constituents, sodium plus potassium and calcium plus magnesium, are plotted to the left, whereas the anion constituents, chloride, bicarbonate, and sulfate, are plotted to the right. All constituents are plotted in milligrams per liter. The figure in the center of the diagrams, where shown, denotes fluoride content in milligrams per liter.

Water from alluvium generally is very hard and locally contains excessive dissolved solids such as at well site 188. Sulfate concentrations are generally above 250 mg/L, and in some areas chloride concentrations are high. Calcium plus magnesium concentrations vary from about 180 to 438 mg/L, with the highest concentration, 2,000 mg/L, reported at well site 188. The chemical quality of water from alluvium can differ greatly within short lateral distances. Such differences may be due partly to variations in quality of recharge from bedrock bordering or underlying the alluvium, or to pumpage that increases the flow of water into the alluvium from nearby streams. Water from terrace deposits is generally of better quality than from alluvium. Water from terrace deposits is usually hard, but sulfate and chloride concentrations generally are low.

The Rush Springs Sandstone and the Marlow Formation in central Caddo County yield water that usually contains less than 500 mg/L of dissolved solids. In this area, sulfate and chloride concentrations are low, and the water is of a calcium bicarbonate type. Generally west and to some extent east of this area the character of the water changes to a calcium sulfate type; water quality deteriorates and water samples usually contain more than 800 mg/L dissolved solids. Sulfate and chloride concentrations most often exceed 250 mg/L. Part of this water-quality deterioration is caused by an increase in gypsum within the formations. However, the change in water quality to the west may also result from the overlying Cloud Chief Formation. In general, water from the Marlow Formation is of poorer quality than from the Rush Springs Sandstone.

The El Reno Group, primarily the Chickasha-Duncan aquifer, yields water that for the most part contains more than 900 mg/L with values ranging from about 470 mg/L to 2,900 mg/L in the Cement area. The character of the water in these formations is generally a calcium/magnesium sulfate type. The Dog Creek-Blaine-Flowerpot Formations of the El Reno Group locally serve as aquifers. The water in these formations usually contains more than 1,000 mg/L of dissolved solids. The water is very hard, and sulfate and dissolved-solids concentrations are generally high. Locally, excessive chloride concentrations also occur in water from these formations.

The water in the Arbuckle-Timbered Hills aquifer in this region is commonly of the calcium carbonate type, but mixtures of calcium and sodium chloride occur locally. Total dissolved solids concentrations average less than 400 mg/L with values ranging from about 300 to 750 mg/L. Calcium/magnesium concentrations vary from 125 to 425 mg/L. Locally high fluoride concentrations have been reported. Sample site 112 has the highest fluoride concentration, 1.9 mg/L, reported for the Cement area.

Chemical Characteristics of Subsurface Water Samples

Table 3-4W shows the composition of brine samples collected from several waterflood units. These analyses represent current chemical characteristics inasmuch as several pore volumes have been flushed through the productive intervals and have significantly altered the composition of the original formation water. The compositions shown may reflect conditions which would be encountered if a micellar-polymer (or any other EOR method) program were initiated in a field which has experienced several years of waterflooding. Obviously total-dissolved-solids (TDS) and Ca^{++}-Mg^{++} concentrations constitute a potential problem if the screening criteria in table 3-1 are relevant. Such a problem might be minimized if (a) the EOR program could be implemented prior to substantial chemical alteration of formation water by waterflooding, (b) the formation water could be "conditioned" by injection of water of relatively good quality, or (c) chemicals with high tolerance to salinity conditions can be utilized. Although the data in table 3-4W indicate chemical conditions which are less than ideal for conventional micellar-polymer operations, many EOR operations will probably involve fields with waterflood histories similar to that of Cement Field.

The chemical characteristics of subsurface water samples which have not been altered by waterflooding (connate) are shown in table 3-4C. These analyses were retrieved from the Brine Data Base which is on file in The University of Oklahoma's Petroleum Data System. It was assumed that each analysis represents an uncontaminated sample from a specific stratigraphic interval.

Classification of Oilfield Waters Collins (1975) has critically reviewed the major classification systems which have been proposed for oilfield waters, and the reader is referred to this work for details. Collins determined that the type and class characteristics of Sulin's classification scheme make this particular system useful for the study of oilfield waters. The Sulin system requires that concentrations of the cations and anions be converted to equivalents per million (epm) and ratios of epm values determine genetic water type and group. In a study of 4,000 samples of oilfield brines, Collins concluded that the most common genetic type of water associated with petroleum is the chloride-calcium type. This type is determined by the ratio (in epm) Cl^{-}-$Na^{+}/Mg^{+}2 > 1$. The data in tables 3-4W and 3-4C satisfy this condition; thus the formation waters evaluated in this study are of the chloride-calcium type. Chemical data on in-situ formation water as well as water associated with strata which are currently under waterflood constitute critical information for planning and implementing EOR projects. Such projects will be designed to conform to specific conditions of depth, temperature, oil viscosity, etc., and chemistry of formation brines appears to be a major consideration under current technology.

Analytical Methods Almost all of the samples on which data are presented in table 3-4W were collected from active waterflood units by field personnel from various companies and representatives of the Oklahoma Geological Survey. Waterflood units are shown on plate 5, figure B, and stratigraphic units are shown in figure 4.

Table 3-5 summarizes the methods used by the Oklahoma Geological Survey to analyze brine samples.

Salinity Data and Calculations Salinity is one of the screening criteria listed in table 3-1, and estimates of this parameter can be made by using data obtained from wire-line logging operations. The salinity values which appear in table 3-6 were estimated from the relation between R_w (water resistivity) and ppm levels of NaCl at specific subsurface temperatures. The resistivity graph for NaCl solutions shown as figure S-3 (Appendix) was taken from the 1972 edition of Schlumberger log-interpretation charts and was used in this study. The example described in the caption illustrates the use of the graph.

In 1975, the Oklahoma City Section of the Society of Petroleum Engineers of AIME published the Survey of Resistivities of Water from Subsurface Formations in Oklahoma. Information contained in the publication includes R_w values at various depths and temperatures. Thus for formations of interest in the study area, it was often possible to obtain R_w data from the SPE publication and use the graph (fig. S-2, in Appendix) to estimate salinity.

In cases where the SPE publication did not list a well near the control wells employed in this study, it was necessary to calculate R_w values. Such calculations involve several steps and require a number of charts prepared by various logging companies. A step-by-step example is given in the Appendix.

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A P P E N D I X

Sample Calculations

Tables 1-1 through 3-6

Permeability Determination from Resistivity Log

Except for a few measured permeabilities taken from published reports or supplied by companies active in the Cement area the permeabilities used in this study were derived by petrophysical analysis of resistivity logs. The results are based on standard procedures of log analysis as exemplified by Schlumberger's log-interpretation charts. An example is given here for the Niles sand in the Anderson Pritchard, Walker No. 2-A well in the NE¼ sec. 1, T. 5 N., R. 10 W., Caddo County, Oklahoma (fig. P-1).

The log segment 4,360 to 4,450 feet includes an oil-saturated portion of the Niles sand. Porosity was determined from porosity logs in the area. Formation water resistivity (R_w) was supplied by the publication Survey of Resistivities of Water from Subsurface Formations in Oklahoma, published by the Oklahoma City Section of the Society of Petroleum Engineers of AIME. The true resistivity of the formation (R_t) is from the lateral curve on the log. The calculation is:

GIVEN

R_t @ 4,360 = 10 ohm-m (point A)

R_t @ 4,450 = 3 ohm-m (point B)

$F_r = 18$ from $\phi = 21\%$ and $0.62/.21^{2.15}$

$R_w = 0.053$ @ 100°F

$\sigma_h = 0.860$ (oil gravity = 33° API)

$\sigma_w = 1.1$ (150,000 ppm salinity)

THEN

$$R_o = F_r R_w = 18 \times 0.053 = 0.954 \text{ ohm-m}$$

$$\Delta R_t = 10 - 3 = 7 \text{ ohm-m}$$

$$\Delta D = 4{,}450 - 4{,}360 = 90 \text{ ft.}$$

$$a = \frac{\Delta R_t}{\Delta D} \times R_o^{-1} = \frac{7}{90} \times \frac{1}{0.954} = 0.0815$$

$$\sigma_w - \sigma_h = 1.1 - 0.860 = 0.240$$

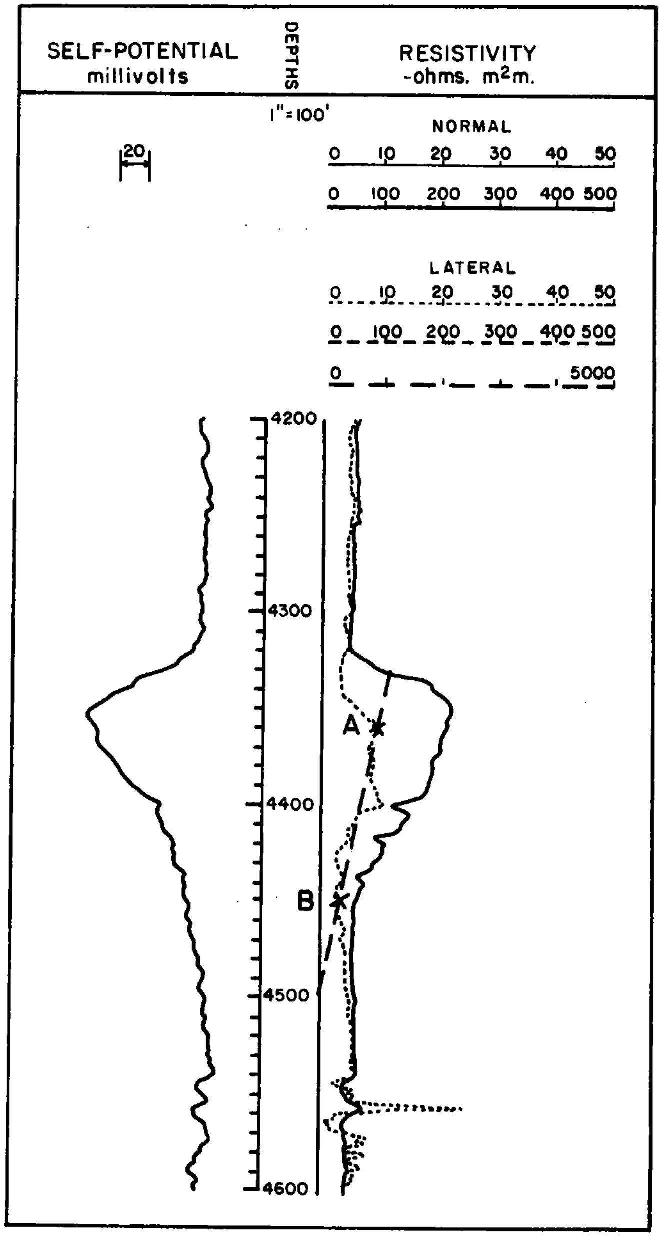


Figure P-1. Niles sand permeability analysis, Anderson Pritchard, Walker No. 2-A, NE¼ sec. 1, T. 5 N., R. 10 W., Caddo County, Oklahoma.

WHERE

R_o = resistivity of formation 100% saturated with water at resistivity R_w
D = well depth
σ_w = water density
σ_h = hydrocarbon density
F_r = formation factor

Using the Schlumberger chart K-1 (fig. P-2), the permeability is empirically established as 13 millidarcies.

Estimation of Salinity from Electric-Log Data

When salinity data are not available, it is possible to estimate this parameter by the use of electric-log data. The following example demonstrates procedures employed in this study.

I. Information taken from electric-log heading. The following data were transposed directly from information printed at the top of the log.

R_{MF} = 1.2 @ 85°F
R_M = 1.6 @ 85°F
Total depth = 5,000'
Temperature @ 5,000' = 120°F

II. SP and resistivity data. Examine the SP and resistivity curves in figure S-1 and consider the zone of interest to be the 35-foot interval which occurs between 3,750 and 3,785.

A. Read the SP for the zone of interest (approximately -80 mv).

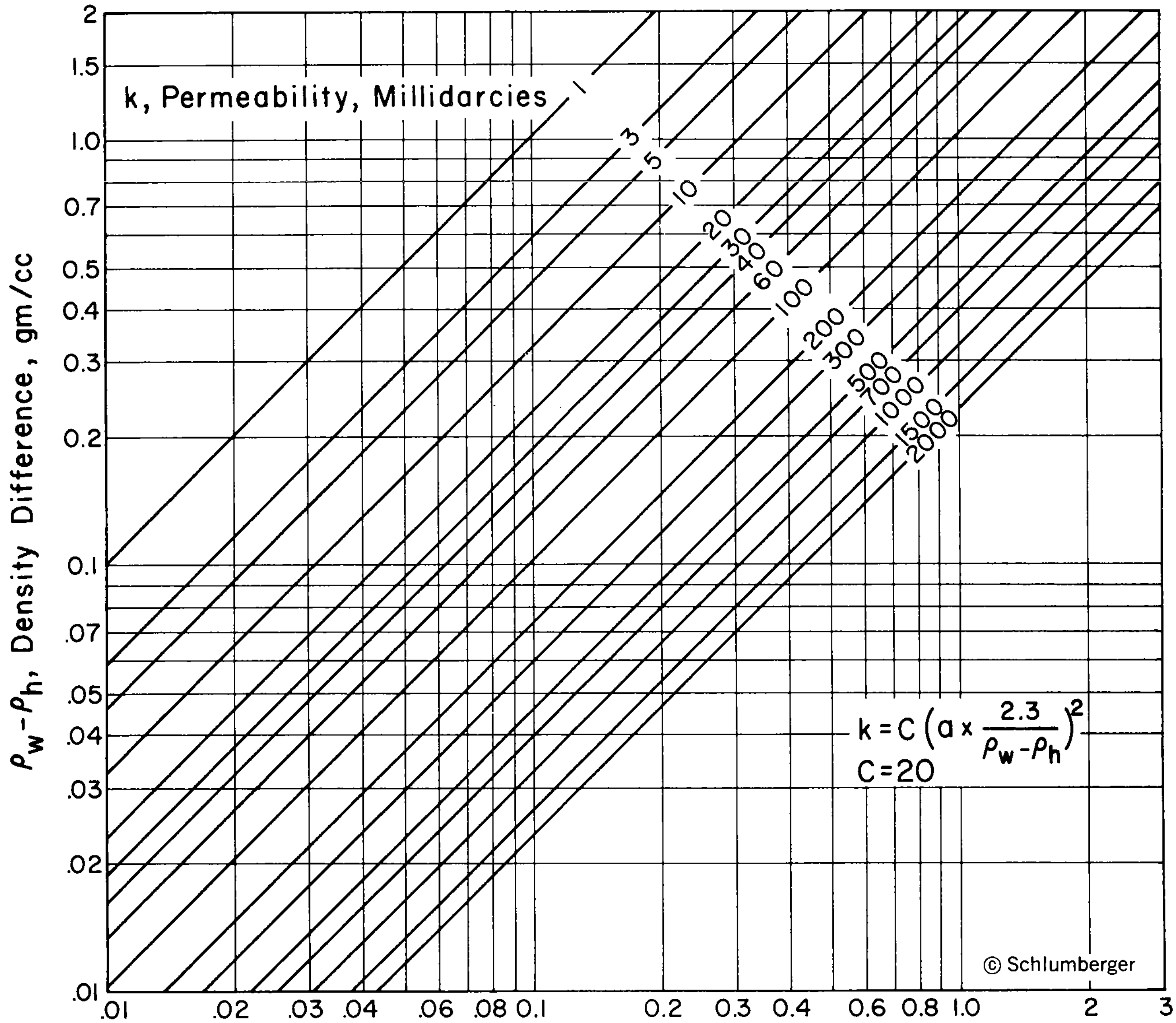
B. Read R_T (formation resistivity) from the lateral log (dotted line); this value is approximately 2.

C. Calculate T_F (formation temperature) for the zone of interest (3,750). For this example, average ambient temperature was assumed to be 65°F.

1. The G_g (geothermal gradient) was calculated as follows:

$$G_g = \frac{BHT - T_A}{TD*}$$

PERMEABILITY FROM RESISTIVITY GRADIENT[15]



a = Basic Resistivity Gradient = $\left(\frac{\Delta R}{\Delta D} \times \frac{1}{R_0}\right)$

A more exact evaluation of permeability can be made if the densities used are for formation conditions. An approximation can be made by using the following standard-condition values:

NaCl Solutions

(14.7 psi, 60°F)	
kppm	gm/cc
0	1.000
50	1.034
100	1.071
150	1.109
200	1.148
250	1.189

Oil

(14.7 psi, 60°F)	
°API	gm/cc
15	0.966
20	0.934
25	0.904
30	0.876
40	0.825
50	0.780

Figure P-2.

where BHT = bottom hole temperature

T_A = ambient temperature

T_D = *total depth (expressed in 100-foot increments)

$$G_g = \frac{120°F - 65°F}{50.0}$$

$$= 1.10 \ °F/100 \text{ feet}$$

2. The temperature at 3,750 feet was determined to be 106°F by the method shown below.

$$T_F = (1.10)(37.5) + 65°F$$

$$= 106°F \text{ (rounded)}$$

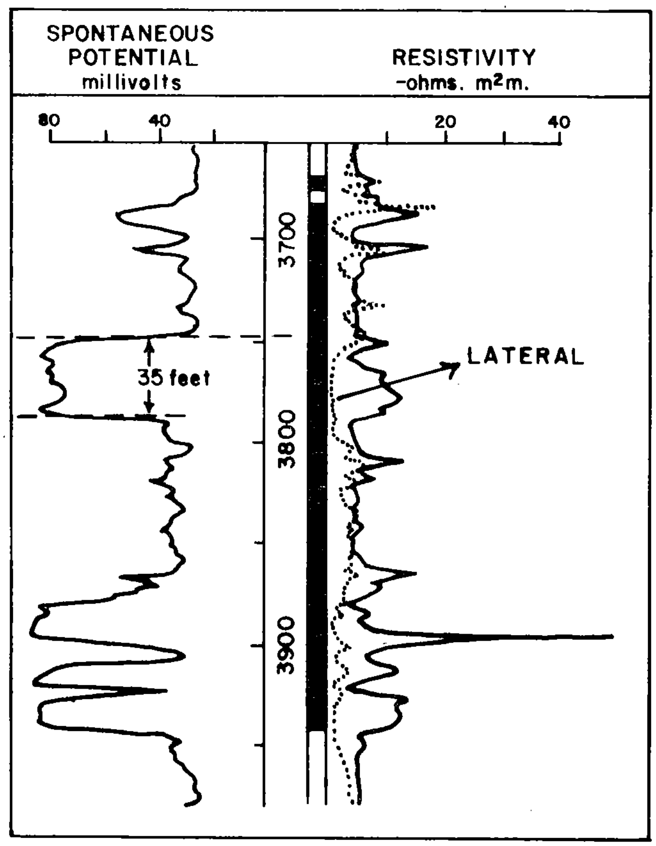


Figure S-1. Segment of resistivity log.

III. Calculate R_{MF} and R_M at 106°F. This requires the formula which accompanies the Resistivity Nomograph for NaCl Solutions (published by Schlumberger). The general relation is:

$$R_2 = R_1 \left(\frac{T_1 + 6.77}{T_2 + 6.77}\right) \qquad \text{EQ. 1}$$

A. Let R_2 equal R_{MF} @ 106°F and substitute the values of R_{MF} given in the Log heading (R_{MF} = 1.2 @ 85°F).

$$R_2 = 1.2 \left(\frac{85 + 6.77}{106 + 6.77}\right)$$
$$= 1.2(.8138)$$
$$= .9765$$

So, R_{MF} at 106°F equals .9765.

B. EQ. 1 can also be used to determine a new R_M value at 106°F. In this case, R_2 will equal R_M @ 106°F.

$$R_2 = 1.6 \left(\frac{85 + 6.77}{106 + 6.77}\right)$$
$$= 1.6\ (.8138)$$
$$= 1.302$$

IV. Estimate $R_{W_{eq}}$ by use of EQ. 2 from Chart No. 5 in the Dresser-Atlas Compilation of Interpretation Charts.

$$R_{W_{eq}} = R_{MF}\ 10^{\frac{SSP}{(60 + 0.133\ T_F)}} \qquad \text{EQ. 2}$$

where R_{MF} = .9765 (from III-A)
SSP = -80 mv (from II-A)
T_F = 106°F (from II-C-2)

thus,

$$R_{W_{eq}} = (.9765)\ (10^{\frac{-80}{74.098}})$$
$$= (.9765)\ (10^{-1.0797})$$
$$= (.9765)\ (.08323)$$
$$= .0813$$

V. Estimate R_W from the $R_{W_{eq}} - R_W$ graph (fig. S-2). This graph is Chart No. 4 in the Dresser Atlas Compilation of Interpretation Charts.

$$R_W \text{ @ } 106°F = .094$$

IV. Use the Schlumberger chart showing the relation between R_W, temperature, and NaCl concentration (fig. S-3) to estimate salinity (approximately 50,000 ppm).

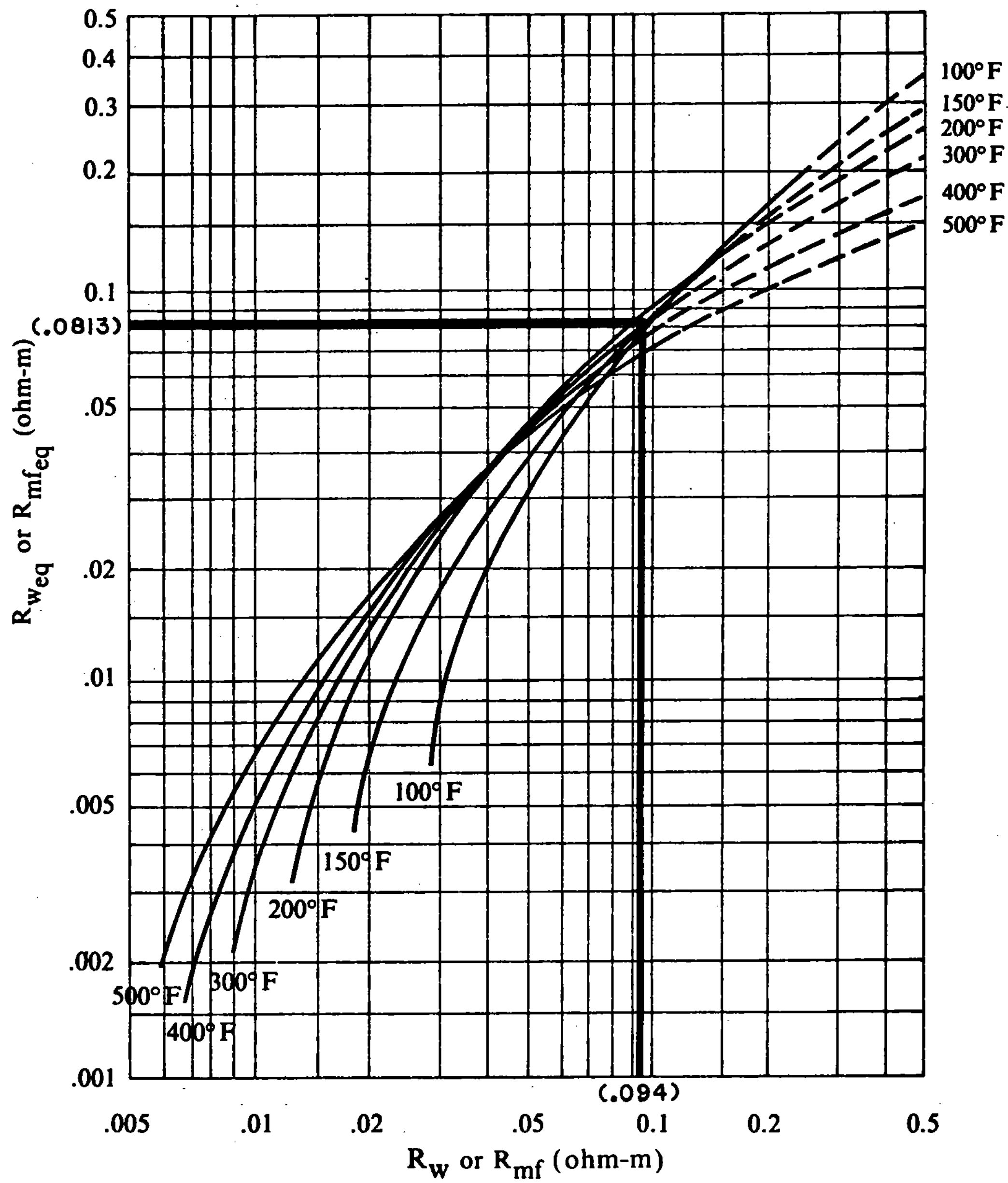


Figure S-2. Relation between R_w, R_{weq}, and temperature.

T A B L E S

Table 1-1. Lakes and ponds in the Cement area (compiled from the Oklahoma Water Resources Board 1976 Oklahoma Water Atlas). (Plotted on plate 1, figure B.)

Map number	Name (designation)	County	Location	Area (acres)	Capacity (acre-feet)
	Lakes of 100 Acres or more in Surface Area				
1	Fort Cobb	Caddo	22 8N 12W	4,070	146,600
2	Ellsworth	Comanche	28,29 4N 11W	5,600	94,475
3	Lawtonka	Comanche	3N 12W	2,398	63,000
4	Spring Creek	Caddo	34 8N 9W	1,950	34,500
5	Public Service	Caddo	35 8N 11W	170	4,600
6	Rush Creek Site 15	Grady	35,36 3N 6W	151	1,237
7	Lake Lewis Burtshi	Grady	29 6N 8W	180	2,140
8	Rush Creek Site 1	Grady	10 3N 7W	227	1,877
9	Taylor	Grady	10 3N 7W	200	1,000
				TOTAL	349,429
	Lakes of 10 to 100 Acres in Surface Area				
10	Horseshoe	Caddo	30 7N 10W	30	240
11	W. N. Rackley	Caddo	27 5N 9W	20	160
12	Louis Hrbacke	Caddo	28 5N 11W	13	60
13	Mindemann	Caddo	13 5N 11W		72
14	Champlin	Caddo	22 5N 11W		88
15	Stanley, Vickre	Caddo	21 5N 12W		90
16	O. M. Ulrey	Caddo	13 5N 10W		56
17	Elliott	Caddo	5 9N 11W		100
18	Kiwanis Youth Camp 2	Caddo	5 9N 11W		100
19	Unknown	Caddo	4 9N 11W		50
20	Brantley	Comanche	32 4N 9W		234
21	Leslie	Comanche	34 4N 9W		70
22	White	Comanche	10 3N 9W		142
23	Birdwell	Comanche	24 4N 10W		52
24	C. F. Jones	Grady	10 6N 7W	12	96
25	Maddox	Grady	24 8N 7W	25	200
26	O. S. Pyle	Grady	14 8N 7W	15	120
27	Twin Lakes	Grady	22 9N 6W	12	96
28	Young	Grady	19 4N 6W		50
29	Hartman	Grady	18 6N 8W		50
30	Alvin Barger	Grady	19 6N 6W		55

Table 1-1. (Continued)

Map number	Name (designation)	County	Location	Area (acres)	Capacity (acre-feet)
31	Campbell	Grady	27 9N 6W		450
32	Sanafer	Grady	33 9N 7W		88
33	Fast Runner Creek Site 1	Caddo	25 8N 12W	12	60
34	Fast Runner Creek Site 3	Caddo	30 8N 11W	17	130
35	Fort Cobb Laterals Site 7	Caddo	36 7N 12W	24	96
36	Fort Cobb Laterals Site 12	Caddo	16 6N 11W	51	234
37	Fort Cobb Laterals Site 13	Caddo	11 6N 11W	11	80
38	Little Washita River Site 26	Caddo	15 5N 10W	27	350
39	Little Washita River Site 18	Comanche	13 4N 9W	29	162
40	Little Washita River Site 23	Comanche	6 4N 9W	10	51
41	Little Washita River Site 32	Comanche	2 4N 9W	12	81
42	Bitter Creek Site 1	Grady	5 7N 6W	26	134
43	Bitter Creek Site 2	Grady	30 8N 6W	23	135
44	Bitter Creek Site 4	Grady	9 8N 6W	23	150
45	Bitter Creek Site 6	Grady	28 9N 6W	20	133
46	Bitter Creek Site 7	Grady	27 9N 6W	15	106
47	Bitter Creek Site 8-B	Grady	35 9N 6W	14	77
48	Bitter Creek Site 20	Grady	35 7N 6W	15	61
49	Roaring Creek Site 3	Grady	15 4N 6W	26	160
50	Roaring Creek Site 4	Grady	11 4N 6W	26	133
51	Roaring Creek Site 7	Grady	17 4N 6W	17	114
52	Roaring Creek Site 8	Grady	32 5N 6W	23	115
53	Roaring Creek Site 9	Grady	36 5N 7W	38	227
54	Roaring Creek Site 10	Grady	29 5N 6W	14	73
55	Roaring Creek Site 11	Grady	28 5N 6W	10	51
56	Roaring Creek Site 13	Grady	27 5N 6W	11	53
57	Roaring Creek Site 16-A	Grady	24 4N 7W	14	183
58	Roaring Creek Site S-2	Grady	10 5N 6W	12	46
59	Roaring Creek Site S-3	Grady	15 5N 6W	14	73
60	Roaring Creek Site S-4	Grady	14 5N 6W	10	38
61	Roaring Creek Site D-4	Grady	7 5N 6W	11	73
62	Roaring Creek Site D-5	Grady	13 5N 7W	12	69
63	Roaring Creek Site D-6	Grady	18 5N 6W	12	60
64	Roaring Creek Site D-7	Grady	8 5N 6W	19	98
65	Rush Creek Site 2	Grady	15 3N 7W	28	217
66	Rush Creek Site 3	Grady	35 4N 7W	24	103
67	Rush Creek Site 4	Grady	14 3N 7W	44	330
68	Rush Creek Site 6	Grady	36 4N 7W	34	200
69	Rush Creek Site 7	Grady	6 3N 6W	15	109
70	Rush Creek Site 8	Grady	8 3N 6W	16	87
71	Rush Creek Site 9	Grady	8 3N 6W	33	202
72	Rush Creek Site 10	Grady	16 3N 6W	96	835
73	Rush Creek Site 11	Grady	9 3N 6W	17	110
74	Rush Creek Site 12	Grady	22 3N 6W	28	229
75	Rush Creek Site 13	Grady	11 3N 6W	37	270

Table 1-1. (Continued)

Map number	Name (designation)	County	Location	Area (acres)	Capacity (acre-feet)
76	Rush Creek Site 14	Grady	26 3N 6W	12	111
77	Little Washita River Site 2	Grady	36 6N 7W	11	57
78	Little Washita River Site 3	Grady	35 6N 7W	30	157
79	Little Washita River Site 4	Grady	26 5N 7W	11	68
80	Little Washita River Site 6	Grady	9 5N 7W	10	44
81	Little Washita River Site 7	Grady	8 5N 7W	16	63
82	Little Washita River Site 9	Grady	30 5N 7W	18	94
83	Little Washita River Site 11	Grady	24 5N 8W	11	67
84	Little Washita River Site 16	Grady	17 4N 8W	15	57
85	Little Washita River Site 34	Grady	31 5N 8W	55	318
86	Little Washita River Site 35	Grady	33 5N 8W	12	58
87	Little Washita River Site 36	Grady	21 5N 8W	25	100
88	Little Washita River Site 38	Grady	6 5N 8W	21	149
89	Little Washita River Site 46	Grady	19 6N 7W	20	96
90	Winter Creek Site 23	Grady	13 6N 6W	13	70
				TOTAL	10,526

<u>Lakes of less than 10 Acres in Surface Area</u>

Map number	Name (designation)	County	Location	Area (acres)	Capacity (acre-feet)
91	Cobb Creek Site 2	Caddo	25 8N 12W	8	45
92	Cobb Creek Site 4	Caddo	31 8N 11W	6	20
93	Cowden Laterals Site 12	Caddo	31 8N 12W	3	19
94	Cowden Laterals Site 13	Caddo	31 8N 12W	5	27
95	Cowden Laterals Site 14	Caddo	32 8N 12W	6	31
96	Fort Cobb Laterals Site 9	Caddo	28 7N 11W	5	49
97	Fort Cobb Laterals Site 10	Caddo	35 7N 11W	8	67
98	Fort Cobb Laterals Site 11	Caddo	3 6N 11W	4	37
99	Spring Creek Site 2	Caddo	5 7N 9W	8	48
100	Sugar Creek Site 2	Caddo	8 8N 10W	8	118
101	Sugar Creek Site 34	Caddo	21 9N 10W	6	30
102	Sugar Creek Site 38	Caddo	17 9N 10W	8	31
103	Sugar Creek Site 42	Caddo	13 9N 11W	4	30
104	Sugar Creek Site L-45	Caddo	12 7N 11W	6	35
105	Tonkawa Creek Site 1A	Caddo	23 6N 10W	9	56
106	Tonkawa Creek Site 3	Caddo	29 6N 10W	3	18
107	Tonkawa Creek Site 6	Caddo	20 6N 10W	5	8
108	Tonkawa Creek Site 8	Caddo	8 6N 10W	6	21
109	Tonkawa Creek Site 9	Caddo	19 6N 10W	6	18
110	Tonkawa Creek Site 10	Caddo	19 6N 10W	4	9

Table 1-1. (Continued)

Map number	Name (designation)	County	Location			Area (acres)	Capacity (acre-feet)
111	Little Washita River Site 21	Comanche	7	4N	9W	6	46
112	Little Washita River Site 33	Comanche	2	4N	9W	6	30
113	Bitter Creek Site 3	Grady	20	8N	6W	6	52
114	Bitter Creek Site 9	Grady	16	8N	6W	4	38
115	Bitter Creek Site 10	Grady	1	8N	6W	3	21
116	Bitter Creek Site 11	Grady	1	8N	6W	9	40
117	Bitter Creek Site 12	Grady	26	8N	6W	6	28
118	Bitter Creek Site 21	Grady	34	7N	6W	7	32
119	Bitter Creek Site 22	Grady	3	6N	6W	6	24
120	Little Washita River Site 1	Grady	31	6N	6W	6	45
121	Little Washita River Site 10	Grady	30	5N	7W	7	20
122	Little Washita River Site 17	Grady	7	4N	8W	5	33
123	Little Washita River Site 41	Grady	20	6N	8W	5	32
124	Little Washita River Site 42	Grady	28	6N	8W	6	35
125	Little Washita River Site 43	Grady	28	6N	8W	4	30
126	Little Washita River Site 45	Grady	30	6N	7W	6	31
127	Roaring Creek Site 5	Grady	15	4N	6W	6	57
128	Roaring Creek Site 12	Grady	28	5N	6W	8	53
129	Roaring Creek Site 14	Grady	35	5N	6W	7	37
130	Roaring Creek Site 16	Grady	7	4N	6W	7	63
131	Roaring Creek Site 17	Grady	25	5N	7W	9	54
132	Roaring Creek Site 18	Grady	30	5N	6W	6	35
133	Roaring Creek Site S-1	Grady	10	5N	6W	4	12
134	Roaring Creek Site S-4	Grady	14	5N	6W	9	38
135	Roaring Creek Site S-5	Grady	14	5N	6W	6	14
136	Roaring Creek Site S-6	Grady	10	5N	6W	2	9
137	Roaring Creek Site D-1	Grady	32	6N	6W	5	24
138	Roaring Creek Site D-2	Grady	5	5N	6W	9	39
139	Roaring Creek Site D-3	Grady	7	5N	6W	5	23
140	Roaring Creek Site D-6	Grady	8	5N	6W	8	36
141	Rush Creek Site 5	Grady	36	4N	7W	9	36
142	Rush Creek Site 16	Grady	13	3N	6W	7	67
143	Rush Creek Site 43	Grady	23	3N	6W	5	33
144	Rush Creek Site 44	Grady	14	3N	6W	6	27
145	Rush Creek Site 49	Grady	31	4N	7W	8	38
						TOTAL	1,949

Table 1-2. Selected ground water data for the Cement area (Plotted on Plate 2, Figure A)

Map Reference Number	Location	County	Depth of Well (feet)	Depth to water (feet)	Yield (gal/min)
1	23 T3N R6W	Grady	40	30	1 (est.)
2	6 T3N R6W	Grady	27	22	N.S.
3	26 T3N R7W	Grady	200	55	N.S.
4	16 T3N R7W	Grady	60	33	N.S.
5	17 T3N R7W	Grady	301	29	N.S.
6	18 T3N R7W	Grady	155	18	N.S.
7	7 T3N R7W	Grady	152	39	N.S.
8	12 T3N R8W	Grady	94	31	N.S.
9	14 T3N R8W	Grady	140	40	260
10	11 T3N R8W	Grady	64	54	N.S.
11	2 T3N R8W	Grady	100	73	N.S.
12	3 T3N R8W	Grady	53	17	N.S.
13	22 T3N R8W	Grady	350	Unknown	N.S.
14	15 T3N R8W	Grady	45	34	N.S.
15	9 T3N R8W	Grady	95	13	N.S.
16	4 T3N R8W	Grady	40	22	N.S.
17	28 T3N R8W	Grady	550	50	800
18	6 T3N R8W	Grady	155	24	85
19	24 T3N R9W	Comanche	30	20	N.S.
20	2 T3N R9W	Comanche	120	18	60
21	8 T3N R9W	Comanche	300	42	60
22	5 T3N R9W	Comanche	136	106	N.S.
23	2 T3N R10W	Comanche	55	20	10
24	22 T3N R10W	Comanche	28	9	N.S.
25	28 T3N R10W	Comanche	125	21	N.S.
26	20 T3NR10W	Comanche	46	26	N.S.
27	8 T3N R10W	Comanche	91	17	N.S.
28	4 T3N R11W	Comanche	20	10	N.S.
29	29 T3N R11W	Comanche	65	20	N.S.
30	29 T3N R11W	Comanche	50	30	N.S.
31	4 T3N R12W	Comanche	21	13	N.S.
32	29 T3N R12W	Comanche	34	17	N.S.
33	15 T3N R12W	Comanche	14	4	N.S.

Table 1-2. (Continued)

Map Reference Number	Location	County	Depth of Well (feet)	Depth of Water (feet)	Yield (gal/min)
34	6 T3N R12W	Comanche	432	flows	1/8
35	26 T4N R6W	Grady	90	64	N.S.
36	1 T4N R6W	Grady	65	34	N.S.
37	5 T4N R6W	Grady	63	5	2
38	23 T4N R7W	Grady	70	49	N.S.
39	22 T4N R7W	Grady	180	71	N.S.
40	3 T4N R7W	Grady	161	145	30
41	3 T4N R7W	Grady	122	50	N.S.
42	3 T4N R7W	Grady	136	63	N.S.
43	9 T4N R7W	Grady	97	54	N.S.
44	9 T4N R7W	Grady	77	5	N.S.
45	16 T4N R7W	Grady	41	27	N.S.
46	21 T4N R7W	Grady	20	14	N.S.
47	5 T4N R7W	Grady	21	13	N.S.
48	29 T4N R7W	Grady	69	20	N.S.
49	30 T4N R7W	Grady	67	58	N.S.
50	32 T4N R7W	Grady	200	35	N.S.
51	36 T4N R8W	Grady	72	48	N.S.
52	25 T4N R8W	Grady	14	4	N.S.
53	26 T4N R8W	Grady	60	56	N.S.
54	23 T4N R8W	Grady	60	50	N.S.
55	15 T4N R8W	Grady	18	15	N.S.
56	10 T4N R8W	Grady	100	73	N.S.
57	21 T4N R8W	Grady	181	74	N.S.
58	33 T4N R8W	Grady	254	85	N.S.
59	28 T4N R8W	Grady	33	27	N.S.
60	20 T4N R8W	Grady	80	66	N.S.
61	17 T4N R8W	Grady	50	32	N.S.
62	6 T4N R8W	Grady	22	12	N.S.
63	26 T4N R9W	Comanche	70	21	200
64	2 T4N R9W	Comanche	Unknown	40	N.S.
65	33 T4N R9W	Comanche	101	20	N.S.
66	15 T4N R10W	Comanche	400	128	N.S.
67	4 T4N R10W	Comanche	100	Unknown	4

Table 1-2. (Continued)

Map Reference Number	Location	County	Depth of Well (feet)	Depth of Water (feet)	Yield (gal/min)
68	29 T4N R10W	Comanche	300	14	N.S.
69	7 T4N R10W	Comanche	160	14	20
70	11 T4N R11W	Comanche	260	Unknown	4
71	31 T4N R11W	Comanche	31	16	N.S.
72	31 T4N R11W	Comanche	19	8	N.S.
73	25 T4N R12W	Comanche	51	10	N.S.
74	36 T4N R12W	Comanche	spring	flows	N.S.
75	13 T4N R12W	Comanche	15	0	200
76	10 T4N R12W	Comanche	12	9	N.S.
77	4 T4N R12W	Comanche	55	13	N.S.
78	9 T4N R12W	Comanche	175	100	2
79	33 T4N R12W	Comanche	277	flows	N.S.
80	29 T4N R12W	Comanche	350	6	33
81	30 T4N R12W	Comanche	60	9	N.S.
82	33 T5N R6W	Grady	449	110	140
83	12 T5N R6W	Grady	105	30	N.S.
84	5 T5N R6W	Grady	80	34	76
85	33 T5N R7W	Grady	92	61	N.S.
86	20 T5N R7W	Grady	128	60	2
87	5 T5N R7W	Grady	17	11	N.S.
88	24 T5N R8W	Grady	409	30	N.S.
89	13 T5N R8W	Grady	365	flows	4
90	26 T5N R8W	Grady	66	13	N.S.
91	22 T5N R8W	Grady	420	110	25
92	14 T5N R8W	Grady	379	flows	55
93	3 T5N R9W	Caddo	200	50	27
94	35 T5N R9W	Caddo	300	35	N.S.
95	4 T5N R9W	Caddo	128	110	N.S.
96	16 T5N R9W	Caddo	200	Unknown	5
97	30 T5N R9W	Caddo	260	Unknown	5
98	18 T5N R9W	Caddo	1,010	692	N.S.
99	7 T5N R9W	Caddo	115	30	8
100	1 T5N R10W	Caddo	135	50	N.S.

Table 1-2. (Continued)

Map Reference Number	Location	County	Depth of Well (feet)	Depth of Water (feet)	Yield (gal/min)
101	1 T5N R10W	Caddo	181	24	N.S.
102	24 T5N R10W	Caddo	100	24	N.S.
103	34 T5N R10W	Caddo	100	Unknown	50
104	8 T5N R10W	Caddo	160	Unknown	5
105	8 T5N R10W	Caddo	79	49	N.S.
106	2 T5N R11W	Caddo	106	17	N.S.
107	21 T5N R11W	Caddo	307	Unknown	40
108	24 T5N R12W	Caddo	200	Unknown	2
109	13 T5N R12W	Caddo	200	Unknown	2
110	33 T5N R12W	Caddo	1,100	flows	1 (est.)
111	28 T5N R12W	Caddo	spring	flows	1 (est.)
112	28 T5N R12W	Caddo	350	55	120
113	16 T5N R12W	Caddo	22	18	N.S.
114	5 T5N R12W	Caddo	50	18	N,S.
115	18 T5N R12W	Caddo	spring	flows	40(est.)
116	36 T6N R6W	Grady	29	10	N.S.
117	26 T6N R6W	Grady	40	18	500
118	4 T6N R6W	Grady	56	63	N.S.
119	31 T6N R6W	Grady	86	15	35
120	34 T6N R7W	Grady	80	39	N.S.
121	33 T6N R7W	Grady	300	flows	N.S.
122	5 T6N R7W	Grady	225	N.S.	N.S.
123	19 T6N R7W	Grady	400	200	N.S.
124	23 T6N R8W	Grady	60	55	1
125	29 T6N R8W	Grady	105	52	N.S.
126	18 T6N R8W	Grady	80	73	N.S.
127	1 T6N R9W	Caddo	46	35	N.S.
128	28 T6N R9W	Caddo	134	60	65
129	17 T6N R9W	Caddo	Unknown	99	N.S.
130	22 T6N R10W	Caddo	133	54	N.S.
131	20 T6N R10W	Caddo	41	26	N.S.
132	20 T6N R10W	Caddo	108	42	N.S.
133	29 T6N R10W	Caddo	220	38	3

Table 1-2. (Continued)

Map Reference Number	Location	County	Depth of Well (feet)	Depth of Water (feet)	Yield (gal/min)
134	3 T5N R10W	Caddo	100	40	5
135	36 T6N R11W	Caddo	77	25	4
135	11 T6N R11W	Caddo	100	26	10
137	3 T6N R11W	Caddo	125	70	10
138	29 T6N R11W	Caddo	288	42	3
139	7 T6N R11W	Caddo	90	7	40
140	31 T5N R11W	Caddo	158	24	90
141	15 T6N R21W	Caddo	55	21	N.S.
142	27 T7N R6W	Grady	185	N.S.	N.S.
143	16 T7N R6W	Grady	105	N.S.	N.S.
144	9 T7N R6W	Grady	64	15	N.S.
145	8 T7N R6W	Grady	28	16	N.S.
146	32 T7N R6W	Grady	200	N.S.	N.S.
147	26 T7N R7W	Grady	24	2	N.S.
148	28 T7N R7W	Grady	200	25	N.S.
149(3 wells)	21 T7N R7W	Grady	44	27	80
150	17 T7N R7W	Grady	23	6	N.S.
151	8 T7N R7W	Grady	80	53	60
152	24 T7N R8W	Grady	22	14	N.S.
153	35 T7N R8W	Grady	34	18	N.S.
154	22 T7N R8W	Grady	22	18	N.S.
155	6 T7N R8W	Grady	40	N.S.	N.S.
156	4 T7N R9W	Caddo	36	10	100
157	17 T7N R9W	Caddo	97	15	N.S.
158	31 T7N R9W	Caddo	120	42	40
159	23 T7N R10W	Caddo	45	N.S.	N.S.
160	14 T7N R10W	Caddo	100	18	320
161	21 T7N R10W	Caddo	40	8	N.S.
162	8 T7N R10W	Caddo	76	15	8
163(5 wells)	24 T7N R11W	Caddo	30	10	100
164	11 T7N R11W	Caddo	108	6	N.S.
165	15 T7N R11W	Caddo	180	85	170

Table 1-2. (Continued)

Map Reference Number	Location	County	Depth of Well (feet)	Depth of Water (feet)	Yield (gal/min)
166	5 T7N R11W	Caddo	125	20	300
167	7 T7N R11W	Caddo	160	40	150
168	31 T7N R11W	Caddo	124	60	12
169	1 T7N R12W	Caddo	155	75	100
170	11 T7N R12W	Caddo	17	13	N.S.
171	34 T7N R12W	Caddo	57	44	N.S.
172	1 T8N R6W	Grady	61	43	N.S.
173	22 T8N R6W	Grady	64	37	N.S.
174	4 T8N R6W	Grady	36	32	N.S.
175	23 T8N R7W	Grady	40	25	N.S.
176	21 T8N R7W	Grady	65	20	15
177	21 T8N R7W	Grady	65	20	N.S.
178	21 T8N R7W	Grady	65	20	0
179	20 T8N R7W	Grady	25	20	N.S.
180	23 T8N R8W	Grady	20	8	N.S.
181	9 T8N R8W	Grady	27	9	10
182	20 T8N R8W	Grady	17	8	N.S.
183	20 T8N R8W	Grady	55	22	N.S.
184	1 T8N R9W	Caddo	22	8	N.S.
185	15 T8N R9W	Caddo	51	41	N.S.
186	28 T8N R9W	Caddo	36	24	N.S.
187	15 T8N R10W	Caddo	111	10	N.S.
188	5 T8N R10W	Caddo	82	N.S.	N.S.
189	32 T8N R10W	Caddo	172	N.S.	N.S.
190	30 T8N R10W	Caddo	84	70	250
191	20 T8N R11W	Caddo	230	109	400
192	8 T8N R11W	Caddo	250	N.S.	N.S.
193	13 T8N R12W	Caddo	212	65	600
194	35 T8N R12W	Caddo	170	N.S.	N.S.
195	3 T8N R12W	Caddo	260	56	750
195	21 T8N R12W	Caddo	215	40	520
197	19 T8N R12W	Caddo	256	N.S.	N.S.

Table 1-2. (Continued)

Map Reference Number	Location	County	Depth of Well (feet)	Depth of Water (feet)	Yield (gal/min)
198	3 T9N R6W	Grady	65	N.S.	N.S.
199	16 T9N R6W	Grady	27	25	N.S.
200	8 T9N R6W	Grady	39	dry	
201	19 T9N R6W	Grady	14	10	N.S.
202	11 T9N R7W	Grady	37	25	N.S.
203	35 T9N R7W	Grady	Unknown	22	N.S.
204	22 T9N R7W	Grady	43	23	N.S.
205	32 T9N R7W	Grady	50	N.S.	N.S.
206	30 T9N R7W	Grady	Unknown	24	N.S.
207	6 T9N R7W	Grady	27	7	N.S.
208	14 T9N R8W	Grady	39	31	N.S.
209	9 T9N R8W	Grady	36	17	N.S.
210	31 T9N R8W	Grady	22	3	N.S.
211	23 T9N R9W	Caddo	13	7	N.S.
212	16 T9N R9W	Caddo	62	49	N.S.
213	36 T9N R10W	Caddo	79	40	N.S.
214	1 T9N R10W	Caddo	Unknown	80	N.S.
215	14 T9N R10W	Caddo	88	87	N.S.
216	16 T9N R10W	Caddo	85	70	N.S.
217	4 T9N R10W	Caddo	57	22	N.S.
218	36 T9N R11W	Caddo	67	20	N.S.
219	11 T9N R11W	Caddo	60	50	N.S.
220	29 T9N R11W	Caddo	234	70	450
221	18 T9N R11W	Caddo	270	80	250
222	1 T9N R12W	Caddo	318	N.S.	N.S.
223	36 T9N R12W	Caddo	290	N.S.	N.S.
224	27 T9N R12W	Caddo	302	60	800
225	17 T9N R12W	Caddo	320	55	780
226	15 T9N R12W	Caddo	254	N.S.	N.S.
227	5 T9N R12W	Caddo	325	60	1,000

Table 3-1. Preferred Characteristics for Micellar-Polymer Flooding

Parameter	Haddenhorst (1976)	Bradshear & Kuvskraa (1978)
Lithology	sandstone	sandstone
Temperature	< 175° F	< 200° F
Net Pay Thickness	> 10 feet	NC
Permeability, md.	> 10	> 20
Viscosity @ Reservoir T	< 20	< 20
Gravity, °API	20-25	> 25
Salinity (ppm TDS)	< 50,000 (formation) < 5,000 (injection)	< 50,000*
Ca^{++} and Mg^{++}, ppm	< 500	< 1,000*

NC - Not critical.

*Considered a constraint under 1978 technology.

Table 3-2. Summary of Surface Water Chemical Analysis. (Plotted on plate 1, figure A)

Map Location Number	Stream and Location	Water Year(s)	Type of Sampling[a]	Calcium (mg/L) max	Calcium (mg/L) min	Magnesium (mg/L) max	Magnesium (mg/L) min	Sodium (mg/L)	Sodium (mg/L) max	Sodium (mg/L) min	Total Dissolved Solids (mg/L) max	Total Dissolved Solids (mg/L) min	Sodium Adsorption Ratio max	Sodium Adsorption Ratio min	Specific Conductance (micromhos/cm @ 25°C) max	Specific Conductance (micromhos/cm @ 25°C) min	References[b]
1	Rush Creek near Rush Springs	1953,1958	P,W	133	67	54	1.4		52	5.6	No data		1.3	.3	872	429	Murphy, 1955; WSP 1973
2	Hell Roaring Creek near Chitwood	1958	P	140	122	54	43	Na Na+K	31 54	31 54	No data		1.1	.6	1,170	1,030	Cummings, 1963
3	Washita River at Alex	1965-1971	D	280	24	107	3.6		180	3	1,670	140	2.7	.1	2,780	200	USGS Oklahoma Water Resources Data (1966-1972)
4	Washita River near Tabler	1947-1952	D	249	38	79	7.8	Na Na+K	127 166	54 .9	1,390	184	N.R.		2,030	55	Walling, 1951; WSP 1188, 1199, 1252
5	Little Washita River at or near Ninnekah	1949-1956 1958,1959 1962 1968-1971	P,D,W	529	57	163	2.4	Na Na+K	1,020 374	16 6.9	5,250	294	9.8	.2	7,510	474	Cummings, 1963; 1965b, 1974; Dover, 1952, 1953, 1954, 1958, 1959; Murphy, 1955; Walling, 1951; WSP 1352; USGS Oklahoma Water Resources Data (1969-1972)
6	West Bitter Creek near Tabler	1953 1960 1965-1971	P,D	240	15	111	4.4		106	2.4	1,200	83	1.9	.1	1,630	125	Cummings, 1966a; WSP, 1291; USGS Oklahoma Water Resources Data (1966-1972)
7	Washita River near Chickasha	1952,1953 1955 1958-1961	P,W	264	78	115	13	Na Na+K	103 116	10 .32	1,510	588	1.9	.2	1,810	548	Cummings, 1963, 1964, 1965a, 1966a; Dover, 1958; WSP 125, 1292
8	Tonkawa Creek near Anadarko	1968-1971	P,D	409	26	97	4.9		149	4.8	2,220	158	2.1	.2	2,670	227	WSP 2156
9	Sugar Creek near Anadarko	1949-1955	P	178	60	44	7.4	Na Na+K	79 43	11 13	913	462	1.4	.4	1,360	414	Dover, 1952, 1953, 1958; Walling, 1951; WSP 1252, 1292, 1353
10	Washita River near Anadarko	1952,1955 1965-1969 1971 1976-1978	P,D	385	30	230	2.7	Na Na+K	760 166	1.4 3.9	2,040	152	2.7	.1	2,700	245	Dover, 1958; WSP 1252; USGS Oklahoma Water Resources Data (1966-1970, 1972, 1977-1979)
11	Sugar Creek near Gracemont	1956-1960	P	138	48	55	11	Na Na+K	53 50	21 15	756	430	1.4	.3	1,130	499	Cummings, 1963, 1964, 1966a; Dover, 1959; Murphy, 1961
12	Cobb Creek near Fort Cobb (published as Pond Creek prior to 1960)	1947,1948 1950-1958 1960,1963	P	132	12	41	5.4	Na Na+K	39 49	3.4 3.4	626	149	5.6	.1	940	195	Cummings, 1963, 1966a, 1966b; Dover, 1952, 1953, 1958, 1959; Murphy, 1955, 1961; Walling, 1951; WSP 1950, 1252, 1352
13	Cache Creek near Apache	1950-1951	P	207	207	56	56	Na+K	95	95	1,220	1,220	N.R.		1,720	1,720	Dover, 1953
14	East Cache Creek near Elgin	1956-1958	D	172	24	56	4.4	Na Na+K	132 74	3.1 41	1,210	112	2.7	.1	1,840	171	Cummings, 1963; Dover, 1959
15	Medicine Creek near Fort Sill	1951	P	50	50	6.1	6.1	Na+K	11	11	190	190	N.R.		327	327	Dover, 1953
16	Beaver Creek near Sterling	1961	P	75	66	58	48		52	29	693	642	1.1	.6	914	793	Cummings, 1965a
17	Little Washita River near Cyril	1958	P	624	260	88	15	Na Na+K	52 82	32 6.2	No Data		.9	.1	2,680	1,230	Cummings, 1963
18	West Chetonia Creek near Cyril	1958	P	322	272	54	43	Na+K	89	84	No Data		1.3	1.2	2,100	1,910	Cummings, 1963
19	East Chetonia Creek near Cyril	1958	P	218	218	15	15	Na+K	47	47	No Data		.8	.8	1,310	1,230	Cummings, 1963
20	McCardo Creek near Cement	1958-1960	P	1,260	627	347	175	Na Na+K	3,230 4,390	2,000 2,100	16,000	8,420	29	18	25,800	13,300	Cummings, 1963, 1964, 1966a
21	Bill's Creek near Cement	1958	P	138	93	59	26	Na Na+K	77 86	77 86	No Data		1.8	1.5	1,430	1,270	Cummings, 1963
22	East Bitter Creek near Tabler	1960 1968-1971	P,D	1,800	8.4	78	6.2		40	3.4	514	84	.9	0	1,100	129	Cummings, 1966a; USGS Oklahoma Water Resources Data (1969-1972)
23	Spring Creek near Tabler	1968-1971	W	72	11	58	4.1		36	3.0	408	75	1.0	.2	699	121	USGS Oklahoma Water Resources Data (1969-1972)
24	West Salt Creek near Chickasha	1968-1971	D,W	200	18	125	4.9		458	5.7	1,990	75	8.6	.3	3,040	122	USGS Oklahoma Water Resources Data (1969-1972)

[a] W = weekly, D = daily, P = periodically.
[b] WSP = U.S.G.S. Water Supply Paper.

Table 3-3. Selected ground-water quality data for the Cement area.
(Plotted on plate 2, figure B)

Map Reference Number	Location	Na+K (mg/L)	Ca+Mg (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	Fluoride (mg/L)	Total Dissolved Solids (mg/L)	Well Depth (feet below land surface)	Depth to Water	Aquifer
3	26 T3N R7W	40	288	105	153	24		429	200	55	Permian
20	2 T3N R9W	40	1000	44	305	720		2900	101/120	18	Rush Springs, Chickasha, Duncan
41	3 T4N R7W	12	275	18	244	48		365	122	50	Permian
48	29 T4N R7W	0	425	53	198	144		603	69	20	Permian
64	2 T4N R9W	35	1125	0	214	960		1660	unknown	40	Rush Springs, Chickasha, Duncan
65	33 T4N R9W	63	1775	305	305	1548		1540	101/120	20	Rush Springs, Chickasha, Duncan
72	31 T4N R11W	92	425	53	458	240	0.6	754	19	8	Arbuckle-Timbered Hills
74	36 T4N R12W	35	275	53	290	72	0.2	412	spring	flows	Arbuckle-Timbered Hills
75	13 T4N R12W	23	275	26	275	48	0.1	349	15	0	Arbuckle-Timbered Hills
79	33 T4N R12W	362	0	298	244	108	35.0	940	277	flows	minor aquifer
83	12 T5N R6W	35	338	35	336	84		346	105	30	Alluvium and Terrace
85	33 T5N R7W	12	200	26	214	36		332	92	61	Permian
95	4 T5N R9W	40	925	18	229	816		1410	128	110	Rush Springs, Chickasha, Duncan
98	18 T5N R9W	173	350	53	229	492	0.4	1000	1010	692	Rush Springs, Chickasha, Duncan
111	SW¼ 28 T5N R12W	190	225	175	275	120	1.5	740	spring	flows	Arbuckle-Timbered Hills
112	NW¼ 28 T5N R12W	98	125	53	351	48	1.9	378	350	55	Arbuckle-Timbered Hills
115	18 T5N R12W	23	363	26	336	48	0.3	299	spring	flows	Arbuckle-Timbered Hills
120	34 T6N R7W	44	613	105	275	60		1060	80	39	Permian
121	33 T6N R7W	270	388	131	183	612		1330	300	flows	Permian
122	5 T6N R7W	518	1775	61	61	2700		4190	225	N.S.	Permian
125	29 T6N R8W	17	625	18	458	228		850	85/105	52	Rush Springs, Chickasha, Duncan
132	20 T6N R10W	29	400	35	244	168		590	108	42	Rush Springs, Chickasha, Duncan
139	7 T6N R11W	29	650	18	198	480		976	90	7	Rush Springs, Chickasha, Duncan
141	15 T6N R12W	46	350	44	458	24		478	55	21	Chickasha, Duncan
142	27 T7N R6W	52	475	26	473	72		648	185	N.S.	Permian
143	16 T7N R6W	17	325	44	275	60		407	105	N.S.	Permian
146	32 T7N R6W	86	338	53	305	168		598	200	N.S.	Permian
147	26 T7N R7W	132	188	88	214	156		563	24	2	Alluvium
151	8 T7N R7W	63	313	26	427	84		481	80	53	Terrace
155	6 T7N R8W	29	450	26	427	108		535	40	N.S.	Alluvium
156	4 T7N R9W	35	500	35	290	252		744	36	10	Alluvium
159	23 T7N R10W	17	338	35	198	84		390	45	N.S.	Rush Springs, Marlow
161	21 T7N R10W	29	263	26	153	72		432	40	8	Terrace
170	11 T7N R12W	58	438	61	183	312		772	17	13	Alluvium
171	34 T7N R12W	52	63	18	153	36		154	57	44	Rush Springs, Marlow
173	22 T8N R6W	81	113	35	214	36		284	64	37	Permian
175	23 T8N R7W	53	138	26	229	48		252	40	25	Permian
181	9 T8N R8W	132	500	53	564	240		870	27	9	El Reno Group
185	15 T8N R9W	40	600	26	244	348		957	51	41	Rush Springs, Marlow
188	5 T8N R10W	1495	2000	884	549	4536		9040	82	N.S.	Alluvium
189	32 T8N R10W	17	175	26	228	36		281	172	N.S.	Rush Springs, Marlow
192	8 T8N R11W	35	675	26	76	672		1120	250	N.S.	Rush Springs, Marlow
194	35 T8N R12W	29	150	0	168	60		263	170	N.S.	Rush Springs, Marlow
197	19 T8N R12W	17	213	26	214	48		307	256	N.S.	Rush Springs, Marlow
198	3 T9N R6W	40	263	26	153	36		452	65	N.S.	Terrace
199	16 T9N R6W	35	145	26	153	36		317	27	25	Terrace
203	35 T9N R7W	104	1025	35	442	288		840C	unknown	22	Permian
205	32 T9N R7W	109	913	79	9	300		975C	50	N.S.	Permian
209	9 T9N R8W	23	38	44	76	384		796	36	17	Rush Springs, Marlow
216	16 T9N R10W	35	275	26	244	36		343	85	70	Rush Springs, Marlow
217	4 T9N R10W	29	175	26	198	36		287	57	22	Rush Springs, Marlow
218	36 T9N R11W	35	750	70	168	528		1220	67	20	Rush Springs, Marlow
222	1 T9N R12W	23	138	0	168	24		180	318	N.S.	Rush Springs, Marlow
223	36 T9N R12W	23	188	9	168	96		310	290	N.S.	Rush Springs, Marlow
225	15 T9N R12W	23	263	18	183	132		408	254	N.S.	Rush Springs, Marlow

Table 3-4C. Analyses of formation water samples.

Stratigraphic Interval	Sample No.	pH	TDS	S.G.	Resistivity @ T (°C) ohm/meter	Barium (+ Strontium)	Bicarbonate	Calcium	Carbonate	Chloride	Iron (+ Alumina)	Magnesium	Sodium (+ Potassium)	Sulfate
					Reported as mg/L									
Pennsylvanian	1	-	150,493	1.094	-	-	18	8,533	-	91,799	-	1,696	46,563	46
Fortuna-Olson	2	-	170,321	1.117	.073 @ 15	(163)	62	9,120	0	105,000	-	2,550	53,460	129
Medrano	3	5.7	56,121	1.041	-	-	115	2,815	-	34,327	-	506	18,172	109
Marchand	4	6.6	50,234	1.035	.017 @ 20	-	79	840	-	30,276	-	209	18,470	360
Marchand	5	-	51,422	1.038	.170 @ 15	(2)	342	912	0	30,800	-	21	19,100	267
Marchand	6	7.8	44,581	1.032	.155 @ 27	43a	579	537	25	26,529	-	276	16,311	190
Rowe	7	-	178,181	1.108	-	-	27	9,701	-	110,008	-	1,972	56,471	2
Wade	8	-	152,044	1.097	-	-	294	7,099	-	93,357	-	1,534	49,646	115
Melton	9	-	46,237	1.036	-	-	791	5,003	-	28,689	-	685	12,603	1,533
Rowe	10	-	178,200	1.108	-	-	61	9,545	-	110,008	-	2,030	56,553	2
Noble-Olson	11	-	177,940	1.120	.065 @ 15	(140)	Tr	10,700	0	110,000	-	2,040	55,200	0
Culp	12	7.7	45,450	-	.145 @ 25	-	1,013	959	-	26,595	-	175	16,355	353
Medrano	13	-	84,872	1.058	-	-	330	2,726	-	52,477	(56)	597	(28,469)	178
Fortuna	14	-	110,288	1.077	-	-	81	4,002	-	67,587	-	1,675	36,334	576
Griffin	15	-	136,148	-	.063 @ 25	-	116	7,767	-	83,682	-	1,454	42,372	135
Medrano	16	-	114,981	1,079	-	-	220	4,947	-	70,223	-	933	38,290	330
Pontotoc	17	5.8	192,809	1.120	.065 @ 15	-	68	10,905	-	118,341	-	2,165	60,506	703
Medrano	18	6.1	114,012	1.079	-	0	138	5,124	-	69,613	present	898	(38,063)	176
Noble-Olson	19	-	124,500	1.084	-	-	108	5,305	-	76,084	-	1,504	(40,611)	887
Rowe	20	-	135,786	1.091	-	-	135	6,024	-	82,916	present	1,694	(44,120)	897
Medrano	21	6.7	112,115	1.078	-	0	332	4,352	-	68,300	present	797	(38,044)	291
Rowe	22	-	157,168	1.108	-	(668)	72	8,028	-	96,739	(63)	1,722	(49,939)	8
Rowe	23	-	143,168	-	.061 @ 25	-	64	7,593	-	88,312	-	1,534	46,654	11
Niles	24	5.9	154,000	1.105	-	-	37	8,900	nil	95,500	86	1,100	49,700	nil
Noble-Olson	25	-	68,700	-	.100 @ 25	-	104	4,010	-	43,650	-	1,560	20,960	380
Fortuna	26	-	122,035	1,082	-	136a	84	3,658	-	74,701	-	945	42,389	39
Medrano	27	7.1	103,662	1.072	-	0	397	3,879	-	63,043	present	727	(35,332)	285
Rowe	28	-	142,472	-	.061 @ 25	-	30	8,318	-	87,879	-	2,493	44,570	26
Niles	29	-	130,874	1.090	-	63	-	7,671	-	80,672	-	1,336	40,928	48
Garner	30	-	166,736	1.113	-	73	16	9,516	-	102,917	-	1,872	52,202	31
Yule	31	-	132,919	-	.053 @ 25	-	47	7,447	-	81,702	-	956	42,008	43
Wade	32	-	124,118	1.088	-	-	236	6,691	-	76,160	-	1,269	39,523	239

- Not analyzed.

[a]Strontium only.

Table 3-4W. Analyses of brine samples collected from waterflood units.

						Reported at mg/l										
Sample No.	Waterflood Unit	pH	TDS	S.G.	Resistivity @ T(°C) ohm/meters	Barium	Bicarbonate	Calcium	Carbonate	Chloride	Hydrogen Sulfide	Iron	Magnesium	Sodium	Sulfate
1	Niles 4-9	6.0	-	1.115	-	88	244	3,840	0	91,050	-	28.0	746	-	7
2	Medrana D-23	7.0	108,000	1.074	.052 @ 23	-	-	3,440	-	66,000	< 0.1	0.8	750	35,200	107
3	Curtis - B	6.7	131,000	1.086	.044 @ 25	-	-	5,650	-	80,000	0.1	14.0	1,380	40,800	< 0.5
4	Sterba - 1	6.1	-	1.130	-	10	97	5,040	0	121,400	-	43.0	1,360	-	227
5	Margaret	6.4	174,000	1.115	.034 @ 25	-	-	8,020	-	104,000	0.2	19.0	1,800	53,800	< 0.5
6	Emma	6.7	96,000	1.062	.057 @ 23	-	-	2,600	-	56,000	< 0.1	46.0	880	31,800	< 0.5
7	Melton	6.4	127,000	1.082	.045 @ 26	-	-	5,280	-	77,000	< 0.1	44.0	1,350	40,400	< 0.5
8	Kidd-Manning	5.5	195,681	-	-	-	-	11,750	-	104,000	0.1	52.0	2,120	-	nil
9	W. Cement	6.5	161,368	1.111	.052 @ 20	330	100	8,990	0	99,300	absent	38.0	1,510	51,100	0
10	Cement - 1	5.4	217,464	1.147	.044 @ 20	316	12	13,100	0	134,000	absent	66.0	1,970	68,000	0
11	E. Cement	6.1	176,990	1.119	.049 @ 20	262	54	9,620	0	109,000	absent	58.0	1,720	56,300	0
12	Niday - 4	5.9	-	1.130	-	118	195	7,120	0	121,400	-	54.0	875	-	42
13	Thomas	5.3	174,000	1.112	.034 @ 25	-	-	8,980	0	108,000	< 0.1	50.0	1,610	52,800	< 0.5

Table 3-5. Methods Employed for Brine Analyses

Determination	Method
pH	electrode and meter
Resistivity	calculated from conductance measurement
Specific Gravity	hydrometer
TDS	gravimetric; 1 ml dried @ 180°C
Calcium	1.2 μ filter; atomic absorption
Chloride	titration; argentometric
Hydrogen Sulfide	Hach kit
Iron	
Total	HCl digestion; atomic absorption
Dissolved	1.2 μ filter; atomic absorption
Magnesium	1.2 μ filter; atomic absorption
Sodium	1.2 μ filter; atomic absorption
Sulfate	gravimetric; precipitated with barium

TABLE 3-6: RESERVOIR CHARACTERISTICS IN CEMENT FIELD

FORMATION FORTUNA SAND

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
33-6N-9W	1510-32	92	-	0.050	10-18	17	-	5-26	140,000
33-6N-9W	1580-1620	93	-	0.050	14-22	20	-	5-26	140,000
33-6N-9W	1680-1704	94	-	0.050	3-8	22	-	5-26	130,000
33-6N-9W	1854-80	95	-	0.049	9-12	18	-	5-26	150,000
33-6N-9W	2364-88	99	-	0.047	7-9	26	-	5-26	125,000
36-6N-10W	1650-70	93	-	0.055	7-12	22	-	5-26	140,000
36-6N-10W	1710-52	94	-	0.055	12-18	24	-	5-26	140,000
36-6N-10W	1900-40	96	-	0.055	9-16	14	-	5-26	140,000
30-6N-9W	2100-12	96	-	0.048	11	18	-	5-26	139,000
30-6N-9W	2180-94	97	-	0.048	9-18	20	-	5-26	139,000
30-6N-9W	2270-2300	98	-	0.047	7-10	21	-	5-26	130,000
30-6N-9W	2500-30	100	-	0.046	9-13	19	-	5-26	140,000
18-5N-8W	2180-2200	96	-	0.270	7-10	20	-	5-26	18,000
18-5N-8W	2310-40	98	-	0.270	5-10	21	-	5-26	18,000
18-5N-6W	2410-40	99	-	0.270	5-11	22	-	5-26	18,000
2-5N-9W	1600-10	-	-		17	20	-	21-33	-
2-5N-9W	1712-28	-	-		10	21	-	5-24	-
2-5N-9W	1880-90	-	-		17	18	-	17-24	-
2-5N-9W	2012-34	-	-		20	18	-	10-26	-
2-5N-9W	2092-2110	-	-		12	21	-	20-40	-
1-5N-10W	1906-28	-	-		-	18	-	15-25	-
1-5N-10W	2544-58	100	-50	0.055	3	21	18	15-26	100,000
8-5N-9W	2076-88	-	-		-	23	-	15-26	-
8-5N-9W	2182-2206	-	-		-	24	-	5-26	-
29-6N-10W	2070-82	-	-		-	22	-	5-26	-
29-6N-10W	2342-52	-	-		-	25	-	5-26	-

FORMATION GARNER SAND

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
1-5N-10W	3532-88	108	-90	0.052	1	21	90	40-65	100,000
2-5N-10W	3900-4000	112	-70	0.100	2	24	67	40-65	45,000
2-5N-10W	4110-40	113	-65	0.100	2.1	24	83	40-65	45,000
2-5N-10W	3652-3700	109	-85	0.046	1	23	68	40-65	140,000
2-5N-10W	4000-50	112	-86	0.050	1	21	84	40-65	100,000
26-5N-10W	3740-54	110	-52	0.150	6	20	80	40-65	46,000
26-5N-10W	3790-3810	110	-98	0.060	2	14	100	40-65	80,000
26-5N-10W	3840-60	111	-83	0.083	2	17	100	40-65	60-000

FORMATION GRIFFIN SAND

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
29-6N-10W	5130-50	120	-	0.046	2.8	14	83	40-65	100,000
29-6N-10W	5060-5130	120	-	0.046	-	-	-	40-65	100,000
21-6N-10W	5250-72	122	-63	0.061	2.1	21	65	40-65	78,000
21-6N-10W	5314-40	123	-80	0.035	2.0	22	45	40-65	78,000
21-6N-10W	5466-98	123	-62	0.071	1.4	23	81	40-65	60,000

TABLE 3-6 (continued)

FORMATION CULP MELTON

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
13-5N-9W	5728-5812	126	-	0.088	30	14-21	28-43	2-13	50,000
22-5N-9W	8552-64	131	-20	0.598	80	10	40	2-13	65,000
22-5N-9W	8904-08	133	-10	0.168	150	4	50	2-13	22,000
22-5N-9W	8954-71	134	-40	0.099	20	8	60	2-13	40,000
22-5N-9W	8980-9004	134	-45	0.250	20	12	55	2-13	13,000
22-5N-9W	9120-50	135	-40	0.181	100	5	50	2-13	18,000
22-5N-9W	9170-98	135	-35	0.171	170	4	40	2-13	23,000
36-6N-10W	5546-60	124	-	0.042	-	6	-	2-13	-
35-6N-9W	6204-26	-	-	-	-	16	-	2-13	-
35-6N-9W	6342-66	-	-	-	-	14	-	2-13	-
35-6N-9W	6470-6520	-	-	-	-	18	-	2-13	-
35-6N-10W	6010-70	129	-	0.040	-	18	-	2-13	110,000
12-5N-9W	4736-50	118	-	0.094	30	8	75	2-13	49,000
12-5N-9W	4756-90	118	-	0.094	32	9.5	61	2-13	49,000

FORMATION MEDRANO

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
22-5N-9W	8230-8300	130	-25	0.373	70-90	8	45	108-440	8,300
36-6N-10W	4704-50	118	-	0.044		7-17	-	108-440	-
35-6N-9W	5700-80	-	-	-	-	20	-	108-440	-
35-6N-10W	5024-44	120	-	0.043	-	18	-	108-440	125,000
35-6N-10W	5046-58	120	-	0.043	-	14	-	108-440	125,000
35-6N-10W	5078-5104	120	-	0.043	-	4	-	108-440	125,000
35-6N-10W	5134-66	121	-	0.043	-	10	-	108-440	125,000
35-6N-10W	5180-96	121	-	0.043	-	18	-	108-440	125,000
21-6N-10W	7790-7840	142	.55	0.070	13	8	58	108-440	51,000

FORMATION ROWE SAND

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
13-5N-9W	3750-60	110	-	0.102	5	20	100	50-100	46,000
22-5N-9W	5198-5248	111	-67	0.0974	1.7	23	70	50-100	50,000
22-5N-9W	5290-5318	111	-90	0.1062	1.9	22	80	50-100	45,000
22-5N-9W	5560-5394	113	-81	0.0532	1.4	19	70	50-100	85,000
22-5N-9W	5708-5716	114	-55	0.0733	3	15	80	50-100	68,000
22-5N-9W	5840-5866	115	-89	0.060	1.9	17	80	50-100	79,000
1-5N-10W	3950-90	112	-110	0.043	1.0	175	100	50-100	143,000
1-5N-10W	4020-40	112	-97	0.043	1.4	16	100	50-100	143,000
1-5N-10W	4110-40	113	-100	0.045	2	20	60	50-100	143,000
21-6N-10W	5688-5712	126	-61	0.074	2.1	19	80	50-100	70,000
2-5N-10W	4280-4310	114	-81	0.096	2	22	83	50-100	50,000
2-5N-10W	4422-50	115	-100	0.045	1	24	62	50-100	140-000
29-6N-10W	5630-50	125	-	0.046	4.9	15	59	50-100	98,000
35-6N-9W	4108-24	-	-	-	-	17	-	50-100	-
35-6N	4124-42	-	-	-	-	16	-	50-100	-

TABLE 3-6 (continued)

FORMATION NILES SAND

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
1-5N-10W	4320-90	115	-60	0.100	10	16	48	40-90	42,000
2-5N-10W	4680-4700	117	-76	0.089	2.1	25	58	40-90	55,000
2-5N-10W	4760-80	118	-80	0.080	3.9	21	53	40-90	55,000
21-6N-10W	6130-50	129	-38	0.073	30	9	42	40-90	59,000
2-5N-10W	4680-4760	118	-80	0.093	5	19	56	40-90	50,000
29-6N-10W	5664-90	125	-	0.046	4.9	15	59	40-90	98,000
29-6N-10W	5730-50	126	-	0.046	3.9	10	100	40-90	96,000
29-6N-10W	5776-5802	126	-	0.046	5	15	58	40-90	96,000
29-6N-10W	5816-68	126	-	0.046	3	14	81	40-90	96,000
29-6N-10W	5924-54	127	-	0.046	4.5	15	61	40-90	95,000
35-6N-9W	4456-94	-	-	-	-	18	-	40-90	-

FORMATION WADE SAND

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
13-5N-9W	4750-4850	118	-	0.097	6	23	47	60-110	50,000
22-5N-4W	6740-60	120	-85	0.038	3	6-18	100	60-110	180,000
22-5N-9W	7030-7104	122	-118	0.032	2.5	18	100	60-110	180,000
21-6N-10W	6960-7010	136	-58	0.073	6.5	12	69	60-110	55,000
21-6N-10W	7060-80	136	-62	0.073	4	13	98	60-110	55,000
21-6N-10W	7390-7412	139	-	0.033	25	15	25	60-110	90,000
21-6N-10W	7520-40	140	-	0.033	25	10	35	60-110	90,000
21-6N-10W	7576-96	141	-	0.033	25	3	100	60-110	90,000
29-6N-10W	7180-96	137	-	0.046	27	7	56	60-110	94,000
35-6N-10W	4980-5010	120	-	0.043	-	19	-	60-110	125,000
35-6N-9W	4950-70	119	-		-	19	-	60-110	-

FORMATION UNNAMED

*From SPE Reprints Series, "Survey of resistivities of water from subsurface formations in Oklahoma," March 1975.

**From charts using Rw and T.

Location	Depth (ft)	Temperature (°F)	SP (mv)	*Rw (ohm-m)	Rt (ohm-m)	Ø (%)	Sw (%)	K (md) calc.	** Salinity (ppm)
18-5N-8W	3680-3722	109	-38	0.046	1.5	23	24	40-120	140,000
18-5N-8W	3850-3884	110	-38	0.046	2	21	61	40-120	140,000
18-5N-8W	4160-4188	113	-26	0.082	2.5	25	78	40-120	40,000
18-5N-8W	4424-58	115	-31	0.058	2	18	100	40-120	90,000
18-5N-8W	4600-30	117	-42	0.035	0.55	23	71	40-120	200,000
18-5N-8W	5140-90	121	-48	0.031	0.6	18	69	40-120	200,000
18-5N-8W	5550-5620	124	-33	0.052	4	13	74	40-120	92,000
18-5N-8W	6740-6900	135	-48	0.032	3.5	16	89	2-15	160,000
18-5N-8W	7160-7254	138	-22	0.084	35	3-5	52	2-15	46,000
18-5N-8W	8104-42	145	-18	0.110	23	10	63	2-15	34,000
18-5N-8W	9472-88	156	-20	0.084	20-30	6	93	2-15	40,000
36-6N-9W	3840-68	110	-60	0.050	1	23	61	40-120	100,000
36-6N-9W	4000-30	112	-60	0.050	1	23	61	40-120	110,000
36-6N-9W	4500-90	116	-70	0.050	0.35	22	100	40-120	110,000
36-6N-9W	4805-35	118	-68	0.050	1	22	64	40-120	125,000
36-6N-9W	5202-35	121	-61	0.050	0.5	26	81	40-120	97,000
36-6N-9W	6290-6320	130	-76	0.050	1	23	65	40-120	84,000
36-6N-9W	7018-64	136	-70	0.050	2	13	62	40-120	80,000
36-6N-9W	8772-94	150	-	0.100	2.6	12.5	75	40-120	73,000

TABLE 3-6 (continued)

22-5N-9W	4230-66	105	-80	0.056	1.2	21	70	50-100	100,000
22-5N-9W	4290-4334	106	-60	0.086	1.5	23	70	50-100	58,000
22-5N-9W	4424-52	106	-55	0.061	1.4	21	60	50-100	78,000
22-5N-9W	4620-52	107	-65	0.110	1.8	24	70	50-100	42,000
22-5N-9W	4850-76	109	-80	0.069	1.3	23	60	50-100	69,000
22-5N-9W	4980-5020	110	-64	0.042	1.0	20	70	50-100	135,000
22-5N-9W	5914-34	115	-75	0.070	1.5	21	70	50-100	66,000
22-5N-9W	6034-68	116	-90	0.072	2.0	18	80	50-100	67,000
13-5N-9W	3846-82	111	-	0.102	5	20	74	50-100	46,000
13-5N-9W	4004-28	112	-	0.098	6	23	59	50-60	50,000
13-5N-9W	4510-30	116	-	0.095	2	18	100	50-60	50,000
21-6N-10W	3910-30	111	- 50	0.053	2.1	24	50	50-60	100,000
21-6N-10W	4258-4302	114	-60	0.078	1.8	22	75	50-60	62,000
21-6N-10W	4300-4410	115	-68	0.091	2	22	85	50-60	50,000
21-6N-10W	4760-4800	119	-44	0.141	2.2	21	100	50-60	30,000
21-6N-10W	5100-32	121	-59	0.080	2.5	21	65	50-60	50,500
21-6N-10W	5590-5620	124	-63	0.075	2.3	19	76	50-60	70,000
1-5N-9W	8490-8510	148	-10	0.082	60	4-6	75	200-260	42,000
1-5N-9W	8650-70	149	-50	0.082	30	8	45	200-260	42,000
1-5N-9W	9250-9400	155	-30	0.079	10-20	9	75	200-260	48,000
1-5N-9W	9570-9740	160	-80	0.076	200	2-4	38	200-260	48,000
12-5N-9W	7860-80	143	-	0.078	36	4	100	200-260	50,000
12-5N-9W	8980-9010	152	-	0.074	30	10	60	200-260	50,000
12-5N-9W	9720-40	157	-	0.071	30	10	60	200-260	50,000
33-6N-9W	1248-60	90	-	0.051	9-12	22	-	25-100	140,000
33-6N-9W	1260-80	90	-	0.051	11-15	23	-	25-70	140,000
33-6N-9W	2682-2704	101	-	0.046	8-10	23	-	25-40	135,000
33-9N-9W	2860-80	103	-	0.045	5-6	22	-	10-25	135,000
33-9N-9W	3192-3204	106	-	0.044	8-10	12	-	10-25	134,000
36-6N-10W	2190-2220	97	-	0.053	8-13	23	-	25-60	100,000
36-6N-10W	2320-60	98	-	0.052	7-12	24	-	25-40	100,000
36-6N-10W	2510-40	100	-	0.052	9-13	20	-	25-35	110,000
30-6N-9W	1660-90	93	-	0.050	1-6	20	-	10-30	130,000
30-6N-9W	1780-1810	94	-	0.049	1-5	22	-	10-18	130,000
30-6N-9W	2610-40	101	-	0.046	9-13	19	-	10-17	140,000
30-6N-9W	2910-30	103	-	0.045	2-6	21	-	10-60	140,000
18-5N-8W	2040-60	96	-	0.270	6-11	24	-	10-18	17,000
18-5N-8W	2570-2600	100	-	0.260	4-10	22	-	10-18	18,000
18-5N-8W	3020-50	104	-	0.242	2-6	22	-	4-10	20,000
18-5N-8W	3400-20	105	-	0.240	9-18	21	-	10-27	20,000
18-5N-8W	3680-3715	109	-	0.240	4-10	21	-	9-24	20,000
2-5N-9W	1478-94	-	-	-	10-16	16	-	9-24	-
2-5N-9W	2338-60	-	-	-	5-15	20	-	9-24	-
1-5N-10W	2012-32	-	-	-	-	20	-	9-24	-
1-5N-10W	2210-30	-	-	-	-	12	-	9-24	-
1-5N-10W	2820-60	-	-	-	-	19	-	9-24	-
34-6N-9W	8726-80	150	-	0.050	-	10	35	2-13	70,000
34-6N-9W	8980-9000	152	-	0.050	-	12	38	2-13	70,000
34-6N-9W	9340-80	155	-	0.050	-	3	64	2-13	65,000
34-6N-9W	10506-514	164	-	0.050	-	8	70	2-13	62,000
34-6N-9W	10700-720	165	-	0.050	-	6	45	2-13	62,000
34-6N-9W	13130-142	185	-	0.050	-	2	40	2-13	59,000
34-6N-9W	14450-462	195	-	0.050	-	4	40	2-13	55,000
34-6N-9W	15640-690	205	-	0.050	-	6	45	2-13	54,000
34-6N-9W	16500-600	212	-	0.050	-	12	30	2-13	51,000
34-6N-9W	16870-890	215	-	0.050	-	8	50	2-13	45,000

TABLE 3-6 (continued)

21-6N-10W	5922-50	127	-68	0.069	2.8	19	65	2-26	60,000
21-6N-10W	6340-70	130	-60	0.073	3.1	17	72	2-26	70,000
21-6N-10W	6712-6826	134	-56	0.073	4.5	11	100	2-26	55,000
21-6N-10W	9380-9460	155	-	0.071	63	20	20	2-26	58,000
21-6N-10W	10730-750	166	-	0.071	35	10	50	2-26	56,000
21-6N-10W	11877-80	175	-	0.100	-	7	52	2-26	28,000
21-6N-10W	14052-60	192	-	0.100	150	5-8	38	2-26	24,000
21-6N-10W	17725-35	221	-	0.100	100	6.5	50	2-26	21,000
2-5N-10W	4944-64	119	-90	0.060	1.5	28	43	50-60	79,000
2-5N-10W	5340-62	123	-80	0.060	2.1	27	40	50-60	79,000
2-5N-10W	5680-5754	126	-70	0.100	1.1	18	100	50-60	40,000
2-5N-10W	6000-48	128	-80	0.094	2.3	18	94	50-60	41,000
2-5N-10W	6150-72	130	-90	0.051	12	13	37	50-60	82,000
1-5N-10W	3720-50	110	-110	0.043	1.5	18	76	50-100	143,000
1-5N-10W	4680-4712	117	-105	0.042	4	15	52	50-100	142,000
1-5N-10W	2210-28	98	-40	0.056	6	15	36	5-26	110,000
1-5N-10W	2464-84	99	-40	0.055	3	14	42	5-26	110,000
1-5N-10W	2544-58	100	-50	0.055	3	21	18	5-26	110,000
1-5n-10W	2920-44	103	-45	0.053	2	15	39	5-26	120,000
1-5N-10W	3300-14	106	-	0.052	4	10	87	5-26	120,000
8-5N-9W	1982-2010	-	-	-	-	21	-	5-26	-
29-6N-10W	3026-38	-	-	-	-	26	-	5-26	-
29-6N-10W	3080-88	-	-	-	-	20	-	5-26	-
12-5N-9W	1240-50	90	-	-	9-12	21	-	5-26	-
12-5N-9W	1670-1700	93	-	-	8-11	24		5-26	-
22-5N-9W	1368-80	-	-	-	-	24		5-26	-
22-5N-9W	1770-94	-	-	-	-	25		5-26	-
22-5N-9W	1960-96	-	-	-	-	23		5-26	-
22-5N-9W	2598-2630	-	-	-	-	21		5-26	-
22-5N-9W	2906-18	-	-	-	-	20		5-26	-
22-5N-9W	3190-3224	-	-	-	-	23		5-26	-
22-5N-9W	3732-50	-	-	-	-	20		5-26	-
2-5N-10W	4982-5030	120	-94	0.050	2	23	48	120-300	90,000
2-5N-10W	5331-51	122	-90	0.049	5	20	82	120-300	51,000
2-5N-10W	6715-80	130	-120	0.040	4	18	40	120-300	110,000
21-6N-10W	3990-4008	110	-	0.042	18	8	60	50-60	120,000
21-6N-10W	4052-76	112	-	0.041	4	5	100	50-60	120,000
21-6N-10W	4110-26	113	-	0.041	8	21	40	50-60	120,000
21-6N-10W	4276-96	114	-	0.040	4	26	35	50-60	111,000
22-6N-10W	3860-90	111	-71	0.109	3	20	84	50-60	45,000
22-6N-10W	4010-32	112	-61	0.150	4	24	72	50-60	45,000
22-6N-10W	4300-4334	114	-91	0.058	2	17	91	50-60	140,000
29-6N-10W	3330-50	106	-	0.046	2.6	15	80	50-60	130,000
29-6N-10W	3366-90	107	-	0.046	3.8	22	45	24-110	130,000
29-6N-10W	3616-46	108	-	0.046	1.5	23	69	24-110	130,000
29-6N-10W	3800-42	110	-	0.046	2 4	20	61	24-110	110,000
29-6N-10W	4316-28	114	-	0.046	9.1	7	97	24-110	105,000
29-6N-10W	5924-54	127	-	0.046	5	15	61	24-110	95,000
29-6N-10W	6582-6622	132	-	0.046	8	12	58	24-110	94,000