TEXAS
WATER
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BOARD

REPORT 52

OCCURRENCE AND QUALITY OF GROUND WATER IN ARCHER COUNTY, TEXAS

JULY 1967

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OCCURRENCE AND QUALITY OF GROUND WATER

IN ARCHER COUNTY, TEXAS

By

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Texas Water Development Board

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in cooperation with the
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FOREWORD

On September 1, 1965 the Texas Water Commission (formerly, before February 1962, the State Board of Water Engineers) experienced a far-reaching realignment of functions and personnel, directed toward the increased emphasis needed for planning and developing Texas' water resources and for administering water rights.

Realigned and concentrated in the Texas Water Development Board were the investigative, planning, development, research, financing, and supporting functions, including the reports review and publication functions. The name Texas Water Commission was changed to Texas Water Rights Commission, and responsibility for functions relating to water-rights administration was vested therein.

For the reader's convenience, references in this report have been altered, where necessary, to reflect the current (post September 1, 1965) assignment of responsibility for the function mentioned. In other words credit for a function performed by the Texas Water Commission before the September 1, 1965 realignment generally will be given in this report either to the Water Development Board or to the Water Rights Commission, depending on which agency now has responsibility for that function.

Ground-water studies that are currently being conducted by the staff of the Texas Water Development Board in a block of counties in north-central Texas were undertaken by the Texas Water Commission beginning January 1962 to meet a growing need for more detailed and accurate ground-water information in this area.

In recognizing the significance of ground water in this area, the Water Development Board is aware of the vital need for obtaining information on the depth of occurrence of usable quality water as the basis for providing adequate and equitable protection for these water supplies.

As initially planned, the investigations will be conducted in the following counties: Archer, Brown, Callahan, Clay, Coleman, Eastland, Jack, Jones, Montague, Palo Pinto, Shackelford, Stephens, Taylor, Throckmorton, and Young Counties. In these counties, several towns with municipal water supplies are served by ground water or have water wells as a standby supply. In addition to meeting municipal needs for water, ground water is often the sole source supplying domestic, farm, and ranch needs.

The area under study is underlain by Pennsylvanian and Permian rocks which either crop out at the surface or underlie Cretaceous and alluvial sediments at shallow depths. Ground water occurs erratically in shallow discontinuous zones of low permeability in Pennsylvanian and Permian rocks, in sands and fractured limestones in the relatively thin Cretaceous sediments, and in Pleistocene to Recent alluvial sediments that are found at the surface in parts of most of the counties included in this study. Initially the objective of these investigations was to provide additional data for use in making recommendations to the Railroad Commission and oil industry as to the depth to which usable quality water should be protected. It was recognized early in the course of the investigations, however, that the scope of the program should be enlarged to provide information for the use of landowners and others interested in water-resource development to facilitate development of the ground-water supplies available.

The present program of study has been under consideration for several years, although personnel had not been available to initiate such a long-range study. However, the scope, objectives, and methods of study to be employed had been part of the planning of the Texas Water Commission, and when funds became available to begin these investigations they were included in the ground-water program of the Commission.

In January 1962, funds allocated to the then Texas Water Commission by the Texas Water Pollution Control Board, for the purpose of investigation and prevention of ground-water pollution made possible the beginning of the present program. These funds were allocated to the Water Commission by the Pollution Control Board under the provision of the Act creating the Pollution Control Board which directs the Texas Water Commission to, "...investigate and ascertain those situations in which the underground waters of the State are being polluted or are threatened with pollution, and it shall report all findings to the Board together with its recommendations in regard thereto."[1/]

It was determined that these studies could be most feasibly conducted on a county-by-county basis, and the initial investigations were begun in Stephens, Young, and Brown Counties. Reports from the results of the investigations in Stephens and Young Counties were published as Texas Water Commission Bulletins 6412 and 6415, respectively, whereas, on September 1, 1965 the ground-water programs became the responsibility of the Texas Water Development Board. Reports on each of the 13 remaining counties will be prepared and published by the Texas Water Development Board as the field studies are completed.

Texas Water Development Board

John J. Vandertulip

John J. Vandertulip
Chief Engineer

1/ 57th Texas Legislature, 1961, Article 7621d, Vernon's Civil Statutes.

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ABSTRACT

Archer County is in the outcrop area of upper Pennsylvanian and lower Permian strata in north-central Texas. Usable ground water is generally limited to zones of the Cisco Group (upper Pennsylvanian) in the southeast quarter of the county. In other areas of the county, usable ground water is of erratic occurrence at shallow depths in the Wichita Group (lower Permian).

Comparison of chemical analyses of ground water in Archer County shows that the water generally increases in mineralization with increasing well depth. High chloride concentrations in water from some wells do not coincide with the normal depth variation, or with the usual quality of ground water produced by other wells in the same areas.

Methods of disposal of oil-field brine account for impairment of quality of some of the ground water in Archer County. Reported brine production for 1961 was 38,353,262 barrels; 99 percent of this brine was reportedly returned to the subsurface through injection and disposal wells.

OCCURRENCE AND QUALITY OF GROUND WATER IN ARCHER COUNTY, TEXAS

INTRODUCTION

Purpose and Scope

The economy and future growth of the north-central Texas area is affected by the availability of usable quality water. Because surface-water supplies of good quality are scarce, additional information regarding the occurrence and chemical quality of ground water was essential to the evaluation of potential water-resource development of the area. The purpose of this study in Archer County was to obtain information regarding occurrence and chemical quality of ground water for use by landowners and others, and to provide sufficient information to State agencies that are responsible for the protection of usable ground water from contamination. The administration of the latter, based on field study data, is designed to be both adequate for the protection of usable-quality ground water and equitable when applied to industries operating within the county.

The objectives of the Archer County study were to obtain basic data on the underground occurrence of usable water; to tabulate available data on brines produced with oil and gas and to determine the location and method of disposal of the brine; to review surface casing and subsurface disposal regulations, in the light of field observation and determine where revisions were needed; and to prepare a report for the use of landowners, the Texas Water Development Board, and other State, private, and Federal agencies.

This report was prepared under the general direction of John J. Vandertulip, Chief Engineer, Richard C. Peckham, director, Ground Water Division, and Bernard B. Baker, assistant director in charge of Availability Programs, and under the direct supervision of Loyd E. Walker, coordinator, West Texas Field Investigation Programs.

Method of Investigation

An inventory of 219 water wells was conducted in 1963 to determine the depths of wells and the type of well construction. This is nearly a complete well inventory for Archer County; a few domestic wells were omitted in the towns of Windthorst and Scotland because of the relatively close spacing of the wells.

Elevations were established on all wells and springs by altimeter with the aid of topographic maps and grade elevations furnished by the Texas

Highway Department. To determine the quality characteristics of the ground water, 207 water samples were collected for chemical analysis.

Available electric logs were used as an aid in the interpretation of subsurface geologic conditions that affect the occurrence of ground water.

Oil-field brine disposal practices were observed, and brine analyses were studied to determine their chemical characteristics. Information concerning brine production was taken from the 1961 salt water inventory conducted by the Railroad Commission of Texas in cooperation with the Texas Water Commission and the Texas Water Pollution Control Board.

Previous Investigations

Recent reconnaissance investigations were made of ground-water resources of the Brazos River basin (Cronin and others, 1963), the Red River basin (Baker and others, 1963), and the Trinity River basin (Peckham and others, 1963), each of these including part of Archer County, but coverage within the county was generalized as would be expected in studies of this type.

Stratigraphy of the north-central Texas area is discussed in Plummer and Moore (1921) and Cheney (1929). Selected references are listed at the end of this report.

Acknowledgements

Appreciation is expressed to the many farmers and ranchers, water well drillers, and oil operators who generously contributed information which aided in this investigation.

Well-Numbering System

The numbers assigned to wells and springs in this report conform to the statewide well-numbering system used by the Texas Water Development Board. This system is based on the division of the State into quadrangles of degrees of latitude and longitude, and repeated division of these quadrangles into smaller ones as shown on Figure 1.

The largest quadrangle, a 1-degree quadrangle, is divided into sixty-four $7\frac{1}{2}$-minute quadrangles, each of which is further divided into nine $2\frac{1}{2}$-minute quadrangles. Each 1-degree quadrangle in the State has been assigned a number (from 1 through 89) for identification. The $7\frac{1}{2}$-minute quadrangles are numbered consecutively from left to right beginning in the upper left hand corner of the 1-degree quadrangle, and the $2\frac{1}{2}$-minute quadrangles within the $7\frac{1}{2}$-minute quadrangle are similarly numbered. The first two digits of a well number identify the 1-degree quadrangle, the second two digits identify the $7\frac{1}{2}$-minute quadrangle, and the fifth digit identifies the $2\frac{1}{2}$-minute quadrangle. The last two digits designate the order in which the well was inventoried within the $2\frac{1}{2}$-minute quadrangle.

Archer County lies wholly within 1-degree quadrangle number 20 shown in Figure 1.

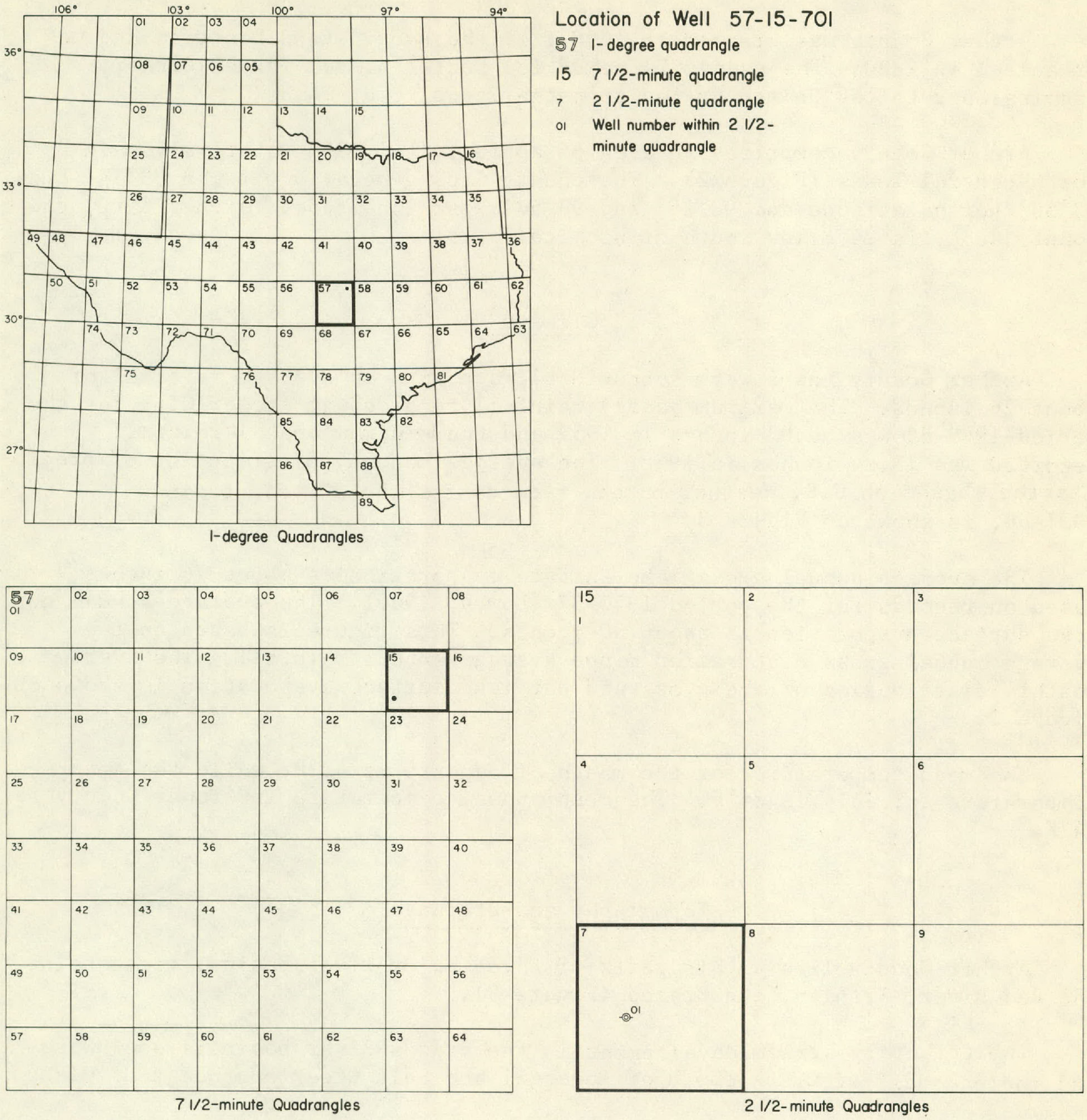


Figure 1

Well - Numbering System

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

GEOGRAPHY

Location

Archer County was created in 1858 from the Fannin Land District and was organized in 1880. The county is named for Doctor Branch Tanner Archer, Commissioner to the United States from the Republic of Texas.

Archer County comprises an area of approximately 900 square miles in north-central Texas (Figure 2). The county lies generally between 33°24' and 33°50' north latitude and 98°25' and 98°57' west longitude. Archer City, the county seat, is 25 miles south of Wichita Falls.

Climate

Archer County has a warm subhumid climate with an average rainfall of about 26 inches. The maximum yearly rainfall recorded at Archer City for the period 1949-65 was 50.03 inches in 1957 and the minimum annual rainfall recorded was 15.24 inches in 1952. The average monthly distribution of precipitation, based on U.S. Weather Bureau records for the 30-year period 1931-60, is shown on Figure 3.

The average annual gross lake surface evaporation is about 76 inches, based on records for the period 1940-57 (Lowry, 1960). The average annual net lake surface evaporation is about 50 inches. This figure is based on the average annual gross evaporation minus average annual rainfall. The average monthly distribution of the gross and net lake surface evaporation is shown on Figure 3.

The mean temperature for the month of January is 42°F, while the mean temperature for July is 84°F. The mean annual temperature in Archer County is 64°F.

Topography and Drainage

Archer County lies within parts of three major river basins, these being the Red River, Trinity, and Brazos (Figure 9).

The tributary stream development in the Brazos River basin is southward and includes Bitter Creek south of Megargel and Salt Creek southeast of Olney Lake.

West Fork of Trinity River is the principal stream in the Trinity River basin. Tributaries to West Fork are Prickly Pear Branch, Waters Branch, Darnell Branch, and Brushy Creek. The general drainage in the Trinity basin is eastward. Topography in this portion of Archer County is rolling to flat and elevations range from 1,050 to about 1,200 feet above mean sea level.

Drainage in the Wichita and Little Wichita Rivers, tributaries to the Red River, is toward the east and northeast. The north and northwest parts of the county are drained by Holliday and Panther Creeks, tributaries of the

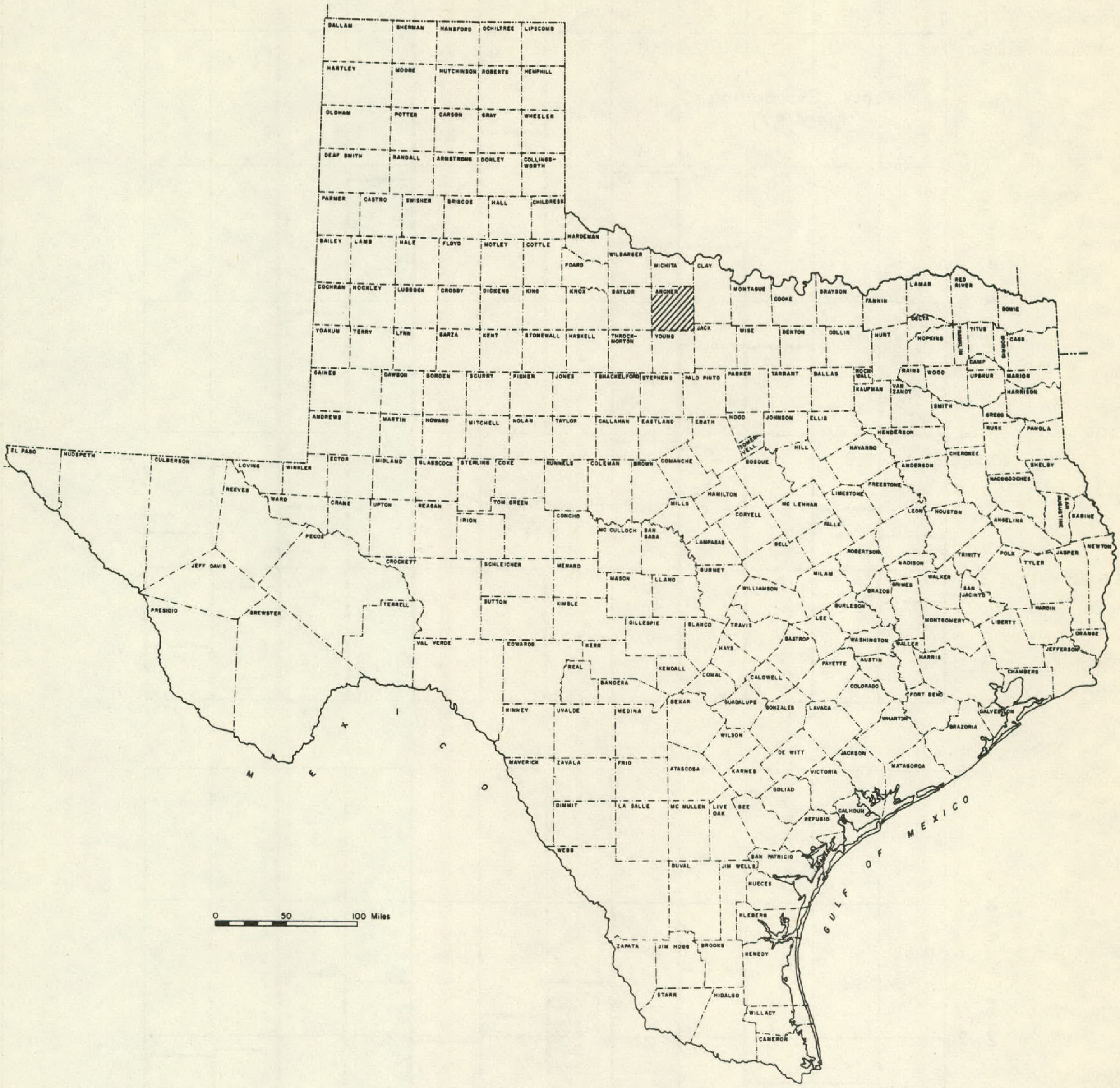


Figure 2

Map of Texas Showing Location of Archer County

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

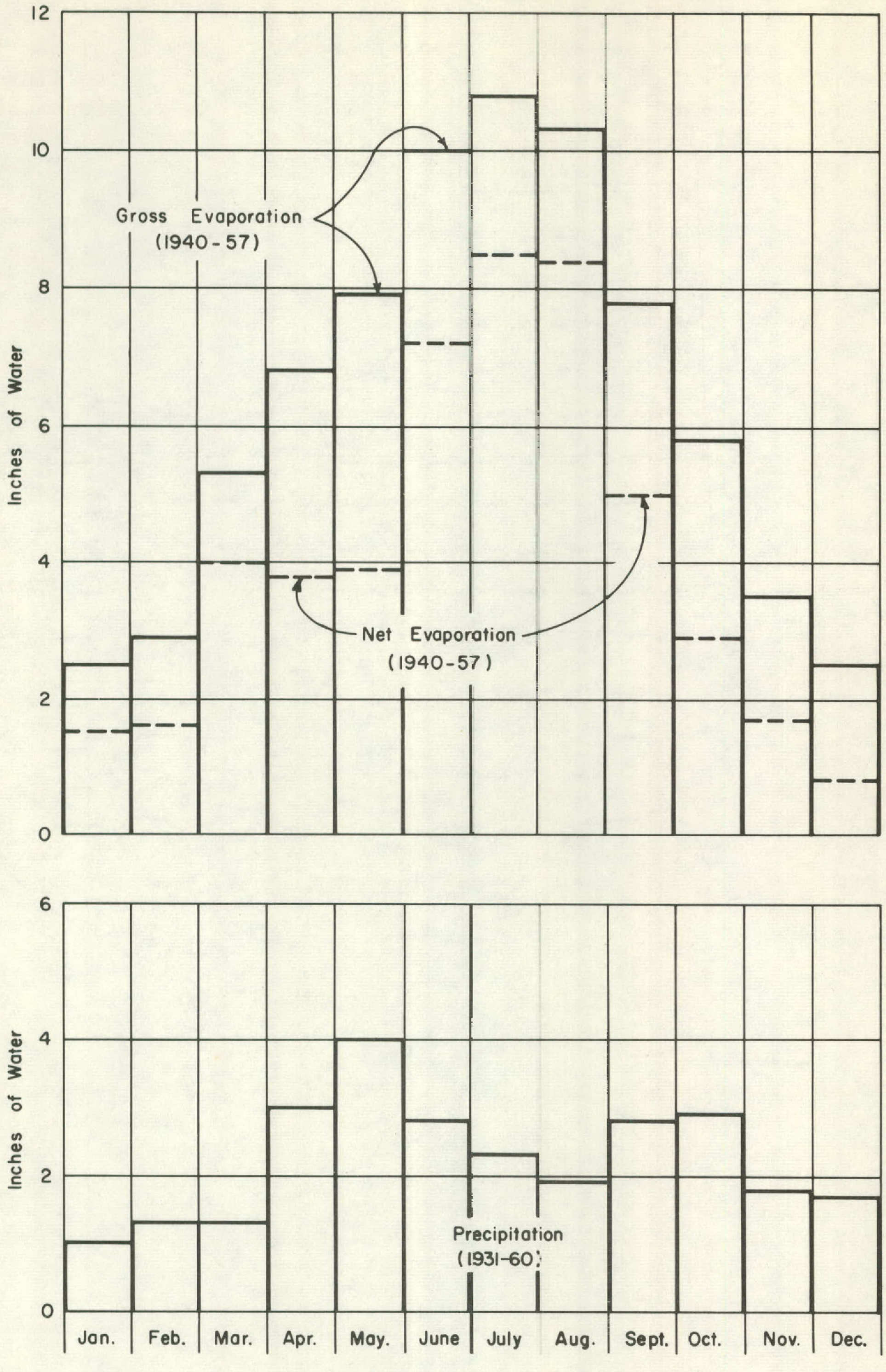


Figure 3

Average Monthy Precipitation and Lake-Surface Evaporation, Archer County

(From records of U.S. Weather Bureau, and Lowry, 1960)

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

Wichita River. The north, middle and south forks of the Little Wichita River drain the west-central, southwest, and central parts of the county.

About 75 percent of the surface area of Archer County is within the Red River basin. Topography within this area varies from flat or rolling in eastern areas of the county to "badland" areas in western portions where the maximum local relief is about 100 feet. Land surface elevations exceed 1,200 feet above mean sea level in some western parts of the county, but range from 900 to 1,000 feet in the eastern portion of the Red River basin.

Lake Kickapoo, with a capacity of 106,000 acre-feet, is about 10 miles northwest of Archer City on North Fork Little Wichita River (Figure 8). This reservoir provides water for the towns of Wichita Falls and Holliday.

Population and Economy

The 1960 population of Archer County was 6,110. About 65 percent of the population is in the towns of Archer City, Holliday, Megargel, Windthorst, Dundee, and Scotland. Residents of Scotland and Windthorst utilize individually owned water wells for their water supply needs, whereas the other towns, which contain about 60 percent of the county's residents, depend on surface water.

The remaining 35 percent of the county's residents live in rural areas where the water supply is from ground water, small surface tanks, cisterns, or is hauled from other areas.

The principal sources of income in Archer County are from agriculture and the petroleum industry. Crude oil production in the county during 1960 was 8,991,848 barrels. Grain and dairy farming, and cattle ranching are found in eastern areas of the county. The western two-thirds of the county is primarily rangeland where cattle are grazed.

OCCURRENCE AND QUALITY OF GROUND WATER

In Archer County ground water of usable quality occurs in rocks of the Cisco Group of upper Pennsylvanian age, and the Wichita Group of lower Permian age. Recognition of these groups is based on geologic mapping in the Brazos River basin (Plummer and Moore, 1921). Table 1 lists the stratigraphic sequence of formations that have been mapped in regions near Archer County, and shows members of these formations which were discernable in subsurface correlation of electric logs in Archer County (Figures 4 and 5).

The complexity of rock sequences in these deposits makes difficult the subsurface correlation of formations and marker beds and the delineation of ground-water zones. These complexities result from discontinuous and cyclic patterns of deposition and are discussed in more detail in the Appendix.

The limestone marker beds shown in Figures 4 and 5 are generally persistent in Archer County. However, the Saddle Creek Limestone is difficult to interpret from electric logs near the southeast corner of the county, where its

Table 1.--Near-surface stratigraphy pertinent to ground-water occurrence in Archer County

System	Group	Formation	Member	Remarks and water-bearing properties
Permian	Wichita			Rocks of Permian age crop out over about 85 percent of Archer County. Most water wells are less than 100 feet deep, many are hand dug, and they usually are bottomed below the water-producing zone in order to provide storage space. Well yields are small, sometimes inadequate. The water is used for domestic and livestock purposes.
——?——?——	----			
Pennsylvanian	Cisco	Harpersville	Saddle Creek Limestone	The Harpersville yields small to moderate supplies of water in southeast Archer County for domestic and livestock uses. Well development at Windthorst is probably limited to the Harperville.
		Thrifty	Breckenridge Limestone	Lower zones of the Thirfty supply about 25 gallons per minute of fresh water to wells for waterflood projects in the southeast corner of Archer County. Upper zones of the formation supply water for domestic and livestock needs northward, where lower zones become saline.
		Graham	Gunsight Limestone	Not known to yield fresh water in Archer County. (Gunsight Limestone through Ranger Limestone)
			Salem School Limestone	
	Canyon	Home Creek Limestone		
		Ranger Limestone		

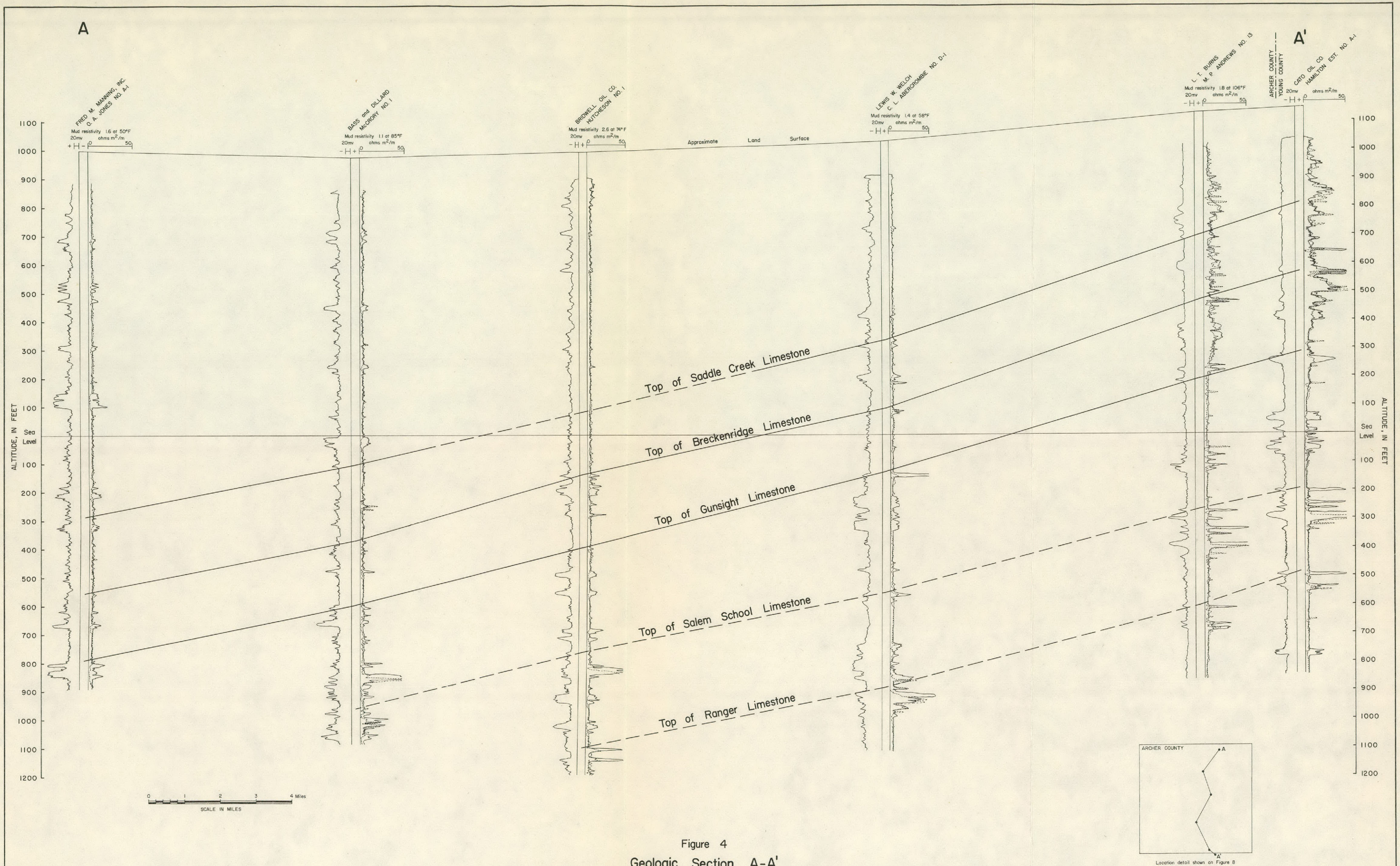


Figure 4

Geologic Section A-A'

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

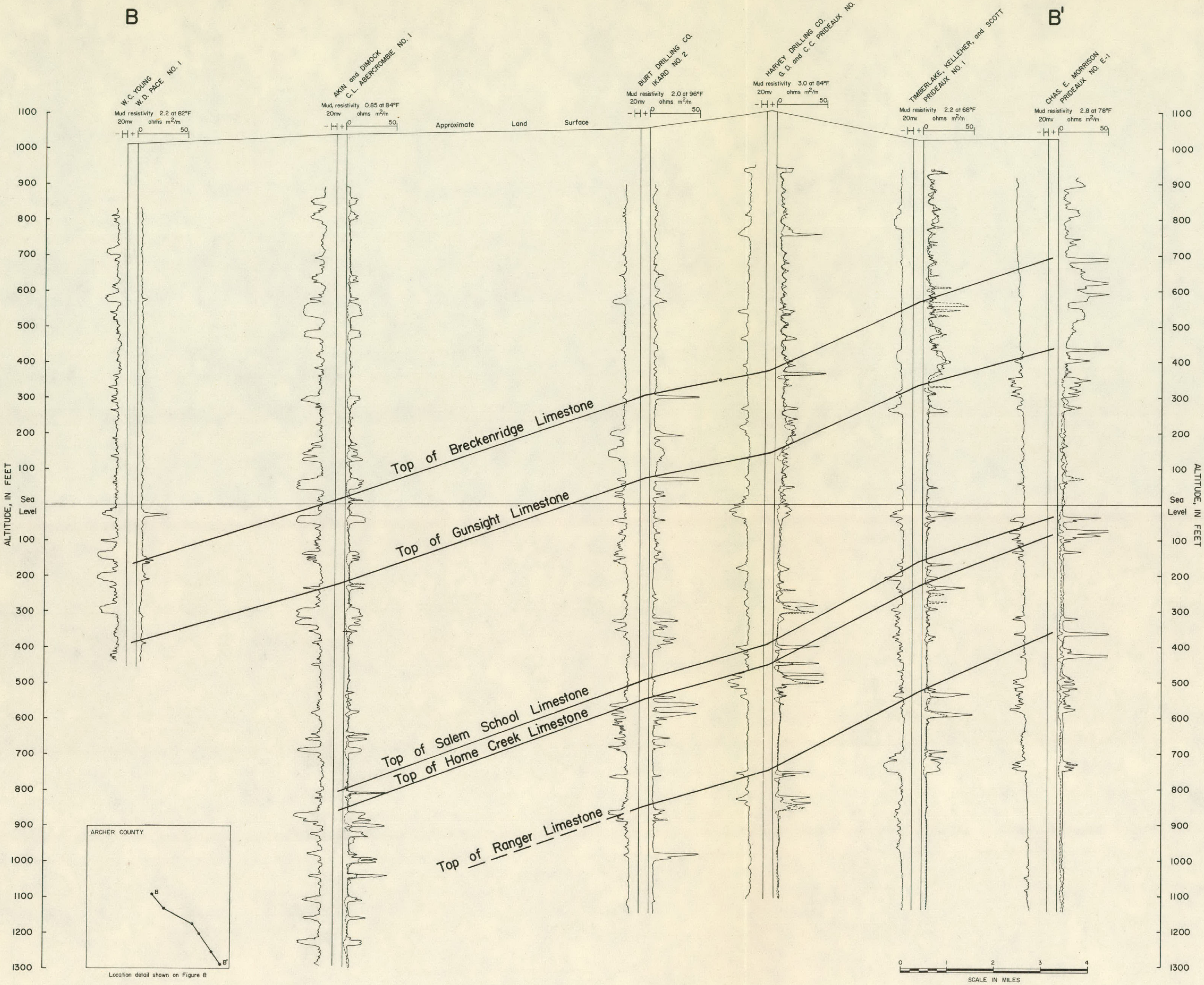


Figure 5

Geologic Section B-B'

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

lithology appears to be gradational from limestone to sandstone and where deeper sand zones locally thicken among shale beds and thin limestone lenses.

No fresh water sands are below the Gunsight Limestone in Archer County. Deeper marker beds are depicted on the cross sections to illustrate the subsurface structure and for correlation with previously completed studies in north-central Texas.

The principal occurrence of ground water of usable quality is in unnamed sands of the Cisco Group, in the southeast quarter of the county as shown by the concentration of water wells on Figure 8.

Certain general hydrologic principles which govern the occurrence and movement of ground water are discussed in the section titled "Ground-Water Hydrology" in the Appendix. This discussion may be helpful in understanding the problems of both finding and developing ground water in Archer County.

The chemical character of the ground water in Archer County varies greatly, as shown by chemical analyses of 207 water samples collected during the summer and fall of 1963 (Table 3). Average concentrations of the principal mineral constituents in the ground water are discussed below.

The average bicarbonate content of water samples analyzed is 484 ppm (parts per million). Ninety-six (46 percent) of the samples exceed the average, and 111 (54 percent) are less than the average.

Bicarbonate content is generally proportional to the depth to the water-bearing zones. The sodium content of the ground water in Archer County also increases with depth. In contrast, however, calcium and magnesium are in higher concentrations in shallow zones than in most deep zones.

The average sodium content is 462 ppm; 75 analyses (36 percent) exceed the average and 132 (64 percent) are less than the average.

The average chloride concentration is 456 ppm, with 74 analyses exceeding the average.

The average calcium concentration is 57 ppm. Seventy (34 percent) of the analyses exceed, and 137 (66 percent) are less than, the average concentration.

The average magnesium concentration is 23 ppm, with 63 samples (30 percent) having a higher concentration and 144 samples (67 percent) containing less than the average.

The average sulfate content of ground water in the county is 160 ppm. Of the 207 water samples analyzed, 73 (35 percent) exceed the average and 134 (65 percent) contain less than the average sulfate content.

The average fluoride content is 1.6 ppm. Seventy-two (35 percent) water samples analyzed exceed the average concentration; 135 (65 percent) contain less than the average concentration.

The average content of dissolved solids in the 207 water samples analyzed is 1,458 ppm. Seventy-eight (37 percent) of these samples exceed the average concentration and 129 (63 percent) contain less than the average concentration.

In general, shallow wells yield water with relatively high concentrations of calcium, magnesium, and bicarbonate ions, and deeper wells yield water that is high in sodium and bicarbonate. Shallow wells, many of them hand dug, are common in both the Wichita and Cisco Groups. Wells ranging in depth from 200 to 700 feet are found only in the upper Cisco Group in the southeast part of the county.

The Appendix contains a discussion of water quality criteria which will be helpful in interpreting the water quality data presented in the report.

Pennsylvanian System

Cisco Group

Rocks of the Cisco Group (upper Pennsylvanian) in Archer County include, in ascending order, the Graham, Thrifty, and Harpersville Formations. However, no fresh water sands occur below the Gunsight Limestone Member which is near the top of the Graham Formation (Table 1). Previous geologic studies and surface mapping of these formations in the north Texas area did not clearly delineate these units in Archer County.

The Cisco Group crops out in the southeast quarter of Archer County and dips to the northwest; it is exposed over about 15 percent of the surface area of the county.

About one-half of the water wells in the county produce from sands of the Cisco Group (Table 2). The areal extent of production of usable ground water from these sands comprises less than 25 percent of the total area of Archer County. Water wells completed in the Cisco Group are in grids 20-28, 20-29, 20-36, and 20-37 (Figure 8).

Ground water from the Cisco Group is used principally for domestic and livestock supply. Six wells near the southeast corner of the county supply fresh water for waterflooding oil reservoirs. These wells are denoted by industrial well symbols on Figure 8.

The maximum yield of ground water from wells completed in sediments of the Cisco Group is about 20 to 25 gallons per minute. This figure is based on reported yields of the wells supplying water for waterflood operations. Water wells completed at depths exceeding 200 feet generally supply enough water for domestic or livestock needs. Wells completed at shallower depths do not always sustain desired yields under prolonged pumpage.

Several shallow, dug wells and lined springs are in the Cisco Group. However, most water well construction in this group consists of 5- to 7-inch steel or galvanized iron casing cemented at or near the land surface. Concrete slabs are used as foundations for electric pumps and windmills.

Water wells completed in the Cisco Group range in depth from about 20 to 650 feet. Depths of the 102 wells in the Cisco Group sampled for chemical analysis are on the following page.

Well depth, in feet	No. of analyses
50 or less	10
51 to 99	23
100 to 200	48
over 200	21

The chemical quality of water in the Cisco Group is highly variable. The principal chemical constituents of the 102 water samples collected from wells completed in this group are discussed below (the ranges of ion concentrations are arbitrarily selected, and do not reflect criteria for use).

About 26 percent of the water samples analyzed had a calcium content greater that 50 ppm. As shown by Table 3 (chemical analyses of water from wells and springs), this relatively high concentration of calcium occurs mostly in water from wells less than 100 feet deep.

Calcium, range in ppm	No. of analyses
50 or less	76
51 to 100	17
over 100	9

The magnesium content is also higher in water from shallow wells. The average magnesium content in the 102 samples is only 13 ppm. Thirty-three of the samples analyzed exceed this average, and 69 contain less than the average.

Bicarbonate and sodium concentrations are generally greatest in the deeper wells. About 25 percent of the samples analyzed contain sodium in excess of 700 ppm; Table 3 reveals that these samples are from relatively deep wells, of which about 20 percent exceed 200 feet in depth.

Bicarbonate, range in ppm	No. of analyses
400 or less	25
401 to 600	32
over 600	45

Sodium, range in ppm	No. of analyses
350 or less	38
351 to 700	38
701 to 1,000	17
over 1,000	9

In general, nitrate concentrations greater than 25 ppm are found in water from wells less than 50 feet deep.

Nitrate, range in ppm	No. of analyses
less than 25	86
26 to 100	7
over 100	9

The range in concentration of chloride is greater than that of other ions in ground water produced from the Cisco Group. It seems that the native or base quality water has, in some areas, been altered as a result of contamination by oil-field brine.

Chloride, range in ppm	No. of analyses
250 or less	43
251 to 500	24
501 to 1,000	26
1,001 to 1,500	2
over 1,500	7

No consistent relationship was found between sulfate content of the samples analyzed and well depth.

Sulfate, range in ppm	No. of analyses
100 or less	42
101 to 300	43
over 300	17

The average content of dissolved solids for the 102 samples of ground water from the Cisco Group is 1,580 ppm. Fifty-eight of the water samples contain less than the average, and 44 exceed the average.

Dissolved Solids, range in ppm	No. of analyses
500 or less	9
501 to 1,000	26
1,001 to 2,000	38
2,001 to 3,000	21
over 3,000	8

The nine samples containing 500 or less ppm of dissolved solids are all from wells less than 200 feet in depth. The eight water samples containing more than 3,000 ppm dissolved solids have particularly large amounts of sodium and chloride; three of these eight samples are from wells that exceed 200 feet in depth.

Permian System

Wichita Group

The Wichita Group (lower Permian) crops out over about 85 percent of the surface area of Archer County. Strata of the Group strike to the northeast and dip to the northwest. Formations and members of the Wichita Group are not listed in Table 1 because the geology of the Group has not been studied in detail in the county and because the shallow ground-water zones in the Group could not be correlated.

The scattered pattern of shallow water-well development in the Wichita Group (Figure 8) indicates the local nature of ground-water zones available for development.

Water wells completed in the Wichita Group are more uniformly shallow than those in the Cisco Group. Well depths in the Wichita Group range from about 20 to 200 feet, but about 90 percent of the wells are less than 100 feet deep, and only one well exceeds 125 feet in depth. Most of the wells are drilled below the water-producing zone in order to create a storage reservoir in the bottom of the well.

Drilled water wells are usually cased with galvanized iron or steel casing, which is cemented at or near the land surface. Dug wells are lined with field stone to prevent caving.

Water wells in the Wichita Group are of low yield, and commonly do not provide an adequate supply as most of the wells cannot sustain prolonged pumpage. The water is used for domestic and livestock purposes, but poor quality in some places precludes use for human consumption.

Water samples were collected for chemical analysis from 105 wells completed in the Wichita Group. The depths of the wells sampled during this study are as follows:

Well depth, in feet	No. of analyses
50 or less	43
51 to 99	52
100 to 200	10

As shown by these analyses (Table 3), the quality of water in the Wichita Group is highly variable. Concentrations of the principal ions are summarized on the following page.

Calcium, range in ppm	No. of analyses
50 or less	50
51 to 100	30
over 100	25

The average magnesium content for the 105 samples analyzed is 32 ppm. Thirty-two analyses exceed the average, and 73 contain less than the average.

Bicarbonate, range in ppm	No. of analyses
400 or less	49
401 to 600	49
over 600	7

Sodium, range in ppm	No. of analyses
350 or less	68
351 to 700	21
701 to 1,000	11
over 1,000	5

Nitrate, range in ppm	No. of analyses
less than 25	71
26 to 50	6
51 to 100	12
over 100	16

Chloride, range in ppm	No. of analyses
0 to 250	57
251 to 500	18
501 to 1,000	20
1,001 to 1,500	5
over 1,500	5

Sulfate, range in ppm	No. of analyses
100 or less	64
100 to 300	31
over 300	10

Dissolved Solids, range in ppm	No. of analyses
500 or less	19
501 to 1,000	42
1,001 to 2,000	25
2,001 to 3,000	11
over 3,000	8

Because wells completed in the Wichita Group are generally shallow, 90 percent of them less than 100 feet deep, little relationship was found between the principal chemical constituents and well depths.

QUALITY-OF-WATER PROTECTION PROGRAMS

Surface Casing

The function of the Surface Casing Program of the Ground Water Division of the Texas Water Development Board is to recommend to oil and gas operators and the Texas Railroad Commission of Texas the depth to which usable quality ground water should be protected in drilling for oil and gas. The authority for participation by the Texas Water Development Board in the surface casing program is derived from rules promulgated by the Railroad Commission under authority given that agency by statutes dealing with the regulation of drilling and production activities of the petroleum industry.

Statewide Rule 13 (formerly Rule 12a) of the Railroad Commission requires that operators obtain a letter from the Texas Water Development Board recommending the depth to which fresh water strata should be protected when drilling a new lease or area, if the lease or area is not covered by field rules or lease recommendations. Railroad Commission Rule 8 (formerly Rule 20) requires that all fresh water strata be protected in drilling or production activities.

In carrying out its duties under Rule 13, the Texas Water Development Broad created the Surface Casing Program in the Ground Water Division. The staff of the Surface Casing Program is responsible for maintaining technical data files upon which to base fresh water protection recommendations in all areas of the State, and for preparing these recommendations for operators contemplating drilling oil or gas tests. The depth to which ground water of usable quality should be protected which is recommended in a given area is based on all pertinent information available to the Surface Casing staff at the time the recommendation is given. Recommended depths in any one area may therefore be revised from time to time as additional subsurface information becomes available.

Known depths of wells producing usable water, or depths of wells which formerly produced water of usable quality, such as domestic, municipal, industrial, livestock, or irrigation wells, are of primary value in determining the depth of usable water. Electric or gamma-ray neutron logs run on oil and gas tests are used in many areas to determine the depth to the base of usable quality ground water. Surface elevation is given special consideration when a recommendation is given in an area that has moderate to high surface relief, as is common to portions of Archer County. This consideration is imperative when the slope of the land surface does not conform to the dip of the underlying rocks, because of the danger that poor quality water will cause contamination of surface and ground water by moving along the dip of the beds to fresh water zones or to points of discharge in stream channels. All of this information is interpreted in the light of the available knowledge of the geology and ground-water hydrology available on the area involved.

In Archer County, a county-wide depth recommendation is not feasible. The depth of surface casing protection which would be required in those areas of the county where deep water wells are found would be an excessive requirement in many other parts of the county. Any lesser requirement would not protect such deep zones. Thus, surface-casing recommendations are made on a well-to-well or lease-to-lease basis in order to provide protection of usable quality water without imposing unnecessary economic burdens on the oil operators in those areas where deep protection is not needed.

During the 8-year period 1958-65, the Surface Casing staff prepared 1,570 recommendations for pretection of usable quality ground water for oil and gas tests drilled in Archer County. Three hundred and twenty-five of these recommendations were prepared during 1965. The depths of these recommendations range from 60 to 750 feet.

Subsurface Disposal

The 57th Texas Legislature enacted Senate Bill 72 (Article 7621b, Vernon's Texas Civil Statutes) which defined a permit system for subsurface disposal of municipal and industrial wastes in Texas. This act in effect designated the Texas Water Development Board as the permit-issuing agency for all injection wells to dispose of "...industrial and municipal waste, other than salt water or other waste arising out of or incidental to the drilling for or the producing of oil or gas...," and the Texas Railroad Commission as the permit-issuing agency for all injection wells "...for the purpose of disposing of salt water or other waste arising out of or incidental to the drilling for or the producing of oil or gas...." Section 2-c of this statute also directed that any person applying to the Railroad Commission for a permit to inject salt water resulting from the drilling for or production of oil or gas shall obtain a letter from the Board stating that the "...drilling of such injection well or the injection of such salt water or other such waste into such subsurface stratum will not endanger the fresh water strata in that area and that the formation or strata to be used for such salt water or other such waste disposal are not fresh water sands."

Subsequent opinions by the Attorney General of Texas pertinent to the implementation of Article 7621b are: (1) that "injection well," when correctly interpreted, includes only those wells which are drilled or used for the purpose of disposal and does not include an injection well where the purpose of the well is to increase production from an oil- or gas-bearing stratum, and (2) that a determination by the Texas Water Development Board is not binding on the Railroad Commission but is merely advisory.

The staff of the Subsurface Disposal Program of the Texas Water Development Board reviews applications to dispose of salt water into subsurface zones and advises the operators and the Railroad Commission of the acceptability of such applications. Waterflood, pilot recovery, and other secondary recovery operations where salt water is injected into subsurface zones which is productive of oil or gas are granted permits by the Railroad Commission without consultation with the Texas Water Development Board. Also, the inspection of construction and completion of all brine injection systems is a regulatory function of the Railroad Commission.

From the effective date of Senate Bill 72, August 28, 1961, to December 1965, 56 applications to the Railroad Commission for salt-water disposal wells in Archer County have been reviewed by the staff of the Subsurface Disposal Program. Each of these applications was reviewed on an individual basis with consideration given to geologic and hydrologic data of the area, the method of completion of the proposed injection well, the volume of salt water to be injected, and injection pressure to be used.

In addition to the salt-water disposal wells, the Railroad Commission, from August 1961 to December 1965, granted permits for 47 projects involving the use of injection wells in waterflood, pressure maintenance, and other secondary-recovery operations in Archer County. The number of injection wells utilized in these projects ranges from one well in pilot recovery programs to as many as 13 or more injection wells in the larger waterflood projects. Generally, these projects are granted permits which contain provisions for expansion of the water-injection facilities by the use of additional injection wells as the operations expand.

OIL-FIELD BRINE PRODUCTION AND DISPOSAL

Quantity and Distribution of Produced Brine

During 1962, the Railroad Commission of Texas, the Texas Water Pollution Control Board, and the then Texas Water Commission cooperated in the collection and tabulation of information submitted by oil and gas operators concerning the 1961 oil-field brine production and disposal in Texas. A summary of this inventory, as it pertains to Archer County, is presented in Table 4.

A total of 38,353,262 barrels of salt water was reported produced with oil and gas in Archer County during 1961. Of this amount, 99.0 percent was reported disposed of by injection into the subsurface.

Table 4 lists the total 1961 brine production and disposal for the principal river basins in the county as follows: Brazos River basin, 1,500,413 barrels; Trinity River basin, 8,013,419 barrels; Red River basin, 28,839,430 barrels. Table 4 also lists the areas of concentration of brine production and disposal, which account for nearly 96 percent of the total annual brine production within the county. These areas are shown on Figure 9, which also shows the major river basin boundaries and vegetative-kill areas. Area totals are subdivided into surface-pit disposal and injection-well disposal, as presented in Table 4 and shown on Figure 9.

Chemical Quality of Produced Brine

Chemical analyses that are representative of the brines produced in the areas shown on Figure 9 are listed in Table 5. The ratio of chloride to sodium is about 2 to 1, and these two ions comprise about 90 percent of the total mineral content of each analysis. Calcium and magnesium are the other predominant minerals.

Sodium concentration in the brine samples ranges from 6,030 to 59,200 ppm. The concentration of chloride ranges from 10,460 to 127,400 ppm, and averages 87,540 ppm. Magnesium ranges from 155 to 2,550 ppm, and calcium from 487 to 17,600 ppm.

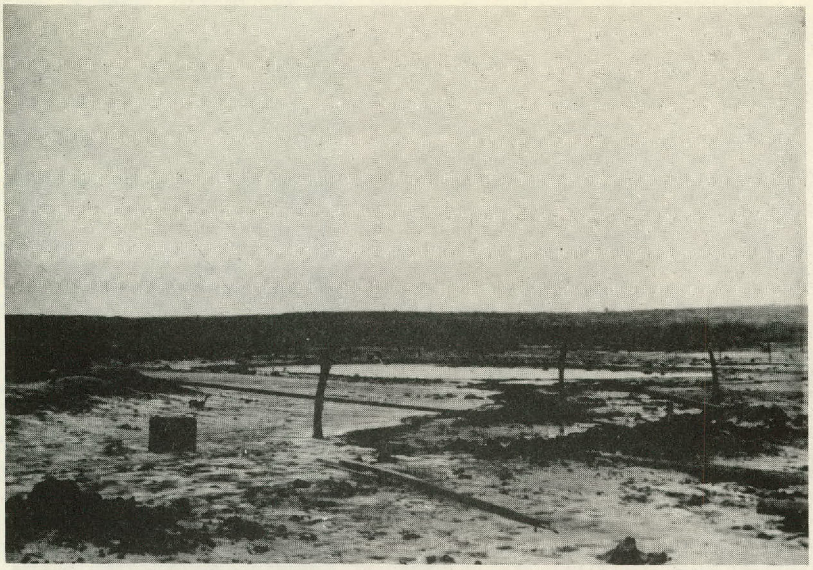
ALTERATION OF NATIVE QUALITY GROUND WATER

The chemical analyses of ground-water samples collected during this investigation reveal that water from some wells contains chloride concentrations which are abnormally high and are not consistent with the usual chloride content of water from other wells in the same area. This variation in chloride content is, in most cases, directly related to the methods of oil-field brine disposal.

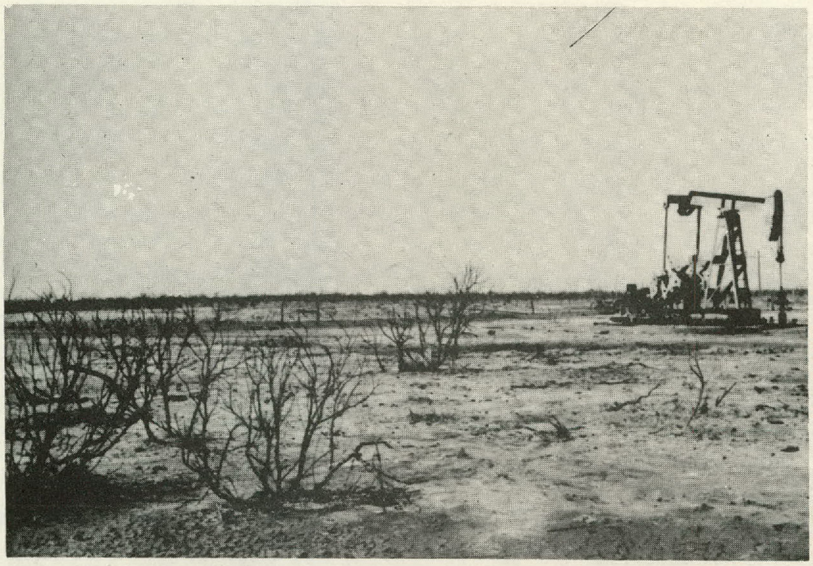
Vegetative-kill areas resulting from the discharge of brine onto the land surface by overflowing brine disposal pits are numerous in Archer County. Information supplied by the Red River Authority indicates that prior to 1960 an estimated 3,201 surface pits existed in the Red River basin in Archer County. By 1963, about 2,116 of these pits were reportedly no longer in use and had been filled with earth. Locations of vegetative-kill areas inspected during this study are shown on Figure 9. They range in size from less than 1 acre to about 15 acres. Photographs of typical disposal pits and vegetative-kill areas are shown on Figure 6.

Brine placed in unlined surface pits, constructed in unconsolidated permeable soils, percolates downward and sometimes enters water-bearing strata. The disposal of brine onto the land surface alters the chemical quality of surface water. This surface water may affect ground-water quality by recharging water-bearing strata.

Another potential source of ground-water contamination is the injection of oil-field brine into the subsurface where: (1) injection wells are inadequately completed, (2) injection is into shallow intervals which are hydraulically related to fresh-water zones, (3) injection pressures are excessive, (4) inadequately cased, cemented, or plugged bore holes penetrate the injection zone in areas near disposal wells, or (5) brine corrosion on the casing or pipe in disposal wells results in failure to restrict the fluid to the desired injection zones.



Site 9 miles south of Mankins



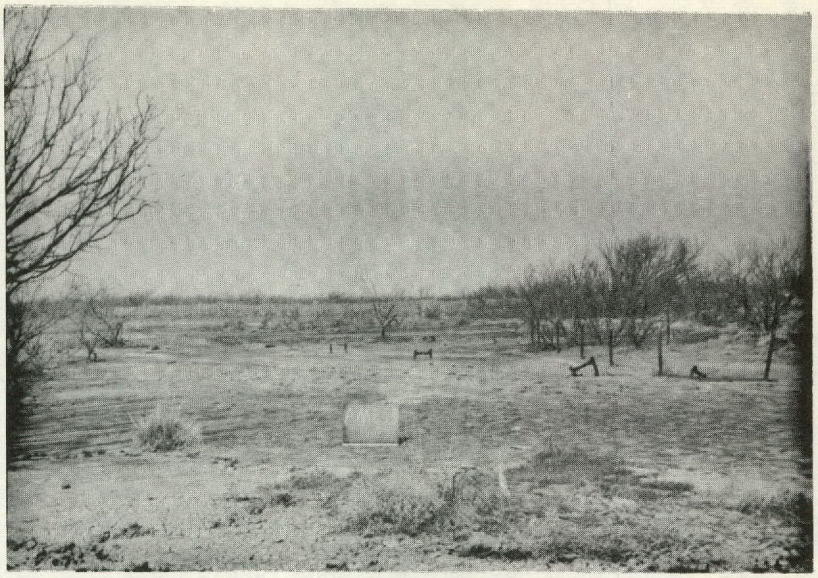
Site 14 miles east of Holliday

Figure 6

Views of Surface Disposal Pits and Vegetative-Kill Area

(Locations shown on Figure 9)

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board.



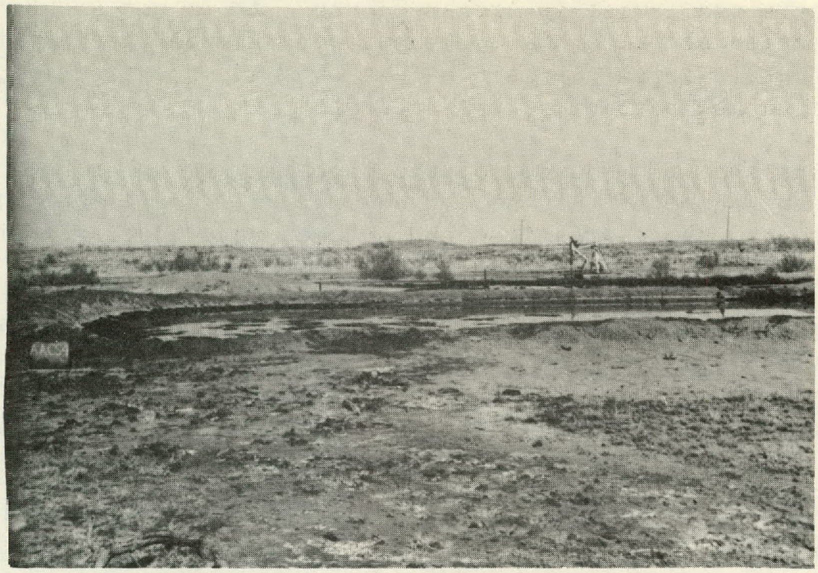
Site 12 miles southwest of Archer City

Site 7 miles south of Archer City

Figure 6 -- Continued

Views of Surface Disposal Pits and Vegetative-Kill Areas
(Locations shown on Figure 9)

Texas Water Development Board in cooperation with the
Texas Water Pollution Control Board



Site 4 miles northwest of Archer City

Site 4 miles northwest of Windthorst

Figure 6 --Continued

Views of Surface Disposal Pits and Vegetative-Kill Areas

(Locations shown on Figure 9)

Texas Water Development Board in cooperation with the
Texas Water Pollution Control Board

Interviews with oil-field workers, pumpers, and landowners in Archer County indicate that improperly plugged wells and inadequately cased wells, drilled many years ago, exist in Archer County. It is not known to what extent subsurface injection of brine has contributed to ground-water contamination in Archer County, but it appears possible that this has occurred in deeper water wells in the southeast portion of the county.

To pin-point specific sources of the contaminants entering ground water was not within the scope of this study; however, all available information indicates the contaminants are, in each instance noted during this study, oil-field brines.

Figure 7 is a series of radial-pattern diagrams which illustrate the relative concentrations of dissolved minerals in native ground water, in water of apparently altered quality in the same area, and in a typical oil-field brine. The diagrams are plotted in equivalents per million (epm). The scale used to illustrate the quality of ground water is 25 times larger than the scale used to represent the brine.

The radial-pattern diagrams in Figure 7 represent the extremes in ground-water quality in Archer County. The diagrams of the apparently contaminated waters appear to be a composite of the diagrams of the brine and the native-quality water in the same area. This is because the apparently contaminated waters contain greater amounts of sodium and chloride, and sometimes calcium and magnesium, than do the native-quality waters, and these are the principal dissolved minerals in the brine. This type of alteration of water quality apparently has resulted from the invasion of salt water into fresh-water zones supplying wells which are within areas of brine disposal (Figure 9).

The following discussion regarding the use of the radial-pattern diagrams is intended to provide a clearer understanding of the basic interpretation provided by these diagrams. Thirteen water wells in grid 20-37, completed at depths of 350 to 650 feet, are in an area of extensive secondary oil-recovery operations. The chemical analyses of water from eleven of these wells (Table 3) show that the chloride content generally ranges from about 300 to 800 ppm, and averages about 600 ppm. However, the waters from wells 20-37-402 and 20-37-702 have chloride concentrations of 1,360 and 1,220 ppm, respectively, about twice the amount in water produced from other wells in the area. On Figure 7, radial-pattern diagrams for these two wells reveal that the most significant difference between their water and water from nearby wells 20-37-401 and 20-37-707 is the greater concentration of sodium and chloride. The proportions of sodium and chloride suggest an admixture of native quality ground water and a salt water similar to that shown by the pattern diagram of the Strawn brine.

The other diagrams of Figure 7 compare in a similar way the quality of ground water from wells in a local area completed at similar depths and the quality of Strawn brine, which is representative of brines of other oil-producing zones. These diagrams illustrate probable quality alteration of ground water, and in each case suggest salt-water contamination.

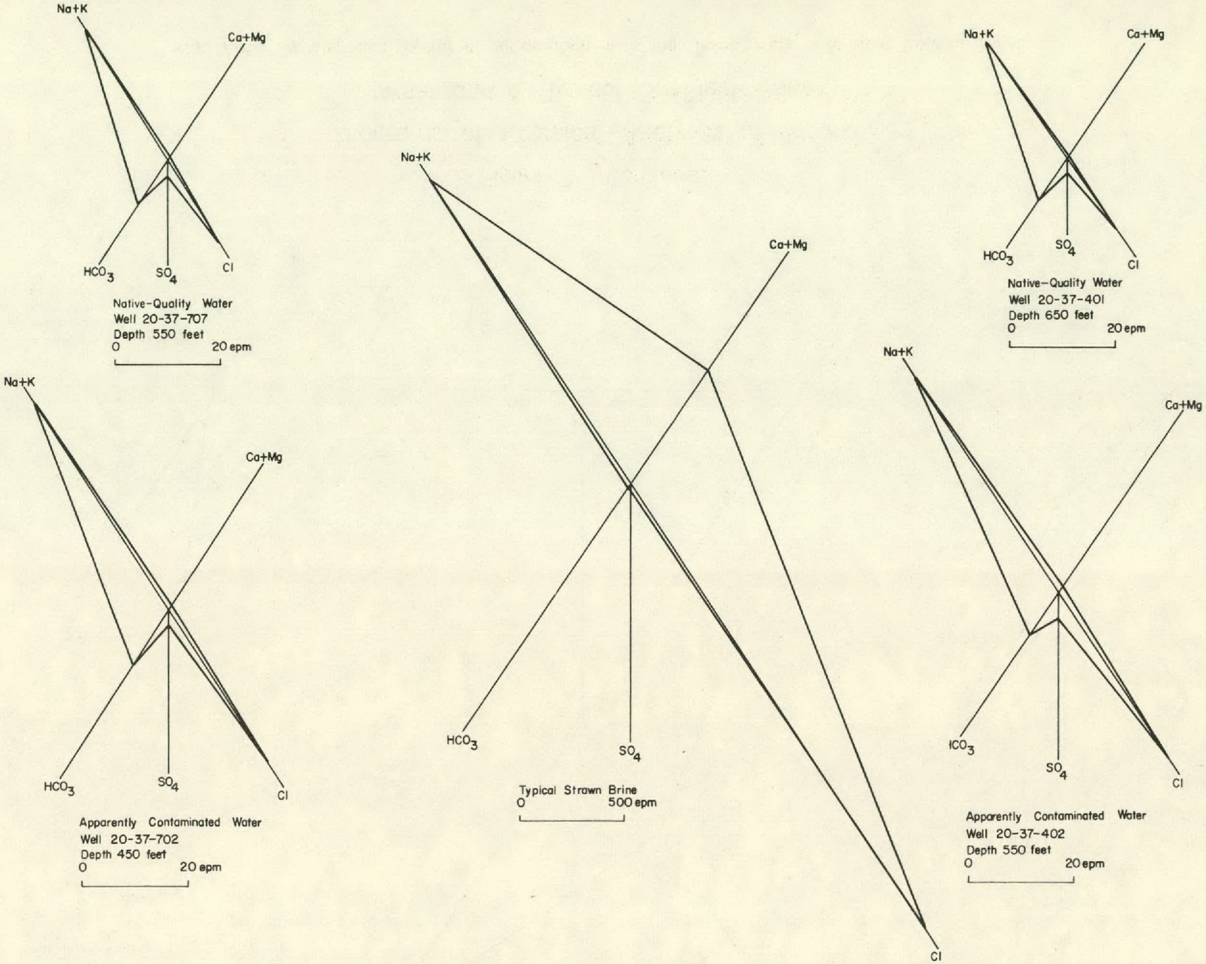


Figure 7

Diagrams of Chemical Analyses of Ground Water and a Typical Oil-Field Brine

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

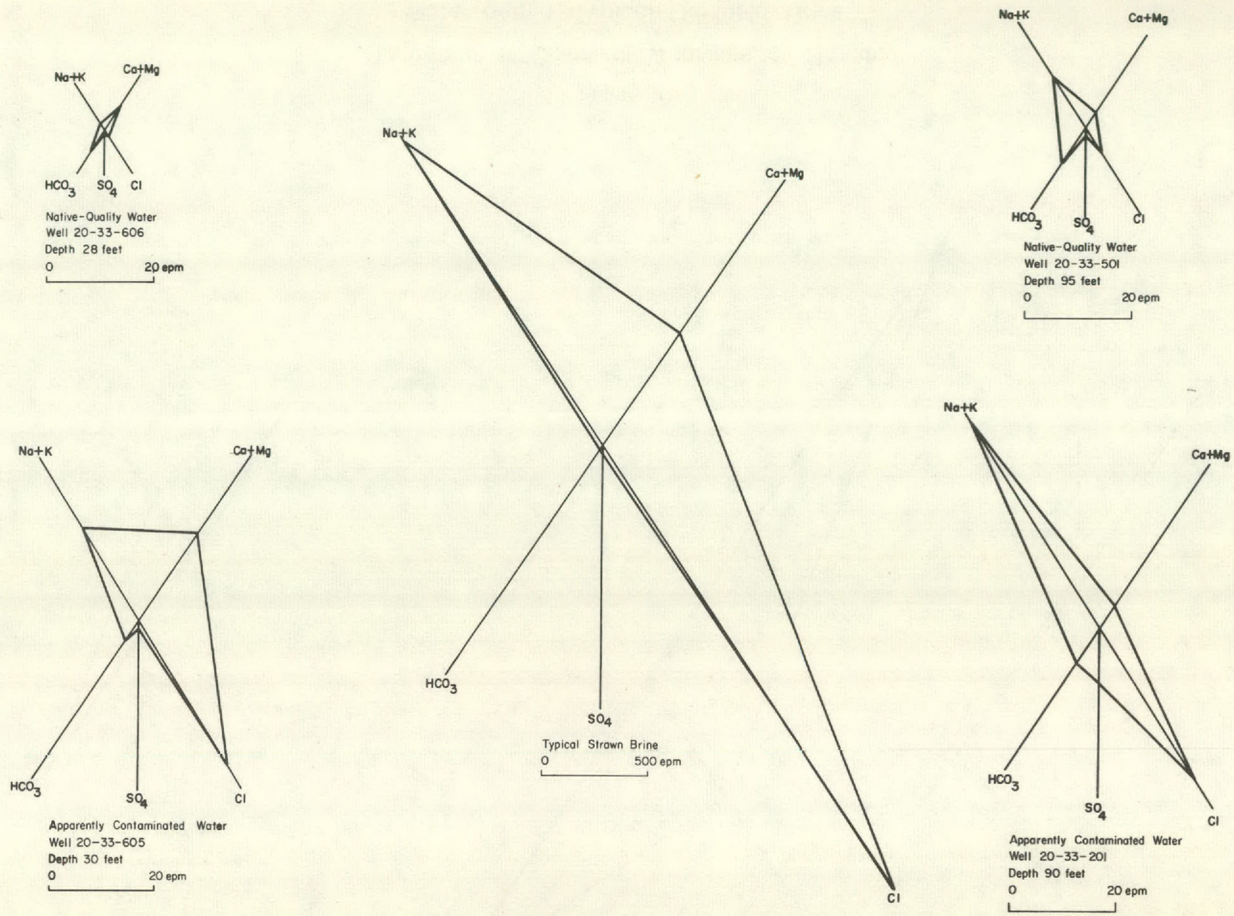


Figure 7--Continued

Diagrams of Chemical Analyses of Ground Water and a Typical Oil-Field Brine

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

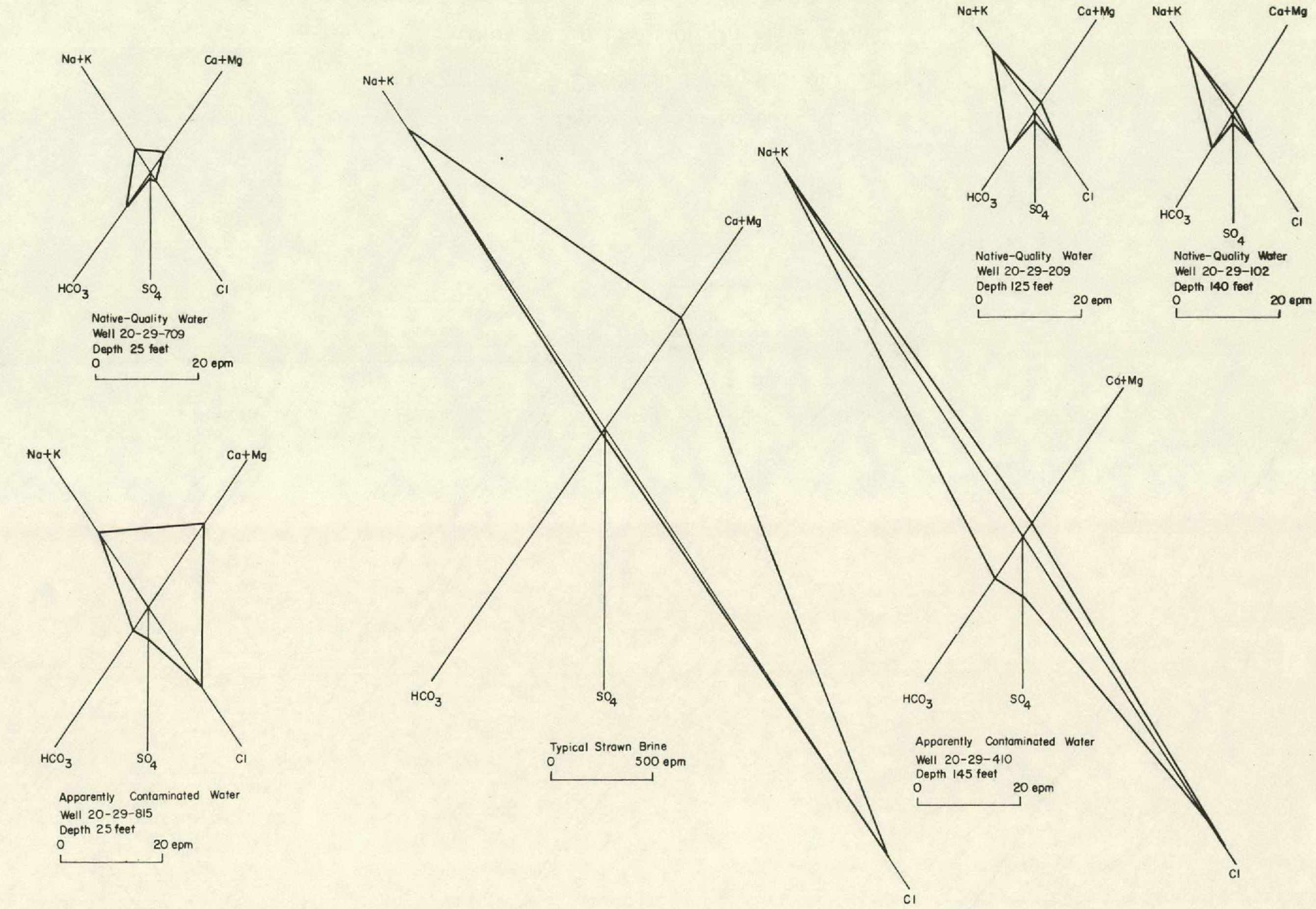


Figure 7--Continued

Diagrams of Chemical Analyses of Ground Water and a Typical Oil-Field Brine

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

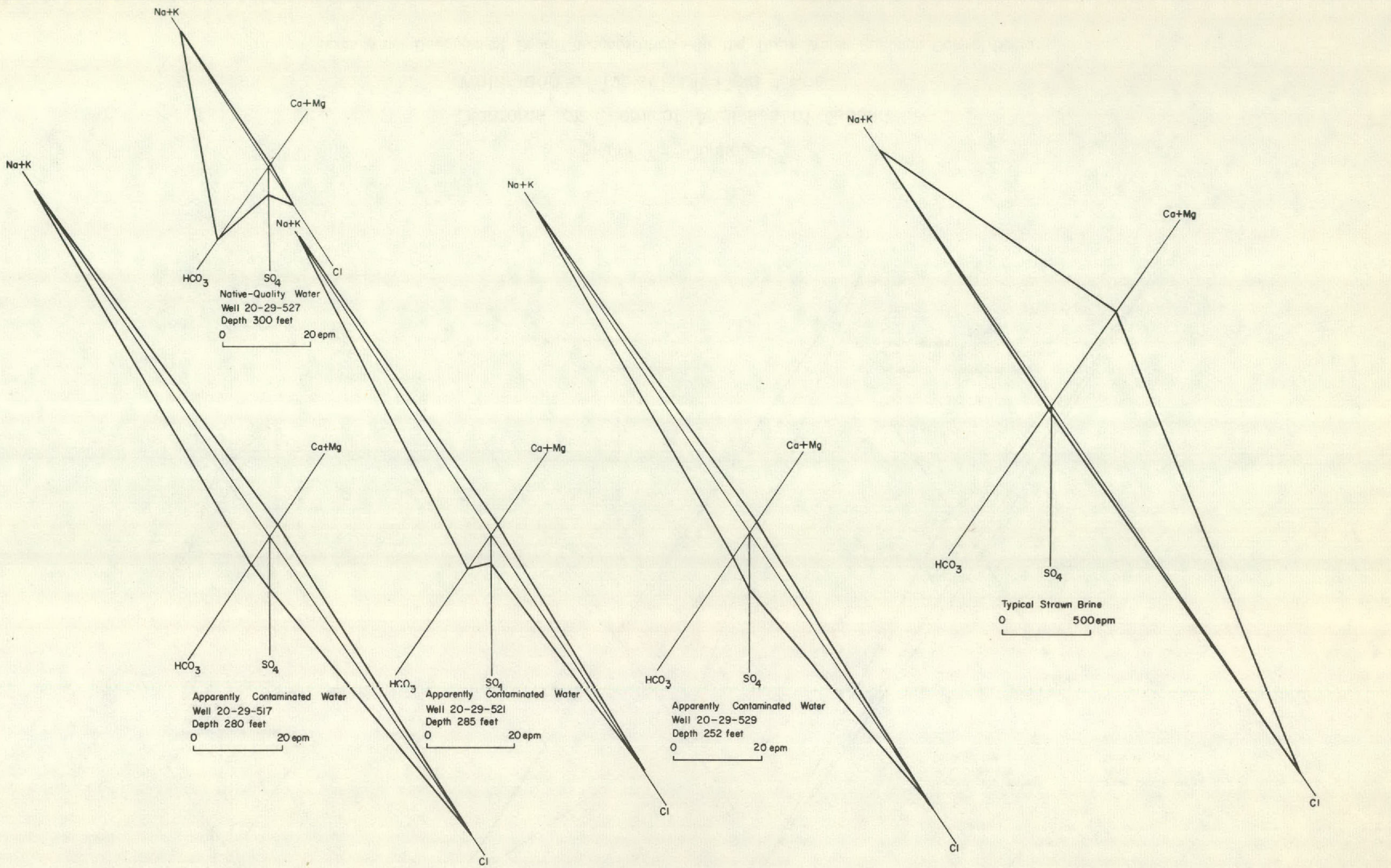


Figure 7--Continued

Diagrams of Chemical Analyses of Ground Water and a Typical Oil-Field Brine

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

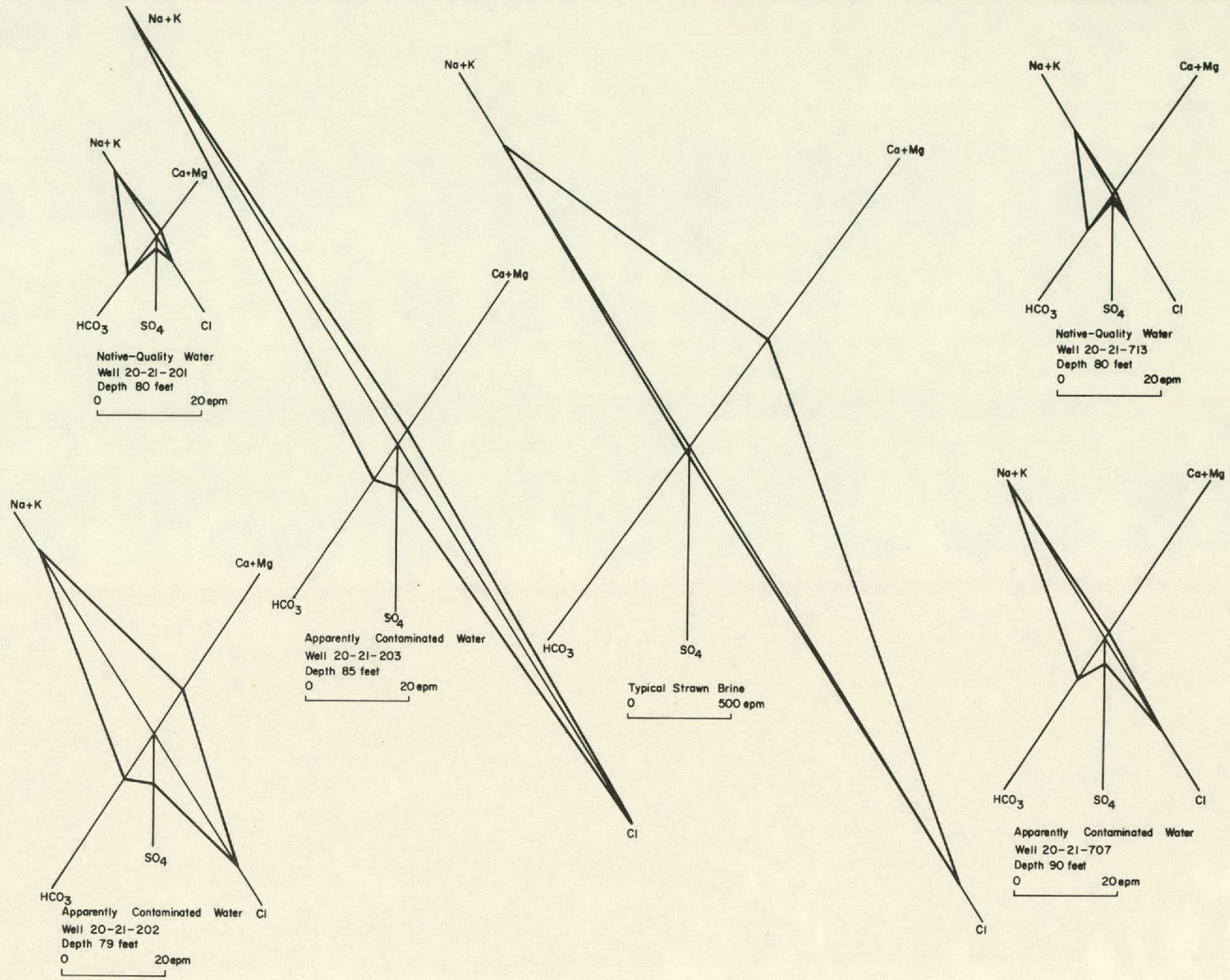


Figure 7--Continued

Diagrams of Chemical Analyses of Ground Water and a Typical Oil-Field Brine

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

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Table 2.--Records of wells and springs, Archer County

Water-bearing unit : W, Wichita Group; C, Cisco Group.
Water levels : Reported water levels given in feet; measured water levels given in feet and hundredths.
Method of lift and type of power: B, bucket or bailer; C, cylinder; Cf, centrifugal; E, electric; G, natural gas, butane, or gasoline; H, hand; J, jet; N, none; S, submersible; T, turbine; W, windmill.
Use of water : D, domestic; Ind, Industrial; N, none; P, public supply; S, livestock.

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing		Water-bearing unit	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
					Diameter (in.)	Depth (ft)			Below land-surface datum (ft)	Date of measurement			
*20-12-601	C. J. Cully	--	1963	80	5	80	W	963	56.89	Oct. 17, 1963	J,E	D	
* 901	B. K. Forcher	--	1925	30	--	--	W	965	23.24	do	J,E	D	
* 13-701	T. B. Medders	--	1950	50	5	50	W	945	13.18	Oct. 16, 1963	J,E	D	
* 702	do	--	1950	65	5	65	W	950	17.56	do	C,W	S	
* 801	W. T. McGregor	--	1946	60	5	60	W	941	15.54	do	J,E	D	
* 802	T. B. Medders	--	1930	35	--	--	W	930	14.87	do	C,W	S	Dug well.
* 803	W. T. McGregor	--	1945	70	5	70	W	935	20.61	Oct. 21, 1963	C,W	S	
* 804	do	--	1950	80	5	80	W	935	24.45	do	C,W	S	
* 19-701	Cowan & McKinney	--	1930	25	--	--	W	1,094	18.12	Dec. 3, 1963	C,W	D	Dug well.
* 801	B. G. Hasson	--	1920	21	--	--	W	1,089	13.61	Dec. 4, 1963	C,W	D	Do.
* 20-501	Dick Coleman	--	1950	125	5	125	W	981	76.06	Oct. 11, 1963	C,W	D	
* 502	do	M. Roberts	1945	125	5	125	W	936	75	do	C,W	D,S	
* 503	Don Coleman	--	1950	100	7	100	W	970	50	Oct. 14, 1963	C,W	D,S	
* 504	do	--	1957	100	5	100	W	970	50	do	C,E	D,S	
* 505	W. M. Coleman	--	1933	88	5	88	W	967	45	Oct. 15, 1963	C,W	D	
* 601	A. B. Edwards	R. Wiseman	1940	40	7	40	W	971	32.01	Oct. 8, 1963	C,W	S	
* 602	do	--	1952	75	5	75	W	972	40	do	C,W	S	
801	W. M. Coleman	--	1936	90	5	90	W	942	14.23	Oct. 15, 1963	C,W	--	
* 21-101	R. L. Bullard	--	1936	42	5	42	W	1,110	20	Oct. 9, 1963	J,E	D	
102	do	--	1940	75	5	75	W	1,107	54.41	do	--	--	
103	do	--	1940	75	5	75	W	1,112	57.12	do	--	--	

See footnote at end of table.

Table 2--Records of wells and springs, Archer County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*20-21-201	J. S. Bridwell	--	1950	80	5	80	W	988	67.85	Oct. 16, 1963	C,W	D	
* 202	do	--	1939	79	4	79	W	965	44.50	do	C,W	S	
* 203	do	--	1950	85	5	85	W	1,008	45	do	C,W	S	
* 204	J.T. Gant	--	1925	42	--	--	W	974	33.17	do	J,E	D	Dug well.
* 401	Lloyd Schrieber	R. Wiseman	1955	90	5	90	W	940	13.35	Oct. 2, 1963	J,E	D	
* 402	A. B. Edwards	F. Hoffman	1936	90	5	90	W	972	43.06	Oct. 8, 1963	C,W	S	
* 403	A. B. Edwards, Jr.	--	1900	90	5	90	W	972	45	do	C,E	D,S	
* 404	J. K. Coleman	T. Thigpen	1940	80	5	80	W	940	20	do	C,W	S	
* 405	do	--	1914	80	5	80	W	950	34.25	Oct. 9, 1963	C,W	D,S	
* 406	do	--	1945	80	4	80	W	935	19.31	do	C,W	S	
* 407	J. K. Coleman, Jr.	--	1930	50	5	50	W	940	33.78	do	C,W	S	
* 703	H. P. Meurer	--	1947	70	6	70	W	982	17	Oct. 7, 1963	C,W	D,S	
* 704	W. A. Morath	--	1911	57	5	57	W	968	40	Oct. 2, 1963	C,E	D	
* 705	Joe Stallcup	--	1953	54	5	54	W	970	11.96	do	J,E	D	
* 706	O. J. Stallcup	--	1955	80	5	80	W	975	15	do	C,W	D	
* 707	Ray Hemmi	R. Wiseman	1960	90	5	90	W	971	39.19	Oct. 7, 1963	J,E	D	
* 708	H. Frerich	--	1910	84	--	--	W	970	48.71	do	C,W	D	Dug well.
* 709	Mrs. J. Hoffman	F. Hoffman	1938	60	5	60	W	979	20	do	C,W	D	
* 710	A. L. Hilbers	--	1963	75	5	75	W	986	15.29	Sept. 9, 1963	J,E	D	
* 711	R. Schenk	L. Stallcup	1953	90	5	90	W	978	18.45	Oct. 7, 1963	J,E	D	
* 712	Helen Hilbers	E. Thomas	1963	82	5	82	W	973	42.69	Oct. 8, 1963	J,E	D	
* 713	Eddie Vieth	R. Wiseman	1961	90	5	90	W	970	40	do	J,E	D	
* 714	H. W. Hilbers	F. Hoffman	1945	70	5	70	W	977	14.40	Sept. 30, 1963	J,E	S	
* 715	do	--	1935	59	5	59	W	990	40	do	C,W	D	
* 801	F. Hoffman	F. Hoffman	1935	110	5	110	W	986	50	Sept. 27, 1963	C,W	S	
* 802	Jess Poirot	do	1936	56	5	56	W	996	20	do	J,E	D	

See footnote at end of table.

Table 2.--Records of wells and springs, Archer County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing		Water-bearing unit	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
					Diameter (in.)	Depth (ft)			Below land-surface datum (ft)	Date of measurement			
*20-21-803	F. Hoffman	--	1900	36	--	--	W	986	18.75	Sept. 27, 1963	J,E	D	Dug well.
* 804	M. A. Berend	F. Hoffman	1938	50	5	50	W	986	14.55	Sept. 26, 1963	C,E	D	
* 805	A. J. Prescher	--	1924	28	--	--	W	1,037	17.59	Sept. 30, 1963	J,E	D,S	Dug well.
* 806	Frank Vieth	--	1910	35	--	--	W	1,003	20.08	do	C,W	S	
* 807	do	--	1946	65	5	65	W	1,001	25	do	J,E	D	
* 808	Paul Krahl	--	1940	25	--	--	W	941	12.45	Oct. 1, 1963	C,W	D,S	Dug well.
* 809	R. Jackson	--	1924	25	--	--	W	937	9.11	do	C,W	D,S	
* 810	Otto Anderle	--	1924	36	--	--	W	925	18.37	do	C,W	D,S	
811	-- Eschman	--	1900	75	5	75	W	974	48.43	do	C,W	--	
* 812	B. Warmuth	--	1945	75	5	75	W	977	45	do	C,W	S	
* 813	J. C. Peysen	--	1920	20	--	--	W	959	14.35	Oct. 2, 1963	J,E	D	Dug well.
* 26-401	J. R. Parkey, Jr.	--	1930	32	--	--	W	1,125	17.24	Oct. 7, 1963	C,W	D	Do.
* 701	W. A. Horkey	--	1945	100	5	100	W	1,256	70.89	Nov. 20, 1963	J,E	D	
* 702	do	--	1918	110	6	110	W	1,256	71.67	do	B,H	D	
* 27-101	Chas. Morrison	--	--	32	--	--	W	1,029	23.01	Nov. 7, 1963	B,H	N	
* 301	M. Baggett	--	1930	25	--	--	W	1,054	15.64	Dec. 3, 1962	J,E	D	
302	Archer City	--	1956	70	--	--	W	--	--	--	N	N	Test hole. Data from U.S. Geological Survey.
* 303	George Bruce	--	1963	93	--	--	W	1,099	12.27	Dec. 6, 1963	B,H	--	Not cased.
* 28-101	Charles King	--	1920	40	--	--	W	1,065	22.18	Oct. 11, 1963	J,E	D,S	
102	J. D. Powell	--	1950	45	5	45	W	1,041	21.73	do	C,G	--	Dug well.
* 103	Tom Fields	L. L. Lowake	1963	82	5	65	W	1,040	28.38	Dec. 6, 1963	B,H	--	
* 104	L. L. Lowake	do	1963	30	7	6	W	1,054	9.38	do	B,H	--	
* 201	R. C. Kinder	--	1925	30	--	--	W	1,036	14.82	Oct. 11, 1963	J,E	D	Dug well.
* 202	J. D. Powell	--	1901	35	--	--	W	1,042	10.81	do	C,E	S	Do.
* 203	Otis Davis	--	1900	30	--	--	W	1,021	10.05	do	J,E	D,S	Do.
* 403	Gene Bell	--	1940	20	--	--	W	1,015	16.27	Dec. 5, 1963	J,E	D	Do.

See footnote at end of table.

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*20-28-404	Duren Bell	--	1935	45	--	--	W	1,034	21.46	Dec. 5, 1963	C,W	D	Dug well.
* 501	C. L. Washburn	M. Roberts	1962	76	5	76	W	--	40	Sept. 26, 1963	J,E	D	
* 701	C. McKinney	--	1930	25	--	--	W	1,099	12.67	Aug. 26, 1963	B,H	D	Dug well.
702	do	--	1955	64	5	64	W	1,119	42.23	do	--	--	
* 901	E. L. Garvey	--	1905	30	5	30	W	1,156	12.25	July 30, 1963	B,H	D	
* 902	Roy Harrison	--	1945	80	5	80	W	1,165	59.12	Aug. 28, 1963	C,W	S	
* 29-101	T. Peysen	R. Wiseman	1952	61	5	61	C	970	45.95	Sept. 25, 1963	C,W	S	
* 102	J. Meurer	--	1952	140	5	140	W	1,010	70	do	C,W	S	
* 103	J. Schreider	--	1934	90	5	90	W	1,005	65	do	C,W	D,S	
* 104	N. Ordener	--	1900	26	--	--	W	976	13.02	Sept. 26, 1953	B,H	D	Dug well.
* 105	F. J. Luig	--	1934	23	--	--	W	--	8.15	do	J,E	D	Do.
* 106	H. Frerich	--	1940	11	--	--	W	956	8.89	Oct. 7, 1963	J,G	S	
* 201	A. J. Zotz	--	1950	177	5	177	C	1,029	120	Sept. 19, 1963	C,E	D,S	
* 202	R. Schroeder	M. Roberts	1957	120	5	120	W	1,019	65	do	C,E	D,S	
* 203	Ed. Moer	--	1944	80	5	80	W	1,010	65	do	C,W	D,S	
* 204	J. Schroeder	M. Roberts	1946	185	5	185	C	1,024	125.12	Sept. 20, 1963	C,E	D	
* 205	C. Wolf	do	1961	209	5	209	C	1,029	137.21	do	C,E	D	
* 206	do	do	1946	204	5	204	C	1,030	135	do	C,E	D,S	
207	V. Veitenheimer	--	1957	80	5	80	C	1,014	68.86	do	--	--	
* 208	H. Wolf	M. Roberts	1951	58	5	58	W	1,036	30	Sept. 25, 1963	C,W	D,S	
* 209	Bill Schroeder	--	1900	125	5	125	C	1,020	65	do	C,E	D	
* 210	James Berend	James Berend	1962	90	5	90	W	1,049	40	Sept. 30, 1963	C,E	D	
* 401	L. Berend	--	1960	75	5	75	C	1,034	52.75	Aug. 13, 1963	C,E	D	
* 402	B. Schroeder	--	1935	21	--	--	C	1,035	10	Sept. 5, 1963	C,W	D	Dug well.
* 403	E. Schroeder	M. Roberts	1956	65	5	65	C	1,028	54.90	do	C,W	D	
* 404	A. Veitenheimer	do	1960	81	5	81	C	1,025	72.81	Sept. 6, 1963	C,W	D	

See footnote at end of table.

Table 2.--Records of wells and springs, Archer County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*20-29-405	A. Veitenheimer	--	1940	161	5	161	C	1,025	90	Sept. 6, 1963	C,E	S	
* 406	L. E. Osterman	M. Roberts	1955	150	5	150	C	1,052	82.47	Sept. 24, 1963	C,E	D,S	
* 407	W. T. Schrieber	do	1959	160	5	160	C	1,055	85	do	C,E	D	
* 408	E. F. Schrieber	--	1918	28	--	--	C	1,010	18.31	do	J,E	D	Dug well.
* 409	John Meurer	M. Roberts	1946	100	5	100	C	995	60	Sept. 25, 1963	C,E	D	
* 410	do	do	1946	145	5	145	C	1,005	51.21	do	C,W	S	
* 502	L. A. Berend	Lindemann	1959	222	6	222	C	1,050	--	--	C,E	P	Supplies water for High School. Data from U.S. Geological Survey.
* 503	W. L. Lindemann	M. Roberts	1954	100	5	100	C	1,050	65	Sept. 16, 1963	J,E	D	
* 504	F. Steinberger	do	1960	100	5	100	C	1,057	40	Sept. 4, 1963	C,E	S	
* 505	do	--	1955	100	5	100	C	1,054	34.05	do	C,W	D,S	
* 506	F. Koetter	--	1933	40	5	40	C	1,075	28.95	Sept. 5, 1963	J,E	D	
* 507	do	M. Roberts	1962	105	5	105	C	1,075	28.90	do	J,E	S	
* 508	S. Vieth	--	1938	120	5	120	C	1,070	25	Sept. 6, 1963	C,E	D	
* 509	S. R. Wolf	--	1933	100	5	100	C	1,032	45	do	C,E	D	
* 510	H. L. Munchrath	M. Roberts	1948	160	5	160	C	1,029	95.61	do	S,E	D,S	
* 511	Bob Steinberger	do	1959	100	6	100	C	1,071	20	Sept. 9, 1963	C,E	D,S	
* 512	E. F. Berend	do	1950	97	5	97	C	1,059	63.97	do	C,E	D	
* 513	L. A. Berend	do	1956	185	5	185	C	1,044	82.35	do	C,E	S	
* 514	do	do	1956	185	5	185	C	1,052	85	do	C,E	S	
* 515	Ray Peysen	do	1957	175	5	175	C	1,052	128.32	do	C,E	D	
* 516	F. Schroeder	do	1962	190	5	190	C	1,045	160.34	do	J,E	D	
* 517	G. Steinberger	B. Poulton	1961	280	5	280	C	1,045	160	Sept. 13, 1963	C,E	S	
* 518	do	M. Roberts	1949	180	5	180	C	1,042	95	do	C,E	D,S	
* 519	W. Hoff	do	1948	80	5	80	C	1,049	30	do	C,E	D	
* 520	A. Roewe	do	1956	90	5	90	C	1,050	64.65	do	C,E	D	
* 521	W. L. Linderman	--	1960	285	5	285	C	1,050	160	Sept. 16, 1963	C,E	D	

See footnote at end of table.

Table 2.--Records of wells and springs, Archer County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*20-29-522	L. A. Berend	--	1948	100	5	100	C	1,049	65	Sept. 16, 1963	C,E	D	
* 523	J. Vietenheimer	--	1948	40	5	40	--	1,019	20	Sept. 4, 1963	J,E	D	
* 524	L. Schroeder	M. Roberts	1956	186	5	186	C	1,050	80	Sept. 16, 1963	C,E	D	
* 525	Catholic Church	do	1954	185	5	185	C	1,084	100	do	C,E	D	
* 526	L. Schroeder	--	1946	76	5	76	C	1,033	30	do	J,E	D	
* 527	J. C. Mann	--	1955	300	7	300	C	1,049	160	Sept. 18, 1963	C,E	D	
* 528	W. V. Weinzapfel	--	1910	90	5	90	C	1,046	50	do	C,W	D	
* 529	T. L. Wolf	R. Wiseman	1952	252	5	252	C	1,029	160	Sept. 17, 1963	C,E	D	
* 530	Joe Parrot	--	1945	195	4	195	C	1,055	111.15	do	C,E	D	
531	Joe Veitenheimer	--	1930	190	5	190	C	1,040	100.47	do	--	--	
* 532	L. Lerner	--	1948	190	5	190	C	1,036	129.97	Sept. 18, 1963	C,E	D	
* 533	T. J. Peysen	R. Wiseman	1960	169	5	169	C	1,025	129.45	do	C,E	D	
* 534	A. J. Berend	--	1940	195	5	195	C	1,037	144.21	Sept. 17, 1963	C,E	D	
* 535	A. Hoffman	M. Roberts	1957	186	5	186	C	1,026	115	Sept. 18, 1963	C,E	D	
* 536	H. Osterman	do	1950	190	5	190	C	1,050	120	Sept. 17, 1963	C,W	D	
* 537	E. Schrieber	do	1950	90	5	90	C	1,069	50	Aug. 9, 1963	C,W	S	
* 538	R. Berend	--	1950	160	5	160	C	1,079	80	Aug. 29, 1963	C,E	D,S	
* 701	J. S. Bridwell	--	--	80	6	80	C	1,100	17.64	Aug. 1, 1963	C,W	--	
* 702	P. Himmels	--	1940	78	5	78	C	1,123	25	do	C,E	D	
* 703	K. Maxey	L. O. Loften	1959	90	5	90	C	1,171	25	July 30, 1963	C,W	D	
* 704	J. S. Bridwell	--	1958	65	7	65	C	1,103	50	Aug. 9, 1963	C,W	D	
* 705	F. C. Winter	F. Hoffman	1951	91	6	91	C	1,141	25	Aug. 13, 1963	C,E	D	
* 706	Mike Wolf	do	1948	100	5	100	C	1,085	59.25	do	C,E	D	
* 707	Dave Meurer	M. Roberts	1959	189	5	189	C	1,070	100	do	C,W	S	
* 708	do	do	1956	180	5	180	C	1,066	100	do	C,E	D	
* 709	A. J. Berend	--	1920	25	--	--	C	1,045	18.05	do	J,E	D,S	Dug well.

See footnote at end of table.

Table 2.--Records of wells and springs, Archer County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing		Water-bearing unit	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
					Diameter (in.)	Depth (ft)			Below land-surface datum (ft)	Date of measurement			
*20-29-801	J. S. Bridwell	--	1933	110	7	110	C	1,157	70	July 30, 1963	C,W	S	
* 802	do	--	1930	100	7	100	C	1,135	70	do	C,W	D,S	
* 803	G. V. Baker	--	--	160	5	160	C	1,167	131.04	Aug. 7, 1963	C,E	D	
* 804	J. S. Bridwell	--	1935	100	5	100	C	1,132	72.55	July 30, 1963	C,W	D,S	
* 805	J. W. Hastings	--	1945	100	7	100	C	1,126	60	Aug. 7, 1963	C,E	D	
* 806	do	--	1952	117	7	117	C	1,106	65	do	C,E	D	
* 807	James Wolf	M. Roberts	1959	112	5	112	C	1,121	92.59	Aug. 8, 1963	J,E	D	
* 808	Jerome Berend	--	1952	140	5	140	C	1,127	107.08	do	C,E	D	
* 809	J. S. Bridwell	--	1956	200	7	200	C	1,137	90.01	do	C,W	D	
* 810	Anton Wolf	M. Roberts	1952	100	5	100	C	1,138	65	do	J,E	D,S	
* 811	Anton Berend	--	1910	25	--	--	C	1,136	11.97	do	J,E	S	Dug well.
* 812	do	--	1951	90	5	90	C	1,112	51.23	do	C,E	D,S	
* 813	E. Schrieber	--	1948	42	5	42	C	1,067	15.45	Aug. 9, 1963	C,E	D	
* 814	Anton Wolf	M. Roberts	1962	62	5	62	C	1,078	34.49	do	J,E	D	
* 815	D. Schrieber	--	1910	25	--	--	C	1,051	15.19	do	J,E	D,S	
* 33-201	R. Hormel	--	1925	90	5	90	W	1,250	40	Nov. 27, 1963	C,W	S	
* 301	J. T. Slaughter	--	1909	45	5	45	W	1,262	12.87	Nov. 20, 1963	J,E	D	
* 302	A. B. Alexander	--	--	50	5	50	W	1,246	23.81	Nov. 27, 1963	C,W	S	
* 501	M. G. Hargraves	--	1937	90	5	90	W	1,275	76.15	Nov. 7, 1963	C,W	D,S	
* 502	Joe Spoonts	--	1922	52	--	--	W	1,268	24	do	C,W	D	Not cased.
* 503	F. W. Kunkel	--	1925	70	5	70	W	1,280	45	do	C,W	--	
* 504	M. G. Hargraves	--	1925	65	7	65	W	1,315	47.01	Nov. 6, 1963	C,W	D	
* 505	Reno Oil Company	--	1930	65	7	65	W	1,305	40	do	C,E	--	
* 506	J. Hrnerik	--	1948	65	7	65	W	1,317	40.35	Nov. 4, 1963	C,W	S	
* 507	-- Kreeger	--	1940	30	--	--	W	1,303	24.39	Nov. 15, 1963	B,H	D	Dug well.
* 508	J. R. Miller	--	1962	50	7	50	W	1,261	9.48	do	J,E	D	

See footnote at end of table.

Table 2.--Records of wells and springs, Archer County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*20-33-601	R. M. Echols	--	1920	20	--	--	W	1,249	11.79	Nov. 4, 1963	C,W	S	Dug well.
* 602	L. M. Hayter	--	1939	70	7	70	W	1,307	45.71	Nov. 15, 1963	C,W	D	
* 603	O. L. Talbot	--	1940	18	--	--	W	1,289	9.55	do	J,E	D	Dug well.
* 604	A. Wilhelm	--	1925	80	5	80	W	1,291	25.75	do	C,E	D	
* 605	John Cuba	--	1920	30	--	--	W	1,273	20.68	Nov. 18, 1963	C,W	D	Dug well.
* 606	J. C. McCluer	--	1926	28	--	--	W	1,269	15	Nov. 20, 1963	J,E	D	Do.
* 34-101	T. W. Kunkel	--	1948	20	--	--	W	1,300	1.55	Nov. 15, 1963	J,E	D	
* 102	Willie Horkey	--	1945	20	7	20	W	1,249	10.45	Nov. 18, 1963	C,W	--	
103	D. L. Bishop	--	1930	38	--	--	W	1,300	19.23	do	--	--	
* 104	Grover Furr	--	--	Spring	--	--	W	1,280	(+)	do	Flows	--	
* 35-401	Jack Neal	--	1953	100	5	100	W	1,185	24.31	Nov. 20, 1963	C,W	S	
* 402	Crenshaw & Whitehill	--	--	200	7	200	W	1,150	134.56	do	C,E	Ind	
403	Leo Kunkel	--	1934	217	7	217	W	1,175	142.46	do	--	--	
* 701	E. Alsup	--	1914	28	--	--	W	1,160	14.90	Nov. 29, 1963	C,W	D	
* 36-101	L. T. Burns	M. Roberts	1955	80	5	80	W	1,144	40	Aug. 26, 1963	C,W	D	
* 301	G. Prideaux	--	1947	250	5	250	C	1,165	150	July 31, 1963	C,W	D,S	
* 601	J. S. Bridwell	--	1937	120	7	120	C	1,090	21.93	Aug. 1, 1963	C,W	D,S	
* 802	Earl Garvey	--	--	80	5	80	C	1,115	35.68	Sept. 19, 1963	C,W	S	
* 902	Burk Royalty Co.	--	1950	500	7	500	C	1,110	324.05	Aug. 1, 1963	C,E	Ind	
* 903	Kouri Oil Company	--	1962	102	4.5	102	C	1,142	50	July 31, 1963	C,E	D	
* 904	C. C. Prideaux	--	1910	50	--	--	C	1,144	27.70	Aug. 1, 1963	J,E	D,S	Dug well.
* 37-101	W. C. Jones	--	1910	80	5	80	C	1,147	40	July 29, 1963	J,E	D	
* 102	J. O. Loftin	--	1936	12	--	--	C	1,102	9.68	do	J,E	D	
* 103	W. McMurtry	--	1940	75	5	75	C	1,136	29.60	do	C,W	D	
* 201	Sallie Ducus	--	1928	60	5	60	C	1,092	21.35	do	J,E	D	

See footnote at end of table.

Table 2.--Records of wells and springs, Archer County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Casing: Diameter (in.)	Casing: Depth (ft)	Water-bearing unit	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*20-37-202	H. Roewe	--	1950	95	5	95	C	1,132	61.34	Aug. 7, 1963	J,E	D	
* 203	M. R. Oliver	--	--	75	5	75	C	1,110	45	do	J,E	D	
* 401	Timberlake, et al.	--	1938	650	7	650	C	1,112	292.85	June 4, 1963	C,E	Ind	
* 402	J. B. Revier Co.	--	1930	550	7	550	C	1,069	227.24	June 6, 1963	S,E	Ind	
* 403	E. Foster	--	--	120	7	120	C	1,040	66.85	June 7, 1963	C,H	--	
* 501	H. O. Prideaux	C. Harmon	1950	550	7	550	C	1,054	225	do	S,E	D	
701	E. Woody	--	1928	475	7	475	C	1,027	217	June 4, 1963	--	--	
* 702	Fresno Oil Co.	--	1935	450	7	450	C	1,081	250	June 6, 1963	C,G	D,Ind	
* 703	Inez Prideaux	--	1950	519	7	519	C	1,076	200	do	C,E	D,S	
* 704	Timberlake, et al.	--	1928	650	7	650	C	1,087	257.92	June 4, 1963	C,E	Ind	
* 705	Ranch Oil Company	--	1927	600	7	600	C	1,110	316.01	June 5, 1963	S,E	D	
* 706	C. E. Morrison	--	1930	600	7	600	C	1,100	295.22	June 6, 1963	C,G	D	
* 707	do	--	1930	550	7	550	C	1,064	221.33	do	C,G	D	
* 801	B. S. & M. Oil Co.	--	1956	650	6	650	C	1,070	236.01	June 4, 1963	--	--	
* 802	O. L. Matlock	L. Martin	1960	450	7	450	C	1,062	200	do	C,E	D	
* 803	B. S. & M. Oil Co.	--	1920	85	7	85	C	1,034	50	do	C,E	D	
* 804	O. L. Matlock	--	1928	450	6	450	C	1,034	220	do	C,E	Ind	
* 805	Erno Woody	--	1928	350	7	350	C	1,025	215.85	do	C,G	Ind	

* Chemical analysis of water shown on Table 3.

Table 3.--Chemical analyses of water from wells and springs, Archer County

(Analyses are in parts per million except specific conductance and pH)

Analyses performed by Texas State Department of Health except as indicated by footnote.

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-12-601	C. J. Cully	80	Oct. 17, 1963	9	25	33	2,190	780	610	2,590	2.1	<0.4	5,834	155	9,100	7.8
901	B. K. Forcher	30	do	9	81	57	770	530	217	950	.9	105	2,451	435	4,180	7.7
13-701	T. B. Medders	50	Oct. 16, 1963	16	49	13	151	500	15	43	.6	<.4	536	176	879	7.7
702	do	65	do	6	46	15	158	388	33	119	.6	<.4	573	177	990	7.9
801	W. T. McGregor	60	do	13	69	31	181	483	46	169	1.2	8.0	855	301	1,310	7.7
802	T. B. Medders	35	do	14	75	14	28	320	12	18	.4	1.5	321	246	545	7.7
803	W. T. McGregor	70	Oct. 21, 1963	11	32	13	359	461	58	333	1.3	<.4	1,036	131	1,860	7.9
804	do	80	do	12	44	17	174	427	44	93	.7	29	623	179	1,077	7.9
19-701	Cowan & McKinney	25	Dec. 3, 1963	13	121	19	81	249	114	130	.6	111	724	423	1,175	7.7
801	B. G. Hasson	21	Dec. 4, 1963	12	158	55	175	273	192	176	.6	390	1,292	620	2,000	8.0
20-501	Dick Coleman	125	Oct. 11, 1963	9	36	15	570	320	217	650	1.5	2	1,657	151	2,860	7.7
502	do	125	do	12	20	10	287	415	17	268	.5	<.4	819	90	1,460	7.8
503	Don Coleman	100	Oct. 14, 1963	8	8	3	700	540	39	760	.8	<.4	1,782	31	3,150	8.2
504	do	100	do	8	4	2	550	560	25	510	1.0	<.4	1,376	19	2,430	8.3
505	W. M. Coleman	88	Oct. 15, 1963	8	5	4	730	570	43	770	.8	<.4	1,841	26	3,250	8.1
601	A. B. Edwards	40	Oct. 8, 1963	17	84	24	121	478	45	81	.8	4	617	310	1,040	7.3
602	do	75	do	16	35	16	160	420	30	93	.3	<.4	556	155	959	7.6
21-101	R. L. Bullard	42	Oct. 9, 1963	14	116	28	74	151	69	140	.6	204	724	405	1,178	7.4
201	J. S. Bridwell	80	Oct. 16, 1963	8	12	11	362	570	100	189	.7	<.4	981	74	1,640	8.4
202	do	79	do	9	124	51	970	640	471	1,090	1.2	3	3,035	520	4,730	7.9
203	do	85	do	8	37	19	2,250	530	411	3,060	1.8	<.4	6,050	174	9,300	7.9

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-21-204	J. T. Gant	42	Oct. 16, 1963	10	54	13	97	283	21	49	0.3	82	466	189	785	7.7
401	L. Schrieber	90	Oct. 2, 1963	17	56	10	16	198	21	21	.4	3.5	242	181	424	7.5
402	A. B. Edwards	90	Oct. 8, 1963	8	19	6	336	495	6	283	.7	<.4	898	71	1,640	7.6
403	do	90	do	9	9	4	468	322	24	550	.7	<.4	1,226	36	2,250	7.7
404	J. K. Coleman	80	do	24	80	16	44	405	13	10	.5	2	394	268	652	7.6
405	do	80	Oct. 9, 1963	11	86	18	233	351	142	263	.3	11	942	287	1,610	7.8
406	do	80	do	11	40	26	226	412	55	230	.6	<.4	791	208	1,440	8.0
407	J. K. Coleman, Jr.	50	do	16	115	30	124	427	64	180	1.0	9	753	412	1,300	7.5
703	H. P. Meurer	80	Oct. 7, 1963	10	44	15	152	376	54	97	1.0	4	559	174	978	7.5
704	W. A. Morath	15	Oct. 2, 1963	15	92	20	170	395	225	105	.6	<.4	820	311	1,280	7.6
705	Joe Stallcup	54	do	11	20	11	184	429	41	77	1.0	<.4	552	96	938	7.9
706	O. J. Stallcup	80	do	8	18	19	890	660	245	910	1.1	<.4	2,404	125	3,990	8.3
707	Ray Hemmi	90	Oct. 7, 1963	8	11	8	830	600	227	800	.8	<.4	2,185	63	3,650	8.1
708	H. Frerich	84	do	9	34	26	650	530	223	680	.7	<.4	1,881	193	3,150	7.4
709	J. Hoffman	60	do	8	109	84	432	439	184	620	.8	112	1,767	620	3,660	7.8
710	A. J. Hilbers	75	Sept. 30, 1963	12	48	16	291	483	109	224	.6	22	945	184	1,630	7.7
711	R. L. Schenk	90	Oct. 7, 1963	12	31	15	213	453	43	138	1.6	2	680	138	1,190	7.6
712	Helen Hilbers	82	Oct. 8, 1963	12	244	148	630	488	610	860	1.8	336	3,084	1,220	4,700	7.5
713	Eddie Vieth	90	do	10	6	4	328	530	46	202	.9	<.4	861	30	1,500	8.1
714	H. W. Hilbers	70	Sept. 30, 1963	14	79	9	57	400	11	12	1.0	.7	387	234	637	7.8
715	do	59	do	8	7	4	386	740	30	153	.6	<.4	964	32	1,600	8.6
801	F. Hoffman	110	Sept. 27, 1963	12	42	11	83	312	24	38	.5	3	372	150	635	7.6
802	J. Poirot	56	do	12	42	11	94	322	21	55	.8	<.4	396	160	685	7.5

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-21-803	F. Hoffman	36	Sept. 27, 1963	11	92	33	208	376	124	222	0.7	76	949	367	1,600	7.4
804	M. A. Berend	50	do	14	57	22	95	410	30	31	1.3	34	482	233	805	7.5
805	A. J. Prescher	28	Sept. 30, 1963	17	21	5	22	102	10	13	.4	11	150	74	252	7.3
806	Frank Vieth	35	do	10	22	11	166	366	65	71	.6	4	534	101	890	8.1
807	do	65	do	12	35	16	183	403	100	73	.5	1.5	655	153	1,032	8.9
808	Paul Krahl	25	Oct. 1, 1963	14	125	26	190	359	84	296	.9	30	945	423	1,670	7.8
809	R. Jackson	25	do	17	64	13	57	161	35	71	.8	84	419	214	710	7.7
810	Otto Anderle	36	do	13	31	23	329	540	93	262	1.1	<.4	1,016	173	1,750	8.1
812	B. Warmuth	75	do	7	44	15	116	290	47	90	.3	22	482	173	852	7.9
813	J. C. Peysen	20	Oct. 2, 1963	17	206	84	153	444	138	416	.9	121	1,355	870	2,290	7.8
26-401	J. R. Parkey	32	Nov. 7, 1963	13	74	17	22	325	10	14	.7	5.5	317	256	568	7.6
701	W. A. Horkey	100	Nov. 20, 1963	9	10	10	890	700	196	880	4.4	<.4	2,344	68	3,960	8.0
702	do	110	do	7	9	8	660	510	148	670	2.5	<.4	1,761	55	3,060	7.9
27-101	C. Morrison	32	Nov. 17, 1963	15	279	312	990	284	510	1,590	2.2	1,394	5,253	1,980	7,360	7.3
301	M. Baggett	25	Dec. 3, 1963	6	40	18	68	224	54	43	1.1	15	355	174	645	8.1
303	G. Bruce	93	Dec. 6, 1963	10	87	42	750	540	227	1,000	.7	20	2,406	389	4,050	7.7
28-101	Charles King	40	Oct. 11, 1963	12	59	48	170	373	69	198	.5	45	791	344	1,360	7.6
103	Tom Fields	82	Dec. 6, 1963	12	186	132	1,310	520	1,320	1,320	2.4	267	4,836	1,010	6,800	7.8
104	L. L. Lowake	30	do	11	59	34	411	417	122	479	1.0	68	1,388	288	2,400	7.6
201	R. C. Kinder	30	Oct. 11, 1963	15	65	17	55	256	38	34	.7	60	410	235	668	7.4
202	J. D. Powell	35	do	14	143	46	445	359	248	479	.1	260	1,877	550	2,940	7.2
203	Otis Davis	30	do	15	76	28	181	315	89	184	1.2	98	830	305	1,360	7.6
403	Gene Bell	20	Dec. 5, 1963	16	135	45	119	346	26	335	.6	16	864	520	1,650	7.5

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-28-404	Duren Bell	45	Dec. 5, 1963	10	59	35	271	415	102	311	0.7	5	999	290	1,750	7.9
501	C. L. Washburn	76	Sept. 26, 1963	10	44	13	97	273	32	77	.9	19	431	167	760	7.8
701	C. McKinney	25	Aug. 26, 1963	14	68	19	97	303	51	81	1.2	33	516	247	870	7.1
901	E. L. Garvey	30	July 29, 1963	14	84	29	75	320	55	82	.9	55	557	328	948	7.6
902	Roy Harrison	80	Aug. 29, 1963	12	47	15	66	317	22	23	.6	.4	339	179	589	7.3
29-101	T. Peysen	61	Sept. 25, 1963	11	29	14	352	560	89	248	1.0	<.4	1,016	129	1,740	7.9
102	J. Meurer	140	do	7	6	5	335	468	57	237	.8	<.4	882	36	1,570	8.0
103	J. Schrieder	90	do	7	12	6	710	780	211	540	3.5	16	1,894	54	3,080	8.2
104	N. Ordner	26	Sept. 27, 1963	14	234	59	177	256	117	346	.6	480	1,550	830	2,400	7.3
105	F. J. Luig	23	Sept. 25, 1963	12	100	32	147	298	74	197	.8	120	827	382	1,400	7.4
106	H. Frerich	11	Oct. 7, 1963	14	62	16	59	344	16	18	.7	13	365	218	624	7.7
201	A. Lotz	177	Sept. 19, 1963	9	7	4	920	780	396	680	1.2	8	2,414	33	3,850	8.1
202	R. Schroeder	120	do	9	16	9	730	730	219	590	1.2	.5	1,939	79	3,200	7.8
203	Ed Moer	80	do	10	44	22	520	449	148	560	.6	17	1,542	201	2,650	7.8
204	J. Schroeder	185	Sept. 20, 1963	9	6	2	900	830	265	690	4.3	<.4	2,288	25	3,760	8.0
205	C. Wolf	209	do	9	6	2	840	760	306	630	3.3	.5	2,174	26	3,550	8.0
206	do	204	do	9	8	4	890	780	312	710	3.1	5.5	2,324	37	3,750	7.8
208	H. Wolf	58	Sept. 25, 1963	12	53	35	186	498	57	157	.4	<.4	747	274	1,300	7.9
209	Bill Schroeder	125	do	9	23	12	347	530	58	280	.7	<.4	991	106	1,704	7.8
210	James Berend	90	Sept. 30, 1963	11	3	--	227	481	27	55	.9	<.4	566	8	910	8.2
401	L. Berend	75	Aug. 13, 1963	12	30	10	153	318	31	109	1.7	2	507	117	884	7.6
402	B. Schroeder	21	Sept. 5, 1963	10	56	20	141	397	60	67	1.1	67	618	222	1,050	7.6
403	E. Schroeder	65	do	10	88	55	550	458	520	540	.7	14	2,007	445	3,170	7.6

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-29-404	A. Veitenheimer	81	Sept. 6, 1963	8	7	3	473	630	97	318	2.8	<0.4	1,210	31	2,110	7.9
405	do	161	do	8	21	7	1,310	520	331	1,570	1.9	<.4	3,560	81	5,830	7.4
406	L. E. Osterman	150	Sept. 24, 1963	7	20	8	1,590	620	429	1,880	2.8	<.4	4,245	83	6,850	7.9
407	W. T. Schrieber	160	do	7	21	9	1,540	500	354	1,880	3.0	<.4	4,056	89	6,750	7.9
408	E. F. Schrieber	28	do	11	103	46	144	467	57	211	.4	5	808	445	1,450	7.6
409	John Meurer	100	Sept. 25, 1963	11	386	107	101	151	105	309	.6	1,218	2,314	1,410	3,300	7.3
410	do	145	do	7	29	13	1,980	610	540	2,410	2.1	<.4	5,291	127	8,100	7.9
a/502	L. A. Berend	222	Feb. 6, 1963	11	3	.8	457	729	106	198	2.8	1.8	1,140	11	1,880	8.2
503	W. L. Lindemann	100	Sept. 16, 1963	10	2	--	328	570	82	107	1.3	5.4	820	6	1,400	8.5
504	F. Steinberger	100	Sept. 4, 1963	10	12	3	880	680	218	870	4.3	<.4	2,034	42	3,900	7.6
505	do	100	do	10	74	24	266	444	116	227	.7	68	1,005	285	1,700	7.5
506	F. Koetter	106	Sept. 5, 1963	12	77	16	98	223	35	110	.4	96	553	258	960	7.1
507	do	40	do	14	78	16	69	222	28	81	.4	104	497	260	870	7.3
508	S. Vieth	120	Sept. 6, 1963	14	12	5	369	670	66	165	.5	<.4	960	53	1,620	7.5
509	S. R. Wolf	100	do	10	19	6	443	580	178	275	2.1	13	1,236	74	2,050	7.7
510	H. L. Munchrath	160	do	9	16	7	810	630	353	690	2.2	10	2,210	68	2,600	7.6
511	Bob Steinberger	100	Sept. 9, 1963	12	9	4	410	710	86	208	.4	<.4	1,079	40	1,860	8.0
512	E. F. Berend	97	do	10	3	1	402	610	143	191	.9	<.4	1,050	12	1,790	7.9
513	L. A. Berend	185	do	9	7	3	311	600	71	107	1.9	<.4	806	29	1,390	8.1
514	do	185	do	10	11	2	640	700	253	426	3.6	3	1,654	38	2,850	7.8
515	Ray Peysen	175	do	9	6	1	660	760	261	408	3.6	<.4	1,724	20	2,880	8.0
516	F. Schroeder	190	do	10	6	2	690	770	215	493	5.0	<.4	1,799	23	3,080	8.0
517	G. Steinberger	280	Sept. 13, 1963	9	44	14	2,190	444	540	2,950	1.7	<.4	5,975	169	9,510	7.7

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-29-518	G. Steinberger	180	Sept. 13, 1963	9	1	2	780	770	282	580	5.2	<0.4	2,038	23	3,450	8.0
519	W. Hoff	80	do	5	71	35	456	540	177	410	.5	160	1,586	320	2,680	7.7
520	A. Roewe	90	do	6	36	20	456	580	207	360	.6	8	1,376	171	2,370	7.7
521	W. L. Lindemann	285	Sept. 16, 1963	6	29	12	1,860	570	302	2,490	2.1	<.4	5,010	120	8,100	7.9
522	L. A. Berend	100	do	10	2	1	353	560	117	126	1.2	<.4	896	11	1,500	8.4
523	J. Veitenheimer	40	Sept. 4, 1963	12	158	44	167	273	107	222	.5	330	1,171	580	1,850	7.1
524	L. Schroeder	186	Sept. 16, 1963	9	5	1	530	810	132	255	3.3	<.4	1,338	15	2,250	8.3
525	Catholic Church	185	do	10	7	1	720	770	261	479	4.5	<.4	1,859	20	3,100	8.0
526	L. Schroeder	76	do	9	26	10	374	760	96	144	3.3	19	1,054	107	1,790	8.0
527	J. C. Mann	300	Sept. 18, 1963	8	6	2	850	1,220	288	383	3.3	<.4	2,140	25	3,350	8.1
528	W. V. Weinzapfel	90	do	9	4	1	700	1,160	207	224	4.8	<.4	1,721	16	2,690	8.0
529	T. L. Wolf	252	Sept. 17, 1963	8	40	12	2,070	403	600	2,260	1.5	<.4	5,596	148	8,760	7.5
530	Joe Parrot	195	do	9	4	2	700	730	242	442	4.3	<.4	1,759	18	2,860	7.9
532	L. Lerner	190	Sept. 18, 1963	9	4	3	700	730	234	463	4.5	.5	1,779	21	2,900	8.0
533	T. J. Peysen	169	do	9	6	2	870	890	245	630	4.1	<.4	2,208	24	3,600	8.0
534	A. J. Berend	195	Sept. 17, 1963	9	6	4	860	900	259	610	3.8	5	2,203	30	3,540	7.9
535	A. Hoffman	186	Sept. 18, 1963	7	11	7	880	880	484	530	3.8	.4	2,353	54	3,610	7.8
536	H. Osterman	190	Sept. 17, 1963	9	2	1	417	820	77	94	3.6	.4	1,004	9	1,630	7.8
537	E. Schrieber	90	Aug. 9, 1963	10	26	11	248	520	46	125	2.2	<.4	726	110	1,230	7.8
538	R. Berend	160	Aug. 29, 1963	9	11	4	407	670	95	192	3.1	1	1,050	46	1,750	7.6
701	J. S. Bridwell	80	Aug. 1, 1963	11	112	59	240	316	174	404	.9	.4	1,160	520	2,000	7.7
702	P. Himmels	78	do	12	34	40	390	440	78	457	1.4	.4	1,226	250	2,190	7.8
703	K. Maxey	90	July 30, 1963	16	102	34	71	178	56	167	.7	117	650	393	1,135	7.4

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium and Potassium (Na + K)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-29-704	J. S. Bridwell	90	Aug. 9, 1963	8	4	1	455	520	143	316	3.0	0.4	1,186	16	1,990	8.2
705	F. C. Winter	91	Aug. 13, 1963	9	30	12	112	370	15	32	1.2	9	402	124	680	7.6
706	Mike Wolf	100	do	10	8	4	560	620	164	415	3.4	3	1,790	37	2,440	7.9
707	Dave Meurer	189	do	10	7	2	890	710	178	850	6.3	2	2,300	28	3,800	7.7
708	do	180	do	10	7	2	930	720	165	880	5.8	.4	2,354	26	3,880	7.8
709	A. J. Berend	25	do	20	69	16	122	433	47	57	1.8	14	550	241	926	7.7
801	J. S. Bridwell	110	July 30, 1963	15	52	12	29	182	20	42	.7	8	269	180	488	7.5
802	do	100	do	11	20	10	322	530	80	185	.9	2	890	93	1,510	7.9
803	do	100	do	15	52	20	382	560	181	266	1.1	.4	1,196	213	1,998	7.7
804	G. U. Baker	160	Aug. 7, 1963	10	8	1	316	414	81	213	2.0	2	840	24	1,450	7.8
805	J. W. Hastings	100	do	11	11	4	401	510	112	277	2.3	.4	1,071	45	1,800	7.9
806	do	117	do	12	42	10	105	322	27	62	1.7	.4	416	146	721	7.6
807	James Wolf	112	do	8	38	16	235	422	95	170	1.5	.4	776	162	1,300	7.5
808	Jerome Berend	140	do	9	4	1	357	510	127	184	2.2	.4	931	13	1,560	7.7
809	J. S. Bridwell	200	Aug. 8, 1963	14	56	17	86	398	23	31	1.5	.4	428	209	713	7.7
810	Anton Wolf	100	do	13	99	34	105	364	36	173	1.3	35	675	386	1,170	7.4
811	Anton Berend	25	do	17	53	20	25	135	26	24	1.5	112	346	214	553	7.5
812	do	90	do	10	82	35	59	301	59	59	2.0	98	557	349	899	7.4
813	E. Schrieber	42	Aug. 9, 1963	13	55	25	145	450	65	81	1.3	16	622	240	1,040	7.5
814	Anton Wolf	62	do	11	42	15	169	397	40	120	1.2	.5	598	169	1,037	7.7
815	D. Schrieber	25	do	12	241	91	403	342	311	650	1.4	399	2,276	970	3,480	7.4
33-201	R. Hormel	90	Nov. 27, 1963	8	35	38	1,060	486	491	1,160	2.0	.4	3,033	245	4,870	8.1
301	J. T. Slaughter	45	Nov. 20, 1963	12	354	115	248	367	930	390	.8	64	2,294	1,360	3,160	7.2

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Cal-cium (Ca)	Magne-sium (Mg)	Sodium and Potassium (Na + K)	Bicar-bonate (HCO_3)	Sul-fate (SO_4)	Chlo-ride (Cl)	Fluo-ride (F)	Ni-trate (NO_3)	Dis-solved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-33-302	A. B. Alexander	50	Nov. 27, 1963	10	75	34	83	366	59	70	0.9	68	594	326	995	7.7
501	M. G. Hargraves	90	Nov. 7, 1963	14	32	24	258	500	88	160	.9	.4	826	178	1,430	7.7
502	J. Spoonts	52	do	14	185	101	440	544	540	510	1.4	104	2,164	880	3,280	7.4
503	F. W. Kunkel	70	Nov. 7, 1963	2	38	6	9	59	36	35	.2	.4	155	120	315	7.0
504	M. G. Hargraves	65	Nov. 6, 1963	13	18	18	165	451	32	53	.7	.4	521	117	917	8.2
505	Reno Oil Company	65	do	11	46	11	193	368	29	163	.6	13	574	162	1,163	7.4
506	J. Hrnerik	65	Nov. 4, 1963	14	115	28	127	295	84	158	1.2	128	800	404	1,380	7.6
507	-- Kreeger	30	Nov. 15, 1966	12	102	43	223	251	129	372	1.3	64	1,073	433	1,890	7.4
508	J. R. Miller	50	do	14	110	61	268	580	276	242	.9	3	1,266	530	2,000	7.3
601	R. M. Echols	20	Nov. 4, 1963	12	67	50	201	520	71	206	1.5	10	876	373	1,550	7.6
602	L. M. Hayter	70	Nov. 15, 1963	9	46	12	221	389	72	177	.7	4	732	164	1,260	7.7
603	O. L. Talbot	18	do	14	113	27	240	399	189	274	.9	10	1,067	392	1,760	7.4
604	A. Wilhelm	80	do	13	88	82	346	488	234	372	4.1	112	1,492	560	2,480	7.6
605	J. Cuba	30	do	14	282	70	469	282	71	1,160	.5	58	2,267	990	4,070	7.2
606	J. C. McCluer	28	Nov. 20, 1963	12	82	20	35	273	33	32	.8	65	411	286	717	7.3
34-101	T. W. Kunkel	20	Nov. 18, 1963	14	160	58	560	353	185	840	1.2	178	2,171	640	3,680	7.4
102	W. Hockey	20	do	15	45	24	252	600	27	177	.9	.4	835	209	1,480	7.5
104	G. Furr	Spring	do	17	266	51	740	272	36	1,530	.9	5.5	2,782	880	4,960	7.6
35-401	J. Neal	100	Nov. 20, 1963	5	222	53	379	375	196	790	.4	.4	1,830	770	3,200	7.3
402	Crenshaw & Whitehill	200	do	4	96	47	2,760	246	1,340	3,400	2.2	.4	7,775	432	11,160	7.2
701	E. Alsup	28	Nov. 29, 1963	14	178	103	670	425	279	1,020	2.4	225	2,704	870	4,500	7.7
36-101	L. T. Burns	80	Aug. 26, 1963	10	25	15	600	520	266	500	1.7	1	1,676	125	2,760	7.9
301	G. Prideaux	250	July 31, 1963	9	47	27	258	411	61	290	1.2	20	911	230	1,710	7.7

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-36-601	J. S. Bridwell	120	July 31, 1963	15	27	9	127	334	37	44	0.6	0.4	420	105	709	7.7
802	Earl Garvey	80	Sept. 19, 1963	8	3	1	390	670	101	140	2.4	.4	980	13	1,600	7.8
902	Burk Royalty	500	Aug. 1, 1963	10	8	6	840	600	104	860	3.6	.4	2,125	46	3,660	7.9
903	Kouri Oil Company	102	July 31, 1963	9	4	2	450	760	144	149	4.1	1	1,134	20	1,850	8.2
904	C. C. Prideaux	50	Aug. 1, 1963	15	240	59	135	300	321	248	.9	215	1,378	840	2,140	7.2
37-101	W. C. Jones	80	July 29, 1963	14	66	22	99	268	32	145	1.1	3	514	255	932	7.7
102	J. O. Loftin	12	do	14	37	13	77	304	17	29	1.1	1	339	148	585	7.8
103	W. McMurty	75	do	16	75	20	94	254	54	93	.9	85	561	270	959	7.4
201	S. Dycus	60	do	12	109	33	151	312	97	165	.7	148	871	480	1,450	7.5
202	H. Roewe	95	Aug. 7, 1963	12	132	45	610	387	580	630	1.6	84	2,283	510	3,500	7.7
203	M. R. Oliver	75	do	11	35	23	362	560	296	152	1.9	.4	1,156	183	1,800	7.7
401	Timberlake, et al.	650	June 5, 1963	3	3	--	660	610	110	560	3.4	.4	1,680	9	2,910	8.9
402	J. B. Revier Company	550	June 6, 1963	9	15	6	1,180	580	223	1,360	1.5	.4	3,085	63	5,210	7.9
403	E. Foster	120	June 7, 1963	16	60	17	73	349	22	52	.5	.4	413	221	719	7.1
[a] 501	H. O. Prideaux	550	Dec. 12, 1955	9	5	1.9	778	625	169	700	--	.2	1,990	22	3,370	8.6
501	do	550	June 7, 1963	10	6	2	740	670	176	670	3.3	.4	1,940	25	3,310	8.1
702	Fresno Oil Company	450	June 6, 1963	7	9	4	1,090	750	137	1,220	2.3	.4	2,839	39	4,860	8.2
[a] 703	Inez Prideaux	519	Nov. 19, 1954	10	2	1.6	495	651	88	315	--	3	1,240	12	2,120	8.2
703	do	519	June 6, 1963	9	2	2	476	640	89	320	2.5	.4	1,215	13	2,110	8.2
704	Timberlake, et al.	650	June 4, 1963	9	9	1	780	700	163	710	3.3	.4	2,024	26	3,460	7.9
705	Rancho Oil	600	June 5, 1963	9	4	3	610	620	53	530	2.7	.4	1,515	22	2,700	8.0
706	C. E. Morrison	600	June 6, 1963	7	4	--	481	640	80	316	3.0	.4	1,225	11	2,120	8.6
707	do	550	do	7	7	1	680	610	131	630	2.8	.4	1,760	23	3,040	8.3

See footnote at end of table.

Table 3.--Chemical analyses of water from wells and springs, Archer County--Continued

Well	Owner	Depth of well (ft)	Date of collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness as $CaCO_3$	Specific conductance (Micromhos at 25°C.)	pH
20-37-801	B. S. & M. Oil Co.	450	June 4, 1963	9	5	2	620	610	111	550	2.9	0.4	1,600	22	2,730	8.1
802	O. L. Matlock	450	do	9	7	2	700	640	150	650	2.9	.4	1,835	25	3,200	8.1
803	B. S. & M. Oil Co.	85	do	8	11	17	880	690	570	620	3.0	.4	2,449	96	3,880	7.8
804	O. L. Matlock	650	do	2	4	--	720	510	51	780	2.9	.4	1,840	11	3,310	8.9
805	E. Woody	350	do	9	6	2	610	610	115	530	2.8	.4	1,580	23	2,710	8.2

a/ Analysis by U.S. Geological Survey.

Table 4.--Reported brine production and disposal in 1961, Archer County

Archer County Totals

Type of disposal	Barrels daily	Barrels in 1961	Percent of total
Injection wells	113,698	37,960,127	99.0
Surface pits	5,613	354,141	.9
Other	116	38,994	.1
Total	119,427	38,353,262	100.0

Basin Totals Within the County

Basin and type of disposal	Barrels daily	Barrels in 1961	Percent of total
RED RIVER BASIN			
Injection wells	84,972	28,501,219	98.8
Surface pits	5,461	300,297	1.0
Other	113	37,914	.2
Total	90,546	28,839,430	100.0
TRINITY RIVER BASIN			
Injection wells	22,457	7,965,535	99.4
Surface pits	133	47,884	.6
Total	22,590	8,013,419	100.0
BRAZOS RIVER BASIN			
Injection wells	6,269	1,493,373	99.5
Surface pits	19	5,960	.4
Other	3	1,080	.1
Total	6,291	1,500,413	100.0

Totals for Areas Shown on Figure 9

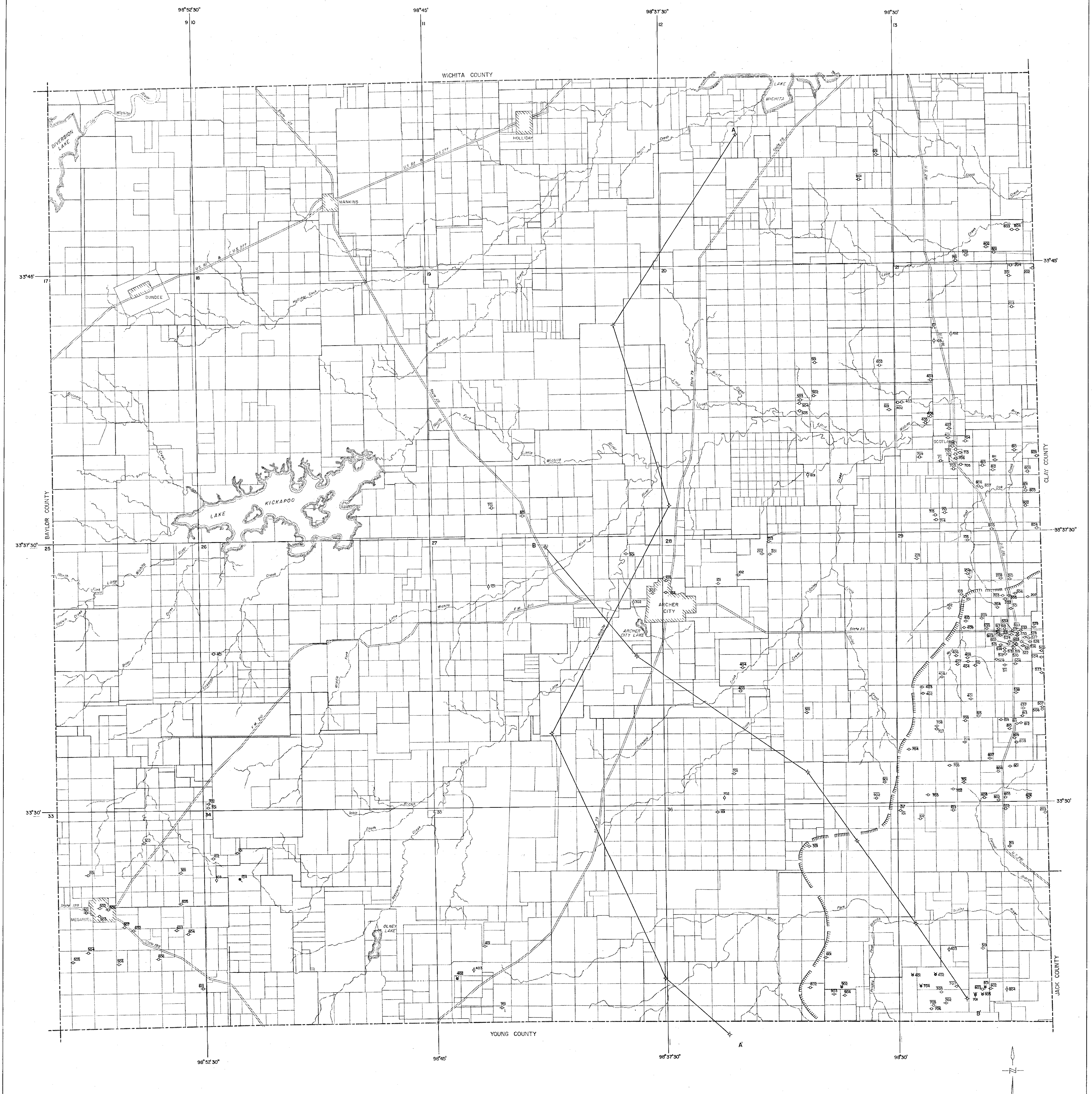
Area	Disposal in injection wells (bbl)	Disposal in pits (bbl)	Other disposal (bbl)	Total brine production (bbl)
1	340,310	9,125	--	349,435
2	6,257,910	22,808	1,095	6,281,813
3	836,667	5,020	7,000	948,687
4	2,716,805	123,811	2,852	2,843,468
5	673,692	30,135	--	703,827
6	723,311	5,085	1,746	630,142
7	2,901,046	9,756	--	2,910,802
8	2,561,111	12,607	365	2,574,083
9	5,106,110	14,250	--	5,120,360
10	4,816,231	37,413	--	6,354,057
11	7,965,535	47,884	--	8,013,419
12	1,493,373	5,960	1,080	--
Total	36,292,101	323,854	14,138	36,730,093

Table 5.--Chemical analyses of oil-field brines, Archer County

(Constituents are given in parts per million)

After Rowland Laxson, et al., 1960, Resistivities and chemical analyses of formation waters from the West Central Texas area: West Central Texas Section of the Society of Petroleum Engineers of A.I.M.E.; and B. J. Service, Inc., 1960, the chemical analyses of brines from some fields in North & West Texas.

Producing horizon	Field	Average depth (feet)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Specific gravity	pH
AREA 1										
Canyon	Kadane	2,533	10,560	1,875	48,500	7	14	98,970	1.126	6.7
AREA 2										
Gunsight	Mankins	1,600	7,450	1,718	39,500	4	2	79,000	1.100	4.6
Reno-Strawn	do	3,700	13,930	2,138	48,330	58	73	105,590	1.138	4.5
Strawn	KMA	4,023	7,867	2,234	31,220	969	2	68,000	1.088	5.3
AREA 3										
Strawn	Mankins	4,000	15,230	2,290	54,500	116	17	117,600	1.155	6.6
AREA 4										
Pennsylvanian	Hull-Silk	4,400	17,304	2,439	54,383	72	28	121,657	1.159	5.7
Caddo	do	4,565	13,590	2,550	54,180	32	174	114,600	1.152	6.6
AREA 5										
Strawn	S. Vogtsberger	4,700	17,600	1,820	59,200	55	51	127,400	1.174	4.8
Do.	Vogtsberger	4,810	16,025	1,963	58,770	95	4	124,750	1.157	5.8
AREA 6										
Cisco	Chalk Hill	1,400	6,513	1,940	36,120	30	7	73,100	1.089	6.8
AREA 7										
Caddo	Tuberville	4,684	12,755	2,375	46,680	0	84	101,350	1.131	3.0
Cisco	Ray	1,400	6,241	1,481	29,110	29	7	60,200	1.076	6.2
AREA 8										
Strawn	Burns	3,223	10,200	1,721	41,000	80	69	85,500	1.105	5.3
AREA 9										
Cisco	Anarene	1,100	6,427	1,585	29,760	57	7	61,830	1.077	6.6
Bend	Conner	5,030	9,000	1,800	38,370	106	308	80,000	1.130	6.4
Mississippian	Hunter Brothers	5,036	8,005	1,378	39,550	120	531	78,720	1.100	7.0
AREA 10										
Caddo	County Regular	4,697	14,340	1,906	44,900	69	36	100,000	1.128	5.5
Do.	Wildcat	4,800	13,190	2,371	45,830	70	28	100,950	1.133	5.8
Mississippian	Green	5,185	12,240	1,483	48,500	111	848	98,000	1.110	--
AREA 11										
Cisco	Prideaux	700	487	155	6,030	197	8	10,460	1.015	7.0
Do.	Andrews	900	3,011	851	17,120	10	7	30,610	1.039	4.3



EXPLANATION

In Use Abandoned

Domestic and Livestock Wells

Public-Supply Wells

Industrial Wells

Spring

Oil Test

Line above last three digits of well number indicates chemical analysis in Table 3

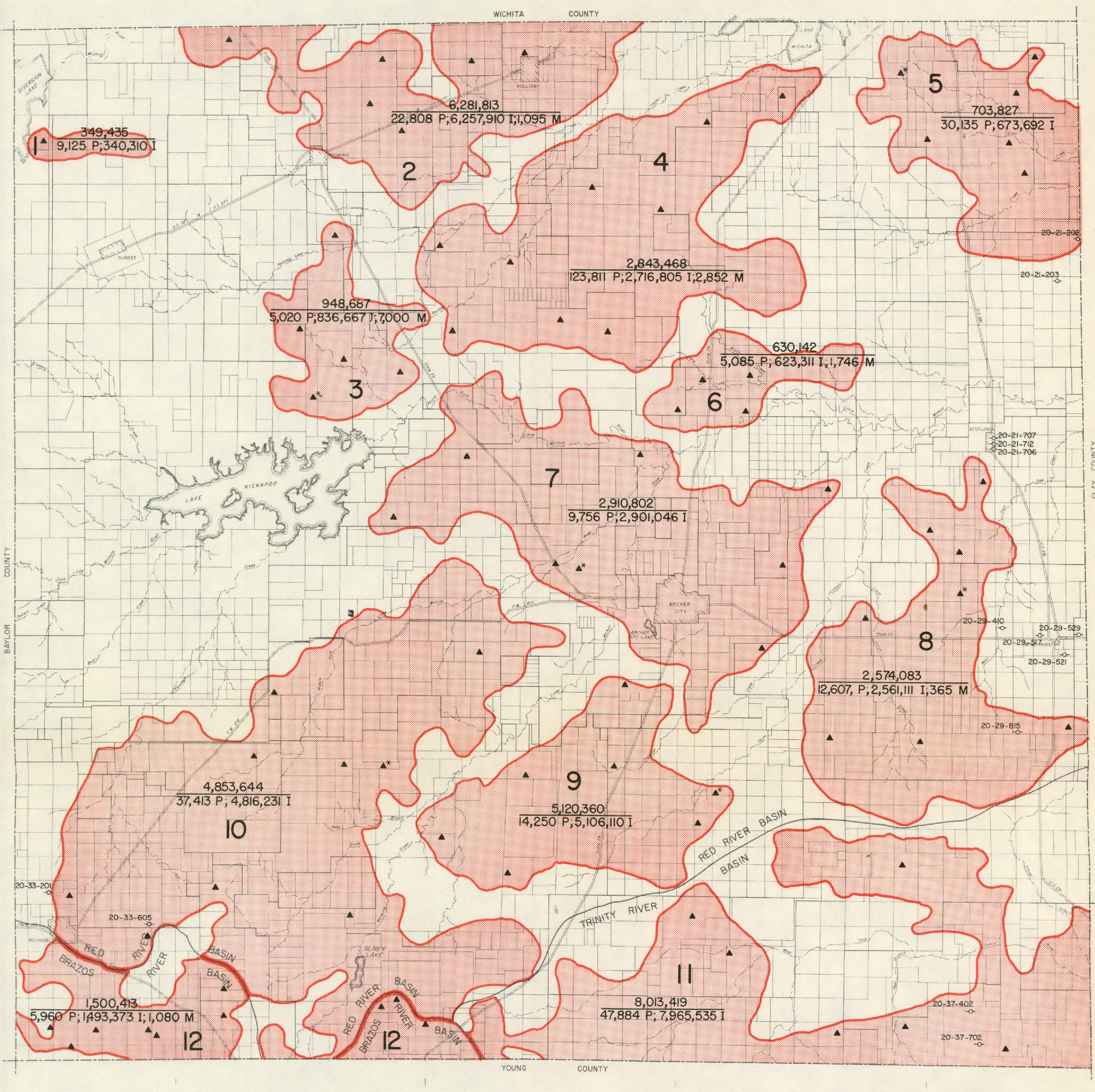
A——A' Line showing location of geologic section (Figures 4 and 5)

Present development limit of wells that produce usable-quality water from rocks of the Cisco Group of Pennsylvanian age

Figure 8

Location of Wells and Springs, Archer County

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board



EXPLANATION

▲* Approximate location of vegetative-kill area; Asterisk indicates photograph shown in Figure 6

Apparently contaminated water well

Area of petroleum production

1,500,413 / 5,960 P;1,493,373 I;1,080 M — Total Reported 1961 Brine Production, in Barrels / Reported 1961 Brine Disposal, in Barrels: Into Pits (P), Injected into Wells (I), and Miscellaneous Disposal (M)

Figure 9

Location and Amounts of Reported 1961 Brine Disposal, Vegetative-Kill Areas, and Apparently Contaminated Water Wells, Archer County

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

APPENDIX

SUPPLEMENTARY DISCUSSIONS OF QUALITY OF WATER, GEOLOGY, AND HYDROLOGY

SUPPLEMENTARY DISCUSSIONS OF QUALITY OF WATER, GEOLOGY, AND HYDROLOGY

Geology of North-Central Texas

Regional Structure

The counties included by the Texas Water Development Board in the study of ground-water resources in north-central Texas are in the Grand Prairie and Osage Plains geographic provinces of Texas. The Grand Prairie region is defined as a belt of counties west of the Balcones fault zones and north of the Llano uplift, and has been described as a modified northeastward continuation of the Edwards Plateau. At the surface in the Grand Prairie region are Cretaceous rocks of the Comanche Series dipping gently to the east and southeast. Some faulting is exhibited in the Cretaceous formations near the Balcones zone, but in general no major structural features are reflected by these beds other than the regional eastward dip. To the west of the Grand Prairie region is the Osage Plains province extending from the Edwards Plateau and Llano uplift northward to the Red River. Surface formations in the Osage Plains of north-cental Texas are of Pennsylvanian and Permian age except where these rocks are overlain locally by remnants of Cretaceous sediments or Recent alluvial deposits. Pennsylvanian and Permian beds of the region form a westward dipping homocline with an average dip of 500 feet per mile. Formations significant to the occurrence of ground water under study in the Osage Plains have not been affected by major structural deformation. The principal, large, buried structural features, illustrated in Figure A1, include the Bend flexure, the Red River uplift, eastern Midland shelf, and the Concho arch and developing Concho foreland.

Despositional History

The geologic environment in which the rock units underlying north-central Texas were laid down and the stratigraphic relationship of these units one to another determine the character of the water-bearing formations, which are the sources of ground water. Structural movement and crustal settling and shifting, which followed the deposition of the rocks in the area, influenced the mode of occurrence of ground water. An understanding of these complex historical events is important to a comprehension of how ground water occurs and how it can best be developed.

The sequence of geologic events significant to the occurrence of ground water in north-central Texas began in Pennsylvanian times, and continued through the deposition of Permian rocks throughout most of the area, Cretaceous sediments over a large part of the area, and Pleistocene to Recent alluvial sediments found at the surface in local areas and along most of the streambeds.

The Pennsylvanian and Permian seas that deposited sediments in the north-central Texas area were shallow--probably less than 100 feet deep. This is evidenced by the large amounts of sandstone, the repetition and extent of coal deposits, and the presence of frequent local unconformities. Present also are conglomerates, mud cracks, ripple marks, cross-bedding, and fossils that are found in a shallow-water environment. Thus, ground water occurs in this area

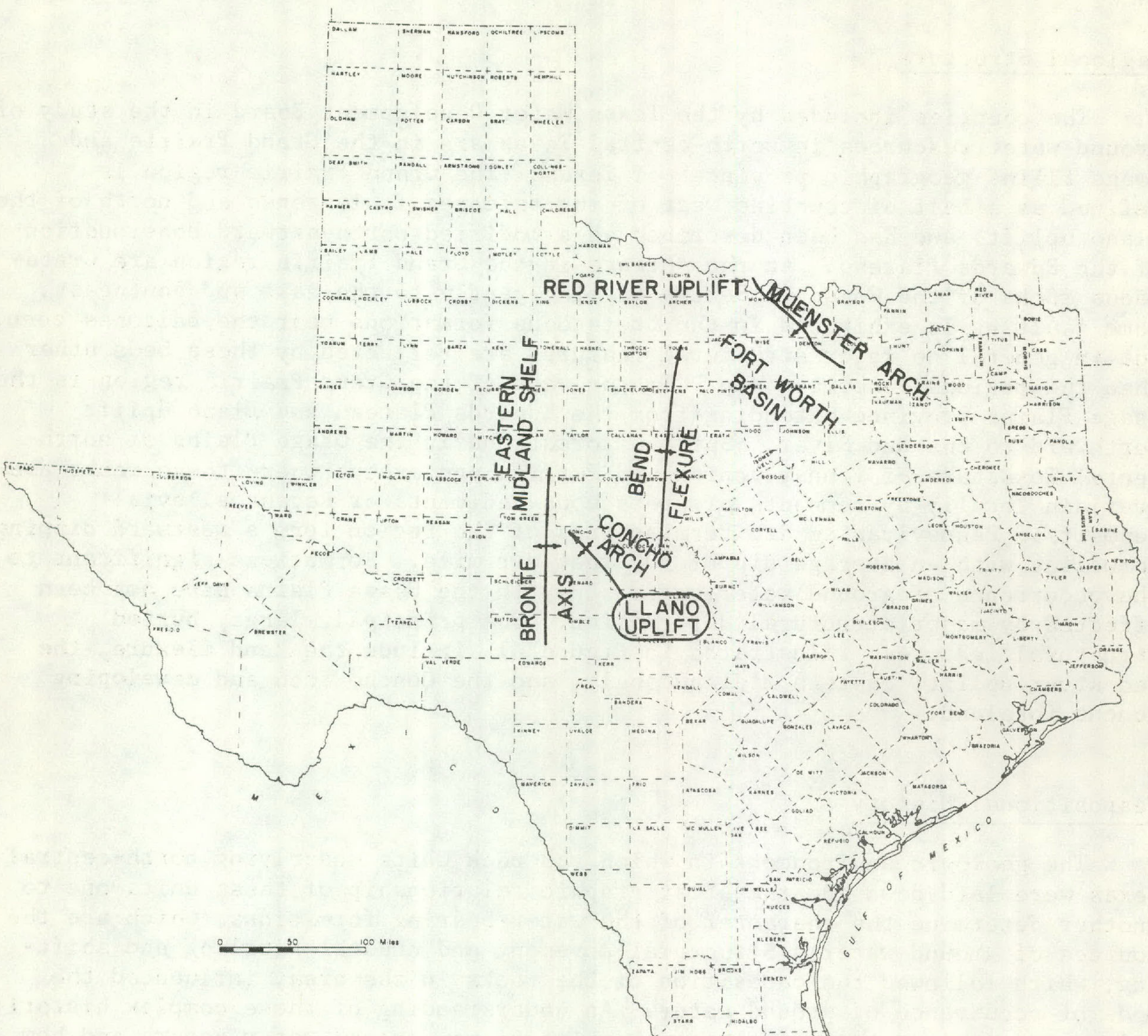


Figure A1

Major Structural Features in North-Central Texas

Texas Water Development Board in cooperation with the Texas Water Pollution Control Board

in formations of sediments deposited very nearly horizontally in shallow seas that were alternately advancing and retreating. Such a depositional environment resulted in a complex system of lateral and vertical changes in the character of the materials deposited. Few widespread continuous mantles of sediments such as those that characterize the Gulf Coast region of Texas are found. However, in contrast to the local, discontinuous, highly variable, shallow-water, clastic deposits characteristic of these periods, certain limestone units are relatively widespread. These limestones were deposited in extensive shallow seas advancing from the north and east, and are traceable as continuous units throughout much of the area under study. Thus, these limestone beds, while only locally significant as water-bearing units, are extremely important as horizon markers indentifying the age and character of the intervening sediments.

Pennsylvanian Deposition

The upper Pennsylvanian rocks of north-central Texas include the Strawn, Canyon, and Cisco Groups, each of which has been subdivided into several formations and members. In the Colorado River basin the Strawn Group is composed principally of alternating beds of sandstone and shale, probably representing near-shore deposits with the source area for the sediments being a land mass to the east and northeast, which is now concealed under younger strata. Beds of the Strawn Group overlap to the west so that the total thickness of the group is probably not greater than 1,200 feet at any one point. Cretaceous rocks overlying these older beds in the area of the Bend flexure prevent tracing individual units of the Strawn on the surface from the Colorado River basin into the Brazos River basin. In general, the Strawn of the Colorado River basin contains coarser sediments than in the Brazos River basin, although beneath the Cretaceous sediments to the north in Wise County the Strawn again assumes a near-shore facies marked by coal beds and lenses of sand and sandy shale.

The Canyon Group in north-central Texas is characterized by thick limestone beds alternating with shale, and contains relatively little sandstone. The source of the sediments in the Canyon was again from the east, and was lower than during Strawn deposition as shown by the decrease of terrigenous clastic material, which marked much of the Strawn deposition. Sandstone lenses in the Canyon Group, of extreme importance to the occurrence of ground water in local areas, probably were deposited in channels formed during periods of non-marine occurrence. In Jack and Wise Counties the character of Canyon sediments--conglomerates, irregular sands, and several coal beds--indicates an approach to the shoreline. Also in the southern region of the Colorado River basin some conglomerates are found in the basal Canyon. The surface expression of the Canyon Group in the Brazos River basin is separated by Cretaceous rocks from Canyon beds in the Colorado River basin, and no definitive stratigraphic correlation of individual formations has been traced from one basin into the other.

There was no widespread erosion of Canyon deposits except perhaps in the western Llano area. Tectonic activity to the north included the gradual uplift of the Red River arch, possibly folding in the Wichita system, and other disturbances in the mid-continent area. Canyon sedimentation was also affected by the continued development of the eastern Midland shelf and the subdued, but still prominent, Concho arch and the Bronte axis.

Sedimentation continued into Cisco time, as evidenced by the lack of a marked unconformity between the Canyon and Cisco strata. Local disconformities and channeling are apparent in both the outcrop areas of these beds and in the subsurface, indicating that the shelf environment of late Canyon time became more and more deltaic locally during Cisco time. The Cisco Group in the north-central Texas region is comprised chiefly of shale, sandstone, conglomerate, and limestone, with local coal beds. Eastward the sand and conglomerate deposits increase in thickness while to the west the conglomerate and the coal disappear. In the northern part of the area the limestone disappears from the Cisco Group as deposition occurred in nonmarine or partially marine environments.

Deposition in the late Pennsylvanian was affected by uplift in the Llano area as the initial westward tilting of the Concho foreland began toward the Midland basin. This westward tilting was to continue throughout Permian time. The Bend flexure, previously called the Bend arch, which extends from the Llano area to the Red River uplift, came into existence during late Pennsylvanian and early Permian times as a result of the differential subsidence of the Midland basin and the eastern Midland shelf, and the consequent westward tilting of the Concho foreland.

Permian Deposition

No major unconformity marks the contact between Pennsylvanian and Permian rocks, indicating relatively continuous deposition from the Cisco of the upper Pennsylvanian into the Wichita of the lower Permian. Local disconformities and channeling are apparent both in the surface and the subsurface, however, with the shoreline of the Permian sea having oscillated back and forth while it continued its slow migration toward the west as the tilting of the Concho foreland into the Midland basin progressed. The extensive Permian sea was shallow over north-central Texas, resulting in deposition of sediments under widely varying conditions.

Rocks of the Wichita Group have been mapped at the surface from the Red River to the Llano uplift. In the Colorado River basin the Wichita Group, representing the oldest Permian deposition, is characterized by a marine shale and limestone facies, while northward the marine beds decrease in importance and red beds become more prominent. Near the Red River, deposition of the Wichita Group was in a marginal marine environment marked chiefly by a red-bed facies of shale and sandstone. Deposition was apparently continuous in the Wichita, and no pronounced unconformities have been found in the Group.

Cretaceous Deposition

The close of Wichita deposition marked the end of the Paleozoic Era in north-central Texas, and great changes in the position of the land masses in Texas were to characterize the beginning of the Mesozoic in the State. The early Mesozoic was a period of continental elevation, and no Triassic deposition is known to have occurred in the area included in this study. This period of non-deposition continued through the Jurassic, and the first marine deposition that occurred in north-central Texas after the close of the Permian was in early Cretaceous times. As a result of the massive change in land-surface elevation in the first half of the Mesozoic, however, drainage in the Texas area had been reversed by the time Cretaceous deposition began. Instead of northwesterly drainage into inland Paleozoic seas, drainage from the earliest Cretaceous period onward was toward the southeast in the direction of what is now the Gulf of Mexico. Thus the regional dip of Cretaceous rocks overlying the Pennsylvanian and Permian sediments of north-central Texas is toward the southeast.

West of an irregular, northeast-trending line through Brown, Eastland, Jack, Wise, and Montague Counties, the only Cretaceous rocks remaining after extensive periods of erosion are remnants and outliers that, although not extensive, are locally significant as sources of ground water and as recharge areas for underlying older rocks. East of this irregular line Cretaceous beds are found at the surface in a continuous band eastward to the outcrop of Eocene sediments.

All of the known Cretaceous deposition in the area of study belongs to the Comanche Series. The Comanche has been divided into the Trinity, Fredericksburg, and Washita Groups, and both the Trinity and the Fredericksburg are found in this area. Generally, all of the Comanche sediments belong to a near-shore or shallow-water environment.

Quality of Ground Water

All ground water contains dissolved mineral constituents. The type and concentration depends upon the source, movement, and the environment of the ground water. Water derived from precipitation is relatively free of mineral matter, but because water has considerable solvent power, it dissolved minerals from the soil and rocks through which it passes. Therefore, the differences in chemical character of ground water reflect in a general way the nature of the geologic formations and the soils that have been in contact with the water. The concentration of dissolved solids generally increases with depth, especially where the movement of the water is restricted. Rocks deposited under marine conditions will contain brackish or highly mineralized water unless flushing by fresh water has been accomplished. This flushing action will occur in the outcrop area and to a limited distance downdip, depending upon the permeability of the rocks.

The chemical quality of ground water that has not been artificially altered is relatively constant, as is the temperature of ground water, which makes it highly desirable for many uses.

In addition to the natural mineralization of water that occurs in its environment, the quality of ground water can also be affected by man. Municipal and domestic sewage systems (including septic tanks), industrial waste, and oil-field brine that is improperly disposed of can enter into ground-water bodies and render them unfit for most uses.

Included among the factors determining the suitability of ground water as a supply are the limitations imposed by the contemplated use of the water. Criteria have been developed to cover most categories of water quality, including bacterial content, physical characteristics, and chemical constituents. Water-quality problems associated with the first two categories can usually be alleviated economically, but the removal of undesirable chemical constituents can be difficult and expensive. For many purposes the dissolved solids content constitutes a major limitation on the use of water. One general classification of water based on dissolved-solids content (Winslow and Kister, 1956, p. 5) is as follows:

Description	Dissolved-solids content (ppm)
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	More than 35,000

The United States Public Health Service has established standards of drinking water to be used on common carriers engaged in interstate commerce. The standards are designed primarily to protect the traveling public, and are often used to evaluate public water supplies. According to these standards, chemical constituents should not be present in the water supply in excess of the listed concentration shown in the following table, except where other more suitable supplies are not available. Some of the standards adopted by the U.S. Public Health Service (1962, p. 2152-2155) are as follows:

Substance	Concentration (ppm)
Chloride (Cl)	250
Fluoride (F)	(*)
Iron (Fe)	.3
Manganese (Mn)	.05
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Total dissolved solids	500

*When fluoride is present naturally in drinking water, the concentration should not average more than the appropriate upper limit shown in the following table.

Annual average of maximum daily air temperatures (°F)	Recommended control limits of fluoride concentrations (ppm)		
	Lower	Optimum	Upper
50.0 - 53.7	0.9	1.2	1.7
53.8 - 58.3	.8	1.1	1.5
58.4 - 63.8	.8	1.0	1.3
63.9 - 70.6	.7	.9	1.2
70.7 - 79.2	.7	.8	1.0
79.3 - 90.5	.6	.7	.8

Water having concentration of chemical constituents in excess of the recommended limits may be objectionable for many reasons. Water containing an excess of 45 ppm of nitrate has been related (Maxcy, 1950, p. 271) to the incidence of infant cyanosis (methemoglobinemia or "blue baby" disease). The high concentrations of nitrate may be an indication of pollution from organic matter, commonly sewage. Iron and manganese in excessive concentrations cause reddish-brown or dark gray precipitates, which stain clothing and plumbing fixtures. Sulfate in water in excess of 250 ppm may produce a laxative effect, and water containing chloride exceeding 250 ppm may have a salty taste. Fluoride in concentrations of about 1 ppm may reduce the incidence of tooth decay, but excessive concentration may cause teeth to become mottled (Dean, Arnold, and Elvove, 1942, p. 1155-1159).

Hardness in water is caused principally by calcium and magnesium. Excessive hardness causes increased consumption of soap, and induces the formation of scale in hot water heaters and water pipes. The following table shows the commonly accepted standards and classifications of water hardness:

Hardness range (ppm)	Classification
60 or less	Soft
61 to 120	Moderately hard
121 to 180	Hard
More than 180	Very hard

Water that is suitable for industrial use may not be acceptable for human consumption, and different standards may apply. Ground water used for industry may be classified into four principal categories: cooling water, boiler water, process water, and water used for secondary recovery of oil by water injection.

Although cooling water is usually selected on the basis of its temperature and source of supply, its chemical quality is also significant. Any characteristic that may adversely affect the heat-exhange surfaces is undesirable. Substances such as magnesium, calcium, iron, and silica may cause the formation of scale. Another objectionable feature that may be found in cooling water is corrosiveness caused by calcium and magnesium chloride, sodium chloride in the presence of magnesium, acids, and the gases oxygen and carbon dioxide.

The production of steam requires high quality-of-water standards. Under the extreme temperature and pressure conditions the problems of corrosion and incrustation are intensified. Under these conditions the presence of silica becomes undesirable as it forms a hard scale or incrustation.

Water coming in contact with, or incorporated into, manufactured products is termed "process water" and is subject to a wide range of quality requirements. These requirements involve physical, biological, and chemical factors. Water used in the manufacture of textiles must be low in dissolved-solids content and free of iron and manganese, which could cause staining. The beverage industry normally requires water free of iron, manganese, and organic substances.

Water used for injection in the secondary recovery of oil is generally that water taken from the oil reservoir. However, this water--usually brine--must generally be supplemented in order to meet the requirements of volume. Careful control must be exercised over the injected water with regard to suspended solids, dissolved gases, microbiological growths, and mineral constituents. Suspended solids in the water, of course, can cause plugging of the reservoir. Hydrogen sulfide, carbon dioxide, and oxygen all have corrosive effects on the well equipment, and oxygen reacting with the metallic ions, primarily iron (Fe^{+++}), will cause plugging of the reservoir. Organisms, iron bacteria, algae, and fungi have an effect of plugging the reservoir or pumping equipment, and the sulfate reducers have a corrosive effect.

Insofar as the mineral constituents are concerned, iron and manganese are undesirable as they cause plugging in injection wells. Sulfates are of interest from a standpoint of deposition. Water that is high in sulfate should not be mixed with water containing appreciable amounts of barium, for this would result in formation of barium sulfate with a very low solubility. The pH value is also significant when corrosion control and the solubilities of calcium carbonate and iron are considered. The higher the pH, the more difficult it is to maintain iron in solution and to keep calcium scale from forming.

Both the concentration and the composition of the dissolved constituents should be considered in appraising quality of water for irrigation. The chemical characteristics that appear to be most important in evaluating the quality of water for irrigation are: (1) relative proportion of sodium to the other cations, (2) total concentration of soluble salt, (3) amount of residual sodium carbonate, and (4) concentration of boron.

The U.S. Salinity Laboratory staff (1954, p. 69-82) proposed a system of classification commonly used for checking the quality of water for irrigation. The classification is based on the salinity hazard as measured by the electrical conductivity of the water and the sodium hazard as measured by the sodium-adsorption ratio (SAR). Figure A2 illustrates this classification system.

The importance of the dissolved constituents of water to be used for irrigation depends upon the degree to which the constituents accumulate in the soil. Kelley (1951, p. 95-99) cited areas having an average annual precipitation of about 18 inches in which the salts did not accumulate in the irrigated soil. It has been suggested (Wilcox, 1955, p. 15) that the system of the

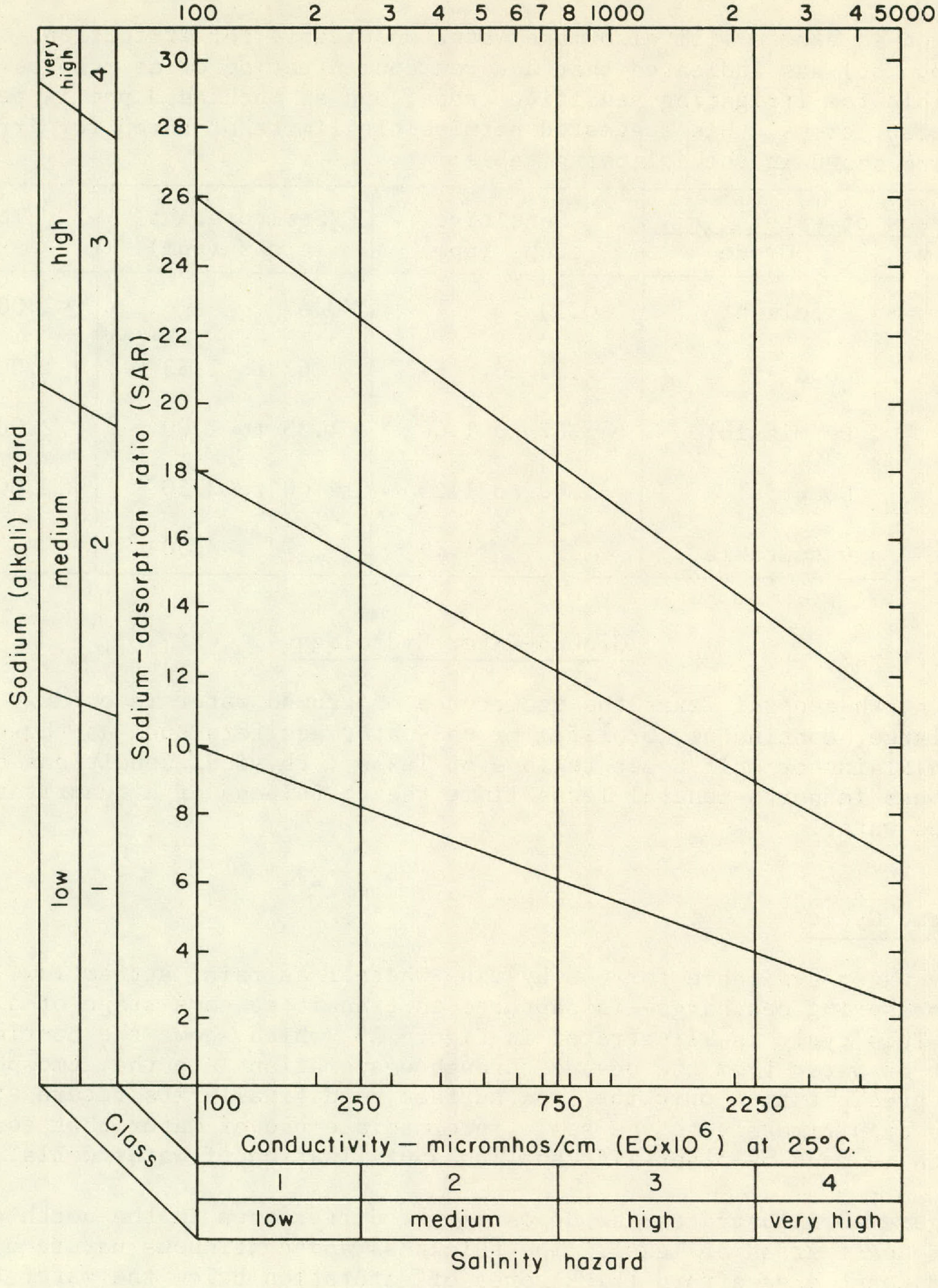


Figure A2

Diagram for the Classification of Irrigation Waters

(After United States Salinity Laboratory Staff, 1954, p. 80)

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classification of irrigation water proposed by the salinity laboratory staff is not directly applicable to the supplemental waters used in areas of relatively high rainfall.

Boron in excess will also make water unsuitable for irrigation. Scofield (1936, p. 286) has indicated that a boron concentration of as much as 1 ppm is permissible for irrigating sensitive crops, and as much as 3 ppm is permissible for tolerant crops. His suggested permissible limits of boron for irrigation waters are shown in the following table:

Classes of water		Sensitive crops (ppm)	Semitolerant crops (ppm)	Tolerant crops (ppm)
Rating	Grade			
1	Excellent	<0.33	<0.67	<1.00
2	Good	.33 to .67	.67 to 1.33	1.00 to 2.00
3	Permissible	.67 to 1.00	1.33 to 2.00	2.00 to 3.00
4	Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
5	Unsuitable	>1.25	>2.50	>3.75

Ground-Water Hydrology

In north-central Texas the occurrence of ground water is erratic, and there are no large, continuous, prolific ground-water aquifers such as those found in the High Plains or Gulf Coast regions of Texas. Physical conditions of ground-water zones in north-central Texas limit the usefulness of a quantitative study of ground water.

Hydrologic Cycle

The water available for use by man--whether as rain, streamflow, water from wells, or spring descharge--is captured in transit at some stage of a hydrologic cycle. This cycle is illustrated in Figure A3, which shows the continuing movement of water from the oceans through evaporation into the atmosphere, then through precipitation onto the land surface, and finally its return either directly or ultimately to the sea. Intermediate use of water that soaks into the earth is made by plant life and man's utilization of water wells.

Figure A3 illustrates the depositional differences in the north-central and Gulf Coast areas of Texas. The thickness and continuous nature of sands in the Gulf Coast area afford thick zones of saturation below the water table which are usually absent in north-central Texas. Also, the dip of strata generally approximates the slope of the land surface in the Gulf Coast area, which is favorable for the flushing of ground-water zones as water moves through them to downdip points of water well pumpage.

Ground-Water Occurrence and Movement

The geologic history of sedimentary deposition and erosion are primary factors controlling the occurrence and movement of ground water in the

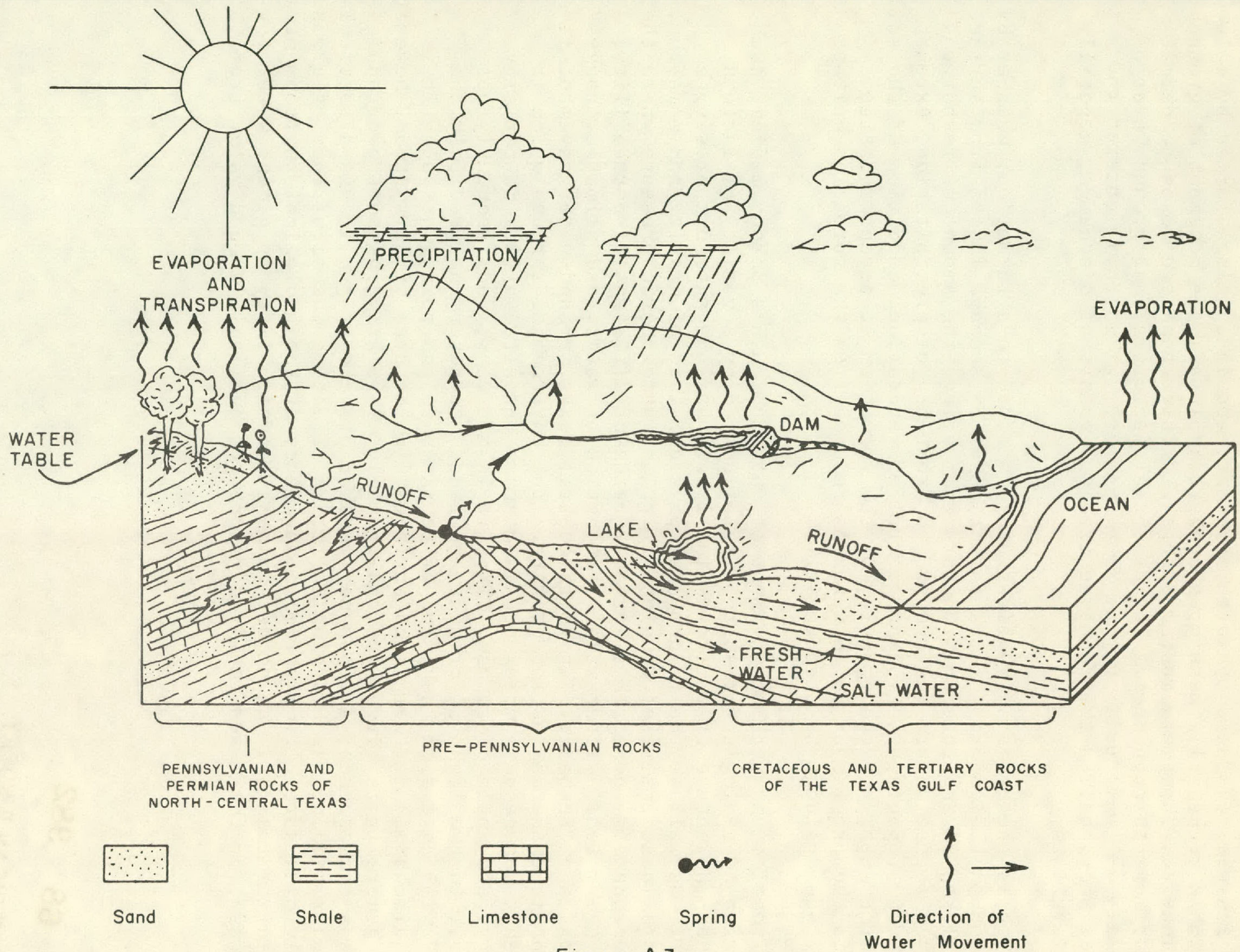

Figure A3

Hydrologic Cycle

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north-central Texas area. The rocks found in the shallow subsurface range from sporadic, uncemented, clastic beds to the more widespread, continuous, cemented or compacted shales, sandstones, and limestones. In uncemented rocks such as sand, gravel, and clay, water occurs in the spaces between individual particles, whereas in well cemented or compacted sedimentary rocks it occurs chiefly in cracks and fissures produced by earth movement, and in openings formed by solution of soluble rocks. If these openings are isolated, the movement of ground water is hindered. However, most openings are interconnected so as to permit ground water move through them. The essential factor is that ground water of usable quality is continually moving from the point at which it entered the ground-water body, called the recharge area, to points of discharge, generally at lower elevations.

Recharge is the process by which water is added to a formation, whether by precipitation on the outcrop of the formation or by seepage losses from surface streams or lakes on the outcrop. Factors that affect the amount of recharge received by a formation are the amount and frequency of precipitation, extent of the outcrop, topography, type and amount of vegetation, condition of the soil in the outcrop area, and the capacity of the formation to accept recharge. Discharge is the process by which water is removed from the formation, either through surface drainage or through wells.

The direction and rate of movement of water through a porous medium, such as an underground geologic formation, is influenced by a variety of factors, which include the nature of the formation itself and the external pressures applied on it as well as the fundamental physical laws of gravity and momentum. These factors include surface tension, friction, atmospheric pressure where the formation encounters the earth's surface, paths of differential permeability, effects of heavy local withdrawals or injection of water, and climatic changes affecting rates of recharge. In north-central Texas, ground-water movement is not constant in either direction or rate. The environment through which it moves is a heterogeneous complex of sedimentary deposits varying in porosity, permeability, and angle of repose. Thus it is not easy, and frequently not even possible in the light of present knowledge, to determine precisely the route water will take from the point of recharge to the points at which it is once again discharged at the ground surface. In the area of this study, however, this route generally is circuitous and probably of relatively short geographic extent. As a consequence, a landowner whether private or public has a particular need for understanding the hydrologic factors affecting the occurrence of ground water. Only by a carefully discriminating study of the geological environment of his immediate locality can he determine the availability of ground water for beneficial use, or the means required to protect available ground water from pollution.