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REPORT 215

OCCURRENCE, QUALITY, AND AVAILABILITY OF GROUND WATER IN JONES COUNTY, TEXAS

By

Robert D. Price, Geologist

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FOREWORD

Effective September 1, 1977, Texas three water resources agencies, the Texas Water Rights Commission, the Texas Water Development Board, and the Texas Water Quality Board, were consolidated to form the Texas Department of Water Resources. A number of publications prepared under the auspices of the predecessor agencies are being published by the TDWR. To effect as little delay as possible in production of these publications, references to these predecessor agencies will not be altered except on their covers and title pages.

Harvey Davis
Executive Director

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OCCURRENCE, QUALITY, AND AVAILABILITY OF GROUND WATER IN JONES COUNTY, TEXAS

ABSTRACT

Jones County, encompassing an area of approximately 950 square miles, is located entirely within the Osage Plains section of the Central Lowlands physiographic province in north-central Texas. The area lies within the Brazos River drainage system, and the Clear Fork Brazos River flows generally southeastward through the county. Anson, the county seat, is 23 miles northwest of Abilene. The 1970 population of the county was 16,106. The climate of the area is warm and subhumid. The mean annual rainfall is 24.25 inches at Abilene.

Pleistocene to Recent sand and gravel deposits, and the underlying beds of Permian age, yield small to moderate quantities of ground water to wells in the county.

The geologic and hydrologic units which yield fresh to moderately saline ground water in Jones County, in the order of their importance, are: the Seymour Formation, the Bullwagon Dolomite Member of the Vale Formation, the Recent alluvium, the Choza Formation, the Vale Formation, the San Angelo Formation, the Lueders Formation, the Arroyo Formation, and the Blaine Formation.

The primary aquifer, the Seymour Formation, is present as scattered patches which mantle the underlying Permian beds. The unit is often non-water bearing, and other areas of the Seymour contain only minor amounts of ground water. The region of major water-bearing development of the Seymour, which is termed "area A," covers approximately 126 square miles and is located just southeast of the city of Anson.

Recharge to the Seymour, derived from precipitation on the outcrop, is estimated at 10,200 acre-feet per year in area A. This is based on the mean annual rainfall recorded at Abilene. Approximately 6.2 percent or 1.8 inches of the rainfall received in 1968 actually reached the water table and went into storage. The quantity of water estimated to be stored within the Seymour Formation in area A is 213,000 acre-feet.

Jones County ground-water pumpage for 1968 is estimated to have been 4,920 acre-feet. Pumpage from the Seymour Formation during that year was 3,160 acre-feet, of which 2,350 acre-feet was in area A. These figures reflect that most of the county ground-water pumpage is from the Seymour Formation and mainly from area A. Approximately 80 percent of the 1968 irrigation pumpage from the Seymour was from this area. It is conservatively estimated that 6,000 acre-feet, or approximately 2.5 times the 1968 pumpage, can safely be developed from the Seymour within area A on a yearly basis.

Water levels in all Jones County aquifers, including the Seymour Formation, have generally risen since 1953. However, within most of area A, there was little or no change in water levels from the winter of 1967-68 to the winter of 1968-69. Recharge and pumpage data suggest that additional water-well development can be made within area A, but it should be located beyond the radius of influence of existing irrigation wells. Overdevelopment or excessive pumpage in existing irrigation areas could cause, locally, a noticeable decline in water level.

Contamination of ground water in Jones County is and has been a minor problem. Most of the sources of potential contamination have been eliminated except in very localized areas.

OCCURRENCE, QUALITY, AND AVAILABILITY OF GROUND WATER IN JONES COUNTY, TEXAS

INTRODUCTION

Location and Extent

Jones County, with an areal extent of approximately 950 square miles, is located in north-central Texas (Figure 1). The county is bounded on the north by Haskell and Stonewall Counties and on the south by Taylor County. Fisher and Shackelford Counties border the county on the west and east, respectively. Jones County is located approximately between $99^\circ36'$ and $100^\circ08'$ west longitude and $32^\circ31'$ and $32^\circ57'$ north latitude. Anson, the county seat, is 23 miles northwest of Abilene on U.S. Highway 277.

Purpose and Scope

The purpose of this study was to determine the occurrence, quality, and availability of ground water in Jones County. Special emphasis was placed on determining the sources of water suitable for municipal, industrial, irrigation, domestic, and livestock use. Areas and possible sources of present or potential ground-water contamination were delineated.

The scope of this project included the collection, compilation, and analysis of data pertaining to the distribution and quality of ground water in the county.

This study was conducted during the period December 13, 1966 through August 26, 1969, under the general direction of John J. Vandertulip, former Chief Engineer; Charles R. Baskin, 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 Investigations.

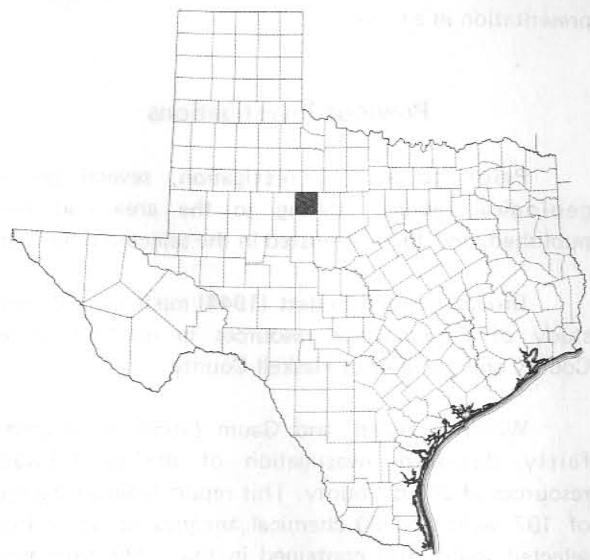

Figure 1.—Location of Jones County

Methods of Investigation

The following methods were used in conducting this investigation:

1. An inventory was made of all municipal, industrial, and irrigation wells, plus all springs, as well as a representative inventory of domestic and livestock wells. Altogether, 1,371 wells and springs were inventoried during this study (Table 6). Water levels were measured in all wells where possible. Information was gathered, when available, on well depths, well construction, date drilled, driller, water-yielding zones, and water-production quantities. Surface elevations of all wells inventoried were determined from topographic maps and electric log well records.

2. Water samples were collected for chemical analysis from 868 selected wells and springs during this

study. These analyses, as well as 17 analyses performed by commercial and private laboratories, are listed in Table 8.

3. Surface and subsurface geologic data were collected and compiled, placing special emphasis on their relationship to ground water.

4. Additional data were collected and compiled on apparent and potential contamination, oil-field brine disposal, climate, and areas of recharge and discharge.

5. Data were tabulated, analyzed, and the necessary illustrations were prepared for coherent presentation in a report.

Previous Investigations

Prior to this investigation, several general geological reports relating to the area had been published, and these are listed in the selected references.

Broadhurst and Follett (1944) made a preliminary study of ground-water resources in northeast Jones County and portions of Haskell County.

Winslow, Doyel, and Gaum (1954) conducted a fairly detailed investigation of the ground-water resources of Jones County. This report included records of 197 wells and 60 chemical analyses of water from selected wells. Also contained in the publication was a brief description of the geology of the county and its relationship to the occurrence of ground water.

Cronin, Follett, Shafer, and Rettman (1963) completed a regional reconnaissance investigation of the ground-water resources of the Brazos River basin, which includes Jones County.

Three contamination reports have been written within the subject area. Shamburger (1958 and 1960) conducted two investigations in the vicinity of Avoca and Stamford. These studies concerned the alleged contamination of California Creek near Avoca and the alleged salt-water contamination of soils near Stamford. An investigation was conducted during 1967 by personnel of the Texas State Department of Health and the Texas Railroad Commission of alleged salt-water contamination of Lake Hamlin in northwest Jones County.[1]

Well-Numbering System

The system used for numbering wells and springs in this report is one developed and adopted by the Texas Water Development Board and presently in use throughout the State (Figure 2). The system is based on division of the State into quadrangles formed by degrees of latitude and longitude, and repeated subdivision of these into smaller quadrangles, as follows:

1. The largest, a one-degree quadrangle, located either partly or entirely within the State, is given a two-digit number from 01 to 89. Thus, the origin of the first two digits of a well number.

2. Each one-degree quadrangle is further subdivided into 64 7½-minute quadrangles which are each assigned a two-digit number from 01 to 64. These two digits are the third and fourth digits of a well number.

3. Lastly, each 7½-minute quadrangle is subdivided into nine 2½-minute quadrangles which are numbered one to nine. This number is the fifth digit of the well number. Within each 2½-minute quadrangle, each well is assigned a two-digit number in the sequence inventoried, beginning with 01; these are the last two digits of the well number.

On the well-location map in this report (Figure 35), only the last three digits of the well number are shown next to the well symbol; the 7½-minute quadrangles are numbered in their northwest corners, and 1-degree quadrangles are designated by large bold numbers.

Acknowledgements

The author is indebted to the many landowners, farmers, water well drillers, oil operators, and municipal officials for permitting access to their wells, aiding in collection of well data, and for granting permission to test their wells. Appreciation is also extended to the various governmental agencies, especially to Mr. Robert B. Rowland, Manager, U.S. Department of Agriculture, Agricultural Stablization and Conservation Service, Jones County Committee; Mr. Kirby Clayton, County Agent, Jones County; Mr. J. Pat Henson, U.S. Department of Agriculture, Soil Conservation Service; and Representatives of the U.S. Geological Survey, the Texas Highway Department, and the Texas State Health Department. Special recognition is extended to Midwest Electric Co-op, Incorporated; Stamford Electric Co-op, Incorporated; Taylor Electric Co-op, Incorporated; and

[1] Bruce, Millard, and Krusekopf, H. H., 1967, Miscellaneous papers on alleged salt-water contamination of Lake Hamlin.

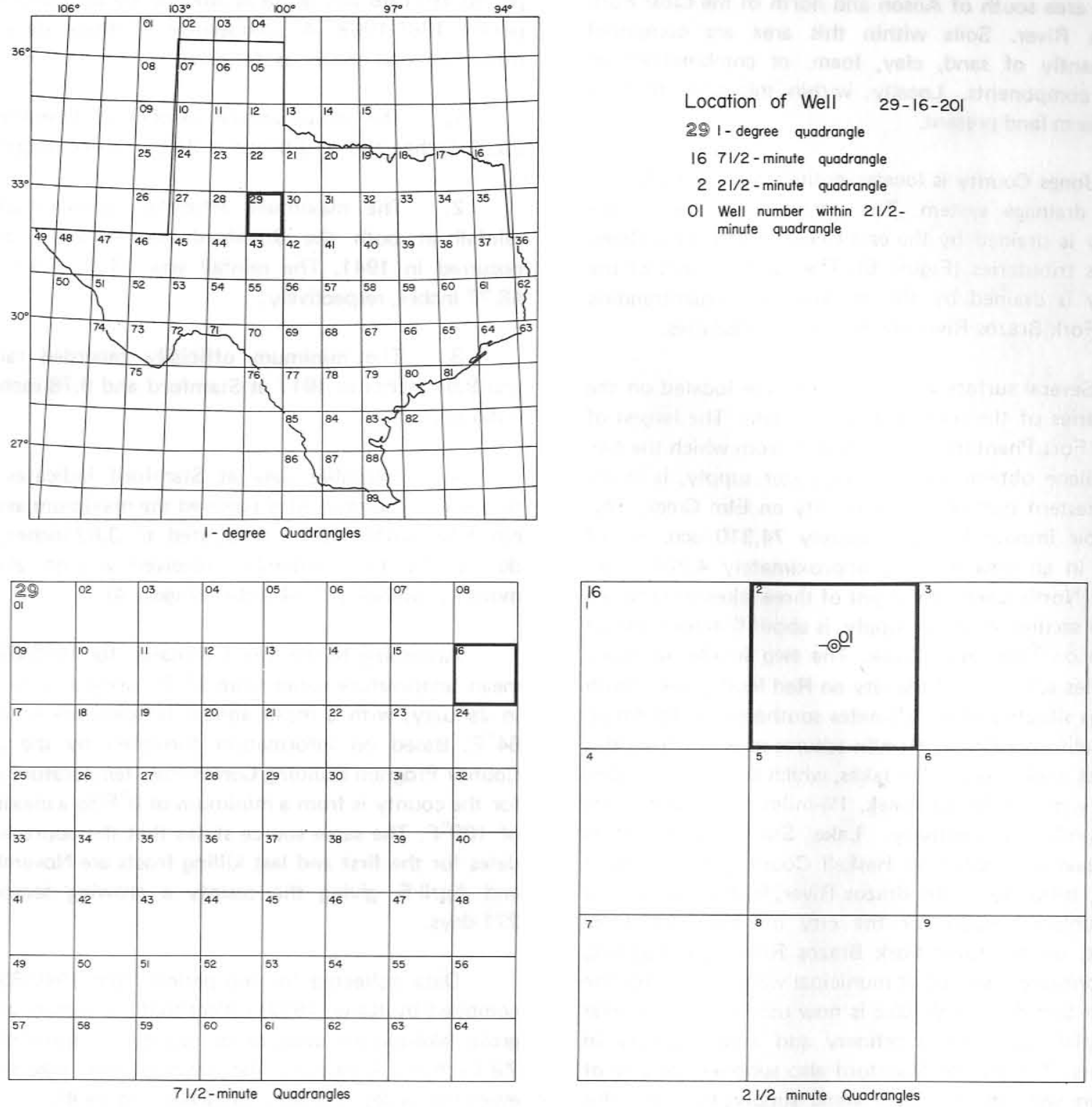

Figure 2.—Well-Numbering System

West Texas Utilities Company for providing data pertinent to this study.

GEOGRAPHIC SETTING

Topography and Drainage

Jones County is located entirely within the Osage Plains section of the Central Lowlands physiographic province. Topographic elevations range from about 1,600 to 2,200 feet for a total relief of about 600 feet. The land surface is in general gently rolling to semi-level. Prominent northeast-trending escarpments are formed by the outcropping Permian limestones and dolomites. One such escarpment is formed by the Merkel Dolomite Member of the Choza Formation and extends across the western third of the county (Figure 5). Similar escarpments are formed by the Rainey Limestone Member of the Arroyo Formation and by limestones of the Lueders Formation in the southeast portion of the county.

Approximately three-quarters of the county is dominated by excellent farm lands of clay loam to loam soils with occasional scattered mesquite trees. Small oak trees, commonly referred to as "shinnery", cover most of the area south of Anson and north of the Clear Fork Brazos River. Soils within this area are composed dominantly of sand, clay, loam, or combinations of these components. Locally, within this area, there is good farm land present.

Jones County is located entirely within the Brazos River drainage system. The northern portion of the county is drained by the east-trending California Creek and its tributaries (Figure 5). The southern part of the county is drained by the generally southeast-trending Clear Fork Brazos River and its minor tributaries.

Several surface-water reservoirs are located on the tributaries of the main drainage system. The largest of these, Fort Phantom Hill Reservoir, from which the city of Abilene obtains much of its water supply, is in the southeastern portion of the county on Elm Creek. This reservoir impounds approximately 74,310 acre-feet of water in an area covering approximately 4,246 acres. Anson North Lake, the largest of three lakes from which Anson secures its water supply, is about 6 miles north of Anson on Thompson Creek. The two smaller lakes are 2½-miles southeast of the city on Red Mud Creek. South Lake is situated about 2½-miles southeast of Hamlin on Dry California Creek. Hamlin secures its water from this lake, as well as two other lakes, which are both in Fisher County on California Creek, 1½-miles and 3 miles west of Hamlin, respectively. Lake Stamford, 10 miles southeast of Haskell, in Haskell County, and on Paint Creek, tributary of the Brazos River, is the main source of municipal water for the city of Stamford. Lake Penick, on the Clear Fork Brazos River near Lueders, was formerly a source of municipal water supply for the city of Stamford. This lake is now used only to provide industrial water for a refinery and a rock quarry in Lueders. The city of Stamford also supplies the city of Lueders with its municipal water supply; however, this water is piped from the city of Stamford. Three small lakes are located west of the city of Stamford at the headwaters of Turkey Paint Creek. These lakes, plus another now destroyed, were once a part of Stamford's municipal water supply. The exact date of discontinuance of their use is unknown. These lakes are now used for livestock purposes by the Swenson Land and Cattle Company.

Climate

The climate of Jones County is warm and subhumid as reflected by records of precipitation and evaporation (Figures 3 and 4). Precipitation records furnished by the U.S. Weather Service at Stamford and at Abilene, in Taylor County, are included in this report (Figure 3). The records at Stamford are for the 57-year period 1911-68 and those at Abilene are for the 83-year period 1885-1968. A comparison of these data and other observations is as follows:

1. The mean annual rainfall at Stamford is 23.63 inches and at Abilene is 24.25 inches (Figure 3).

2. The maximum officially recorded annual rainfall at both the Stamford and Abilene stations occurred in 1941. The rainfall was 43.23 inches and 48.77 inches, respectively.

3. The minimum officially recorded rainfall was 9.94 inches in 1917 at Stamford and 9.78 inches in 1956 at Abilene.

4. Available data at Stamford indicates that during early summer May received the maximum average monthly rainfall which amounted to 3.82 inches, and during the fall September received a high average monthly rainfall of 2.74 inches (Figure 4).

According to the Texas Almanac for 1968-69, the mean temperature varies from 97°F during July to 30°F in January, with a mean annual temperature of about 64°F. Based on information furnished by the Jones County Program Building Committee, temperature range for the county is from a minimum of 0°F to a maximum of 109°F. The same source states that the approximate dates for the first and last killing frosts are November 5 and April 5, giving the county a growing season of 271 days.

Data collected for the period from 1940-65 and compiled by Kane (1967) reflect that the average annual gross lake-surface evaporation depth is approximately 79 inches; however, the average net lake-surface evaporation depth is only 56 inches (Figure 4).

History, Population, and Economy

Anson Jones, for whom Jones County and the county seat, Anson, were named, was Minister of the United States in 1838, Secretary of State of the Republic of Texas from 1841-44, and the last President of the Republic of Texas. Prior to 1881, when Jones County organized its own county government, the area was part of Shackelford County. The first county seat was located at Fort Phantom Hill and was later moved to Anson in 1882. The first known settlers in the area which was later to be known as Jones County were people who came along the Old Butterfield Trail in 1858.

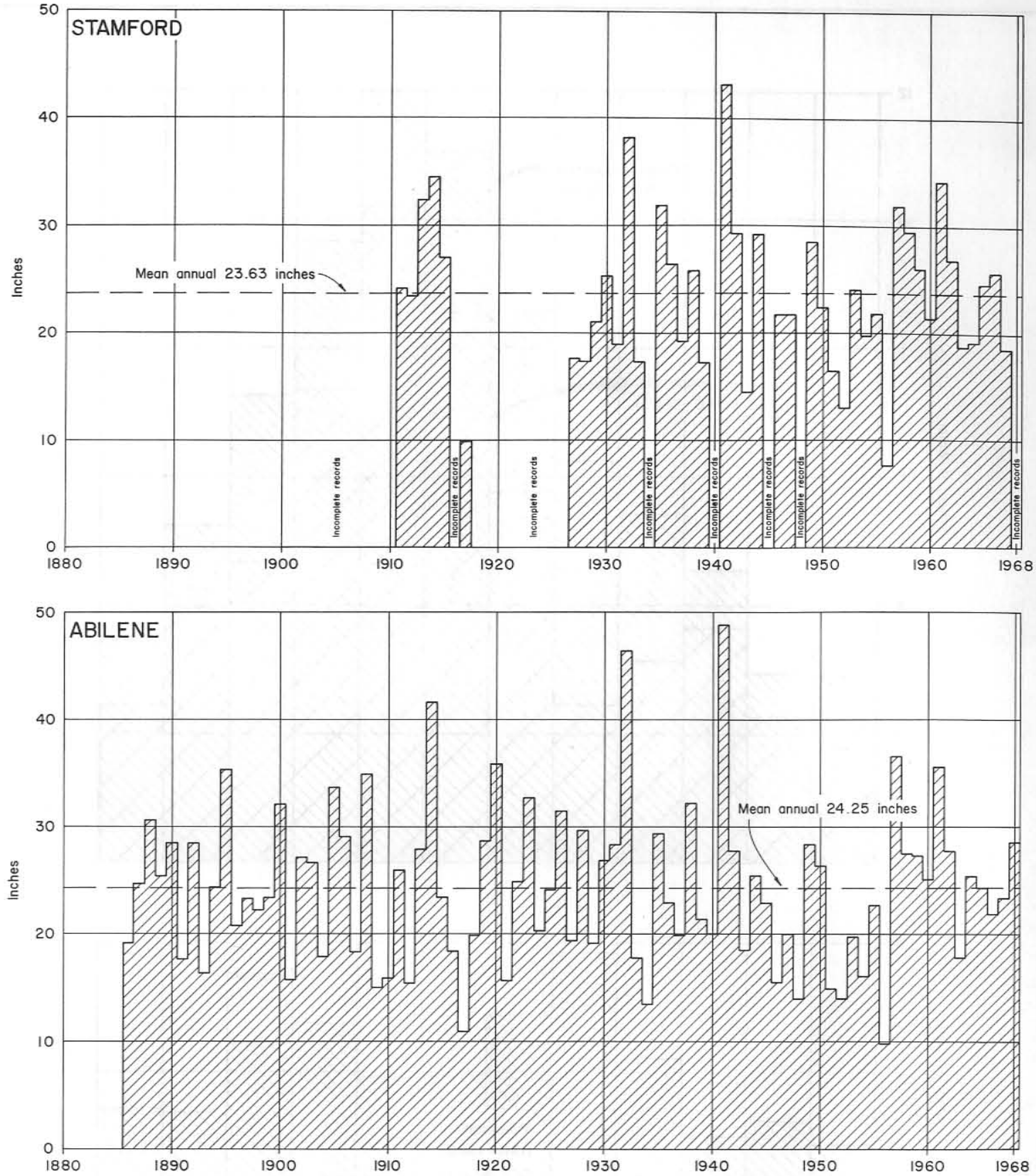

Figure 3.—Annual Precipitation at Abilene, Taylor County and at Stamford, Jones County (From Records of U.S. Weather Service)

According to the 1970 federal census, Jones County had a population of 16,106 with Anson having a population of 2,615, Stamford 4,428, and Hamlin 3,322. Of the total population, 27 percent reside on the farm and 73 percent are urban dwellers.

Jones County is one of the best farming counties of the State and, according to the Texas Almanac for 1968-69, farm income accounts for approximately one-third of a total income of slightly less than $36 million. Two-thirds of the farm income is from cotton. Other crops grown include grain sorghums, wheat, corn, peanuts, small grains, and hay. Cattle and calf sales account for about $1.5 million of the total farm income.

The value of mineral extractions in Jones County accounts for slightly less than $13 million of the total

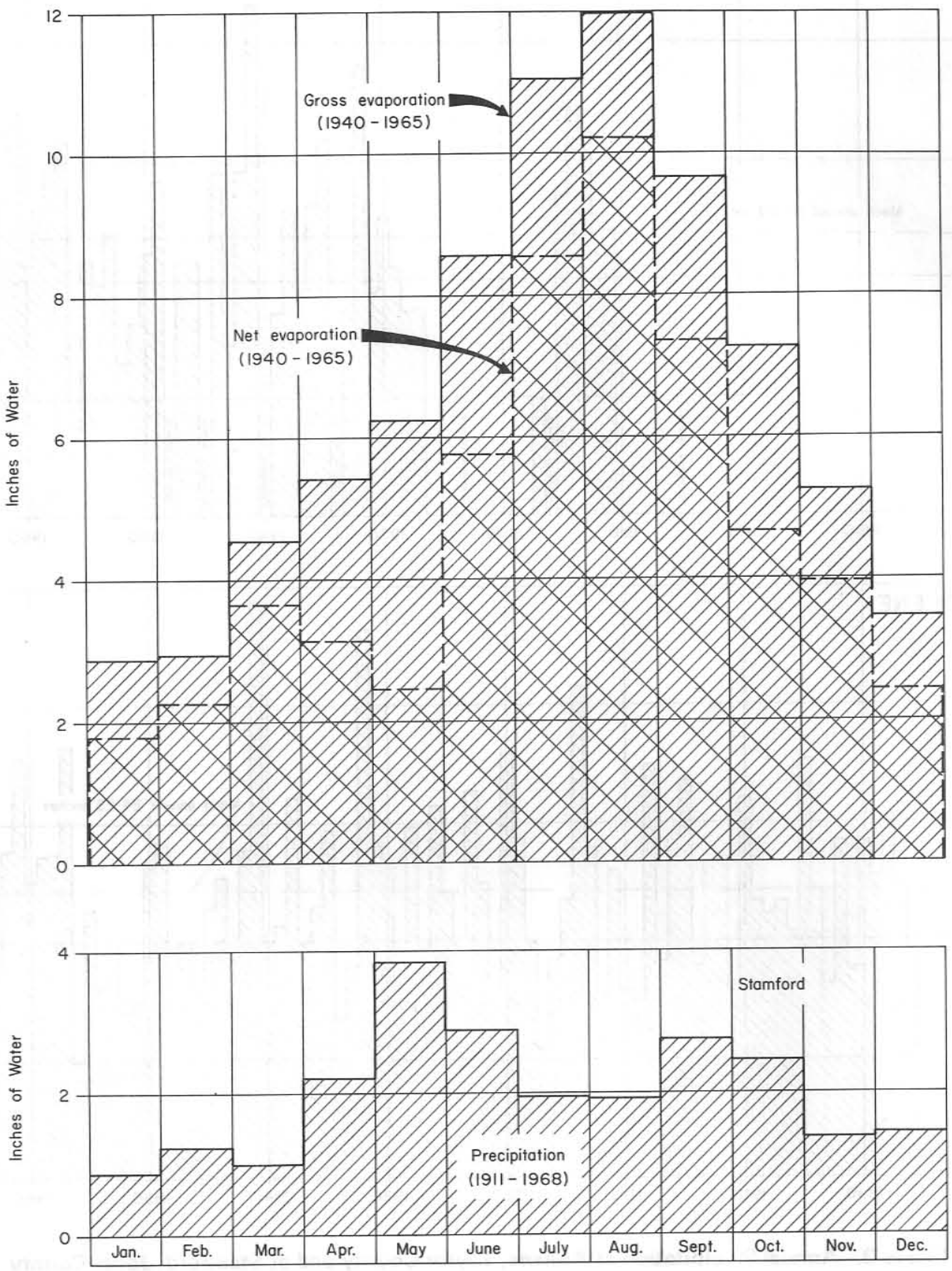

Figure 4

Average Monthly Precipitation at Stamford, and Average Monthly Lake-Surface Evaporation in Jones County (From Records of U.S. Weather Service, and Kane, 1967) income for the county. Oil and gas, first discovered in the county in 1926, are produced in many scattered areas and are the most valuable minerals produced. Over 149.2 million barrels of oil was produced in the county from 1926 to 1970 (Petroleum Information Corporation, 1969). A total of 2,676,937 barrels was produced in 1969. The production of crude oil has diminished considerably during the past several years. Natural gas liquids, sand and gravel, natural gas, and limestone production make up the balance of the mineral extractions.

The remainder of industrial income is derived from commercial establishments and small industries in the cities of the county.

GEOLOGY

General Geology

Stratigraphy

Underlying Jones County, rocks representing various geologic systems are present (Figures 36, 37, and 38). The systems, listed in order from the oldest to youngest, are: Precambrian, Cambrian, Ordovician, Mississippian, Pennsylvanian, Permian, and Quaternary. The general lithology of the various rock units and their stratigraphic relationship are shown on the above referenced cross-sections. These rocks are composed mainly of limestone, dolomite, shale, and clastics which, for the most part, were deposited in epicontinental seas of relative shallow depth. The sequence of rock types indicates that during their deposition there were repeated transgressions and regressions of the seas. Since pre-Permian rocks produce ground waters of a brine quality (dissolved solids greater than 35,000 mg/l), no further discussion will be made of these units. See Tables 9 and 10 for data on the chemical quality of water in the pre-Permian rocks.

The oldest rock units exposed at the surface are of three groups belonging to the Permian System. Listed in order from the oldest to youngest, they are: the Wichita, Clear Fork, and Pease River Groups. These units are overlain, over much of the county, by much younger Quaternary deposits of the Seymour Formation and Recent alluvium (Figure 5). A description of the geologic formations and their water-bearing characteristics is given in Table 1. Their stratigraphic relationship and structural attitude are illustrated in Figures 36, 37, and 38.

At their maximum extent, shallow Permian seas were very widespread through Texas (Eardley, 1951, plate 9). The seas extended from the southwest, in Mexico, over the north-central Texas area, including Jones County; over all of West Texas and into the neighboring states of New Mexico and Oklahoma; and as far north as Kansas (Sellards and others, 1932, p. 185-186).

During the early stages of Permian deposition, or during the time in which the Wichita Group was deposited, there was believed to be a land mass to the east of the Jones County area. During this time, dominantly marine shales and shelf limestones were deposited in the shallow seas covering Jones County and surrounding areas. Drainage outlets to the sea were believed restricted by the growth of an apparent delta, in the vicinity of the Arbuckle and Wichita Mountains of Oklahoma, and this caused a gradual northward change in the lithology of the Wichita Group into a marginal marine redbed sequence just south of the Red River (Stafford, 1960, p. 278).

Deposition of the Clear Fork Group, composed of thin, poorly developed limestones and dolomites, interbedded with redbeds and local anhydrite, suggests that the seas were becoming more restricted and that the climate was becoming more arid.

The Pease River Group, of Upper Permian age, is marked by an increase in nonmarine clastics at the beginning of its deposition. This is indicated by the deposition of the San Angelo sandstone and conglomerates. This increase in nonmarine clastics, accompanied by a marked erosional unconformity between the San Angelo sandstone and the underlying Clear Fork Group, suggests a renewed uplift of the source area, believed to have been east of the north-central Texas area. Later deposition of thick beds of evaporites, interfingered with redbeds and beds of limestone and dolomitic limestone, suggests a much more restricted sea and an even more arid climate.

Unconformably overlying the rocks of Permian age within Jones County are semiconsolidated and unconsolidated deposits of clay, sand, and gravel of Quaternary age. These are the principal water-bearing beds of the area (Figure 36 and Table 1).

The geologic record between the Permian System and the Quaternary System is not recorded in the rock sequence of the subject area. However, Van Siclen (1957, p. 56-57), states that prior to Pleistocene time, the Jones County and surrounding area was eroded to a nearly flat plain which had a gentle slope to the east.

Table 1.—Geologic Units and Their Water-Bearing Properties in Jones County

SYSTEM	SERIES OR GROUP	FORMATION	MEMBERS	APPROXIMATE MAXIMUM THICKNESS (feet)	LITHOLOGIC CHARACTER	WATER-BEARING CHARACTERISTICS
Quaternary	Recent Series	Alluvium		60	Cross-bedded gravels, sandstones, fine silts, and sandy clays occurring as erratic deposits in stream valley of Clear Fork Brazos River and its major tributaries.	Yields fresh to moderately saline water in small to moderate quantities in scattered areas.
	Pleistocene Series	Seymour		115	Contains fine-grained, white, light tan to red sands and silts; reddish-orange and gray clay; white to buff nodules of caliche (usually near surface). Lower portion of the formation is generally cross-bedded, interstrafified lenses of orange clay, sand, and coarse gravels or conglomerates composed of well rounded pebbles of quartz, quartzite, igneous crystalline rocks, bone fragments, petrified wood, scattered water-worn Cretaceous fossils, and cobbles and pebbles of limestone. The formation may contain volcanic ash, as it is present in outcrop to the north near Munday, Texas.	Yields fresh to moderately saline (most is slightly saline) water in small to moderate quantities to wells in east two-thirds of the county.
Permian	Pease River Group	Blaine		55	Thin beds of slightly fossiliferous gray dolomite, lenticular to massive gypsum, and some limy sandstone, interbedded with red and gray gypsiferous shales.	Yields slightly saline to moderately saline water in small quantities to wells in the northwest part of the county.
		San Angelo		110	Cross-bedded sandstone, greenish-gray, usually well consolidated, medium-grained, sub-angular to well-rounded near top of unit. Lower portion is clay balls, and sandstone as above interbedded with cherty conglomerates, gypsum nodules, streaks of "satin spar" gypsum, and red and green shales.	Yields fresh to moderately saline (mainly) water in small quantities to wells in the west one-sixth of the county.
	Clear Fork Group	Choza	Merkel Dolomite	15 550	The persistent, gray Merkel Dolomite is present at or near the top of the Choza Formation. The remainder of the Choza consists of semi-persistent beds of gray dolomitic limestones and gypsum interbedded with red shale and, locally, thin argillaceous sandstone units.	Yield fresh to moderately saline water in small to moderate quantities to wells in the western part of the county.
		Vale	Bullwagon Dolomite	20 385	Upper portion of the formation is comprised of many thin beds of gray dolomite and gypsum interbedded with some clay, but mainly red shales. Lower portion of unit is dominantly red shale with thin stringers of dolomite and a few thin lenticular shaly sandstones. This lower red shale unit thins to the west.	Yields fresh to moderately saline water in small (mainly) to moderate quantities to wells in the western part of the county.
		Arroyo	Sandpipe Limestone Lytle Lake Limestone Rainey Limestone	270	White, cream-colored, buff and brown, thin-bedded and poorly developed limestones, dolomites, and marls interbedded with thick gray and red shales and lenticular shaly sandstones. Gypsum is present, locally, near the base of the formation in the Lytle Lake and Rainey Members.	Yields moderately saline water in small quantities to one well near the outcrop in the eastern part of the county.
	Wichita Group	Lueders	Lake Kemp Limestone Maybelle Limestone Paint Rock Limestone	75	Massive to thin beds of gray to buff, fossiliferous limestone interbedded with argillaceous limestone and gray to greenish gray blue, or black shale. Unit grades into dolomite westward in the subsurface.	Yields fresh to slightly saline water in small quantities to wells near the outcrop in the eastern part of the county.
		Clyde	Talpa Limestone Grape Creek Limestone	235	Interbedded, highly fossiliferous, gray and buff limestone; argillaceous limestone and gray shale.	Not known to yield fresh to moderately saline water to wells in Jones County.
		Belle Plains	Bead Mountain Limestone Valera Shale Jagger Bend Limestone Voss Shale Elm Creek Limestone Jim Ned Shale	530	Interbedded, highly fossiliferous, gray and buff limestone; argillaceous limestone; brown sucrosic dolomite; white to light gray anhydrite; and gray, greenish-gray, and pale red shales.	Do.
		Admiral	Overall Limestone Wildcat Creek Shale Hords Creek Limestone Lost Creek Shale	155	Thin-bedded cherty limestones, local lenticular sandstone lenses, and greenish gray shales.	Do.
		Putnam	Coleman Junction Limestone Santa Anna Branch Shale	165	Thin, light gray, finely crystalline to dense limestones; thick, non-fissile, red to greenish-gray, fossiliferous shales; and local thin lenticular sandstones.	Do.
		Moran	Sedwick Limestone Gouldbusk Limestone Ibex Limestone Watts Creek Shale	415	Thin, white to cream, pale green or brown to gray, finely crystalline to dense, fossiliferous limestones; lenticular or channel-fill sandstone; and thick, pale red to greenish-gray, silty to sandy carbonaceous shales.	Do.
		Pueblo	Camp Colorado Limestone Salt Creek Bend Shale Stockwether Limestone Camp Creek Shale Saddle Creek Limestone Waldrip	390	Thin-bedded, light to medium gray, buff, pale green, finely crystalline to dense, fossiliferous limestones; thick shales, medium to light gray, some red, greenish gray with local channel-fill deposits of coarse-grained sandstone and some conglomerates.	Do.

Yield of Wells: Small, less than 100 gpm (gallons per minute); moderate, 100-1,000 gpm; large, more than 1,000 gpm.
Quality of Water as ppm (parts per million) dissolved solids: Fresh, less than 1,000 ppm; slightly saline, 1,000 to 3,000 ppm; moderately saline, 3,000 to 10,000 ppm; very saline, 10,000 to 35,000 ppm; brine, greater than 35,000 ppm.

During this time, all sediments younger than Permian age were removed.

Following this and during Pleistocene time, streams thought to have been well established for quite some time, geologically, were depositing sediments over a large area of north-central Texas. These sediments were believed to have been derived and transported from the west. These deposits, referred to as the Seymour Formation, formed a nearly continuous, sheet-type deposit over wide areas and probably covered the entire area of Jones County at one time. Deposition of the sediments was thought to have been controlled by repeated cycles of terrestrial alluviation and erosion caused principally by climatic changes associated with the advance and retreat of glacial ice sheets which were located in the northern United States and farther north (Van Siclen, 1957, p. 46-60).

Seymour deposits were later subjected to erosion during Recent time and the result is the so-called "high terrace gravels" which now appear as scattered patches capping southeast-trending interstream areas. The existing valleys of major streams now contain unconsolidated alluvial deposits which were in part derived from the eroded Seymour Formation.

Structure

The major subsurface structural features in north-central Texas include the Concho arch, the Concho platform, the Bend flexure, the Red River uplift, and the Midland shelf. The locations of these structural features are shown on Figure 6.

Jones County is located on the Concho platform on the west flank of the Bend flexure (Cheney and Goss, 1952). This platform is the result of subsidence and tilting, beneath the Midland basin, of the Concho arch which was once the most dominant feature of north-central and northwest Texas. The Bend flexure is actually a portion of the former Concho arch which was supposedly created by: 1) the subsidence of the Fort Worth basin during early to middle Pennsylvanian time and 2) an Upper Pennsylvanian—Early Permian down-warp of a portion of the foreland area and the gradual westward tilting of the entire area. This movement was the beginning of the Midland basin (Farris and others, 1963, p. 12). The latter tilting formed the present-day westerly-sloping homocline in the post-Bend strata (Figures 36, 37 and 38).

The exposed Permian beds of Jones County dip to the west-northwest at approximately 40 feet per mile. The overlying surficial deposits comprising the Seymour Formation and Recent alluvium dip very gently to the east-southeast.

The formations significant to the occurrence of usable-quality ground water in Jones County have not been affected appreciably by any of the major structural deformations other than by tilting as described above.

Geologic Units and their Water-Bearing Properties

In the description of the water-bearing properties of geologic units, the yields of wells are described as follows:

DESCRIPTION	YIELD (gallons per minute)
Small	Less than 100
Moderate	100 to 1,000
Large	More than 1,000

In general, the chemical quality of the water is classified according to the dissolved-solids content (Winslow and Kister, 1956, p. 5). A table listing these classifications is found in the chemical quality criteria section of this report.

Both Permian and Quaternary age rocks are exposed at the surface in Jones County and they provide fresh to moderately saline waters in small to moderate quantities to wells within the county.

Fresh to moderately saline waters are not known to occur below the Lueders Formation of Permian age within Jones County. Tables 9 and 10 indicate the chemical quality of waters found at greater depth. Geologic sections (Figures 36, 37, and 38) show the stratigraphic relationship of the older units for comparison and correlation with previous north-central Texas ground-water studies.

Permian System

Wichita Group

The oldest rocks exposed in Jones County are members of the Lueders Formation which is the uppermost formation of the Wichita Group of lower Permian age (Figure 5). The group is composed mainly

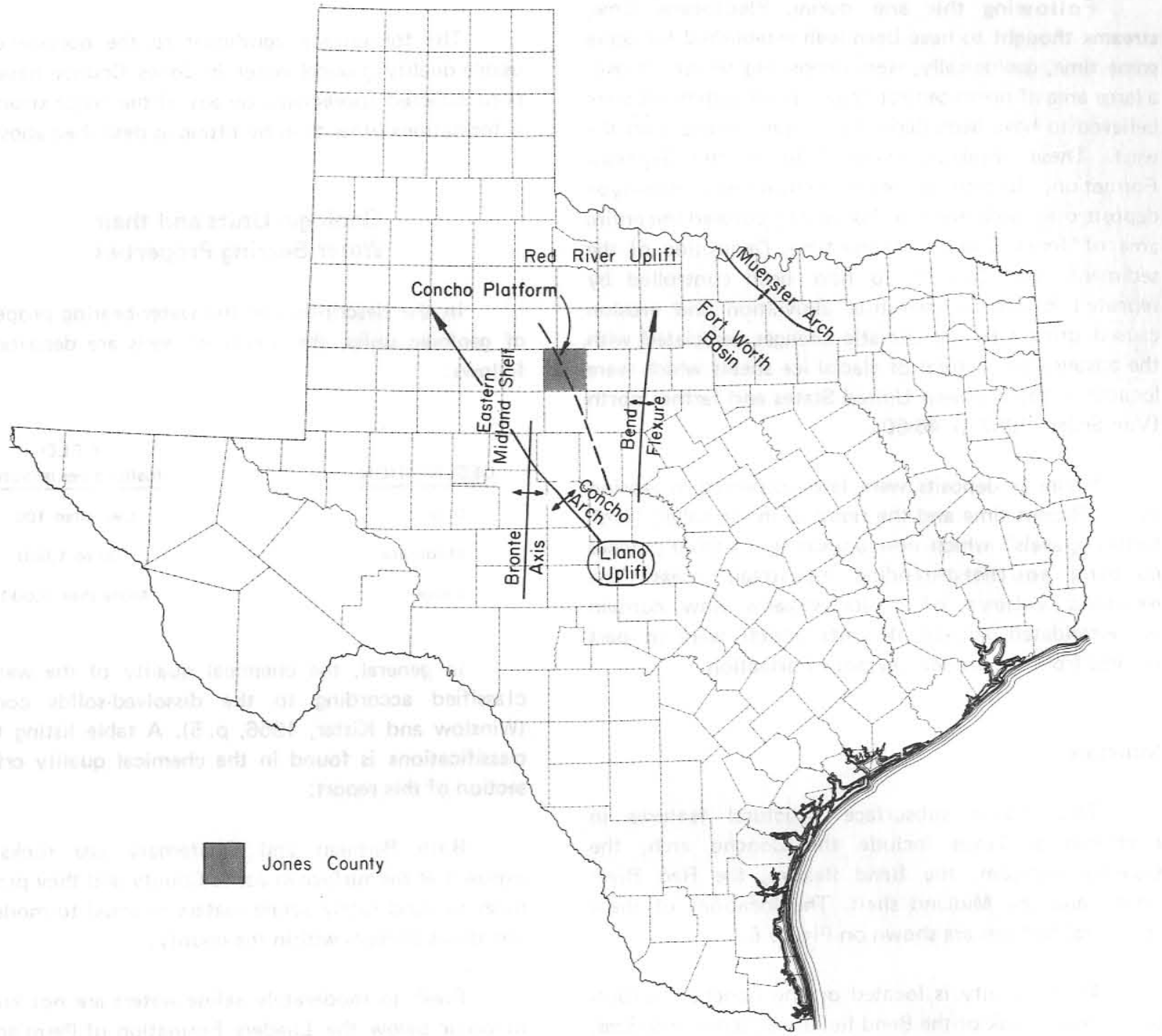

Figure 6.—Major Structural Features in North-Central Texas

of gray and red shale, limestone (most abundant in the upper portion), sandstone and siltstone (common only in the lower half of the group), rarely conglomerate, and a few thin beds of coal (Stafford, 1960, p. 266).

This group is comprised of seven recognized formations, only one of which, the Lueders Formation, crops out in Jones County (Table 1).

Lueders Formation

The Lueders Formation, composed of the three members, the Paint Rock Limestone, the Maybelle Limestone, and the youngest, the Lake Kemp Limestone, was originally described by Garrett and others (1930). The Lueders consists of alternating thick beds of medium-light to light-gray limestone and blue, gray, and black shale (Stafford, 1960, p. 276). The unit is about 75 feet thick in Jones County (Table 1).

The outcrop pattern of the Lueders is a narrow north-trending band along Deadman Creek to its intersection with the Clear Fork Brazos River. From this point, the outcrop is along the river to the vicinity of Lueders where it passes into Shackelford County (Figure 5).

The formation occurs throughout the rest of Jones County west of the outcrop; however, it is confined to the subsurface where it underlies and is covered by the younger Arroyo Formation or by rocks of Quaternary age. The beds dip west-northwest at about 40 feet per mile.

Accumulations of ground water in this formation are directly dependent upon the amount of local fracturing and solution channels. For this reason, the formation is not a reliable or prolific aquifer. Most wells producing from this unit are situated at or near the outcrop where zones of permeability are locally present. The water-bearing parts of the formation are thought to be very limited, occurring near the creeks of drainage ways which cross the outcrop.

The upper member of the Lueders Formation, which is fractured and permeable at or near the outcrop, yields fresh to slightly saline water in small quantities to a few wells in the extreme southeast part of the county (Tables 6 and 8 and Figure 35).

Clear Fork Group

Resting conformably upon the Lueders Formation of the Wichita Group is the Clear Fork Group. This group was named by Cummins (1890, p. 188) and crops out, or subcrops beneath surficial deposits of Quaternary age, in a belt trending generally north and approximately 25 miles wide (Figure 5). Rocks of the Clear Fork Group occur at the surface or in the subsurface throughout all of Jones County except a narrow band in the southeastern portion of the county.

The represented thickness of the Clear Fork is approximately 1,205 feet. The beds dip west-northwest at approximately 40 feet per mile and consist mainly of white, cream-colored, buff and brown, thin-bedded to shaly limestones, interbedded with marls and dolomites near the base which grade upward into red nonmarine shales and then into dolomites near the top of the unit (Farris and others, 1963, p. 19).

Water-bearing strata of the Clear Fork Group consist of fractured limestones and dolomites which are locally permeable (Table 1). These strata yield fresh to moderately saline waters in small to moderate quantities to many wells within Jones County (Tables 6, and 8, and Figure 35).

In ascending order, the Clear Fork Group is comprised of the Arroyo, Vale, and Choza Formations.

Arroyo Formation

The Arroyo Formation, the lowermost formation of the Clear Fork Group, was named by Beede and Waite (1916, p. 45-46). The formation rests conformably on the underlying Lueders Formation. The Vale Formation conformably overlies the unit. The Arroyo Formation is comprised of approximately 270 feet of limestones, dolomites, anhydrite, shaly sandstones, marl, and shales (Table 1). Where water is present, the anhydrite has generally been altered to gypsum.

The Arroyo crops out in a generally north-trending band about 8 miles wide (Figure 5) in approximately the east one-fifth of the county. It is overlain locally by rocks of Quaternary age.

The Rainey Limestone, which is the basal member of the Arroyo Formation, outcrops and forms a prominent escarpment in the vicinity of Fort Phantom Hill Reservoir in southeastern Jones County.

The extent of usable water in the Arroyo Formation is unknown. It is not believed to be extensive as only one well is known to yield water from the Arroyo. Situated near the outcrop in the eastern part of the county, this well (30-04-704) yields a small quantity of moderately saline water (Table 8 and Figure 35).

Vale Formation

Beede and Waite (1916, p. 47) originally described the Vale Formation. It consists of dominantly red shales with thin stringers of gray dolomite and a few lenticular, shaly sandstones near its base. The upper part contains the Bullwagon Dolomite Member which consists of thin stringers of gray dolomite interbedded with gray clay, red shale, and anhydrite or gypsum. The formation is about 385 feet thick in Jones County.

This formation crops out, or subcrops beneath Quaternary deposits, in a generally north-trending strip about 8 miles wide through the middle of Jones County (Figure 5). The Seymour Formation covers an estimated 75 percent of the Vale Formation's outcrop area. This relationship, along with several streams which flow across the Vale outcrop, provides excellent recharge of the fractured and locally permeable Bullwagon Dolomite as well as other thin, water-producing stringers of dolomite in the Vale and above the Bullwagon Dolomite.

The formation dips west-northwest beneath younger sediments of Permian and Quaternary age at about 40 feet to the mile. It is present in the subsurface over all of Jones County west of its outcrop (Figures 36, 37 and 38).

The Vale Formation yields small to moderate quantities of fresh to moderately saline water to many wells in and west of the outcrop (Tables 6 and 8 and Figure 35). The downdip limits of usable quality water are unknown; however, ground water of less than 2,000 mg/l dissolved solids is present in existing wells to a maximum distance of 3 miles, and water suitable for livestock watering is being used 5 miles west of the known outcrop.

Bullwagon Dolomite Member.—The Bullwagon Dolomite Member, located near the top of the Vale Formation, is approximately 20 feet thick and is composed of thin beds of light-gray sucrosic dolomite separated by gray clay and reddish shale. It was described by Wrather (1917). The unit reportedly thins to 1 to 3 feet to the north in Haskell County (Ogilbee and others, 1962, p. 17).

The outcrop and subcrop of this unit is represented as a thin band trending generally north through the approximate center of Jones County (Figure 5). Water-bearing rocks of Quaternary age cover this unit in most of the county. It crops out mainly along the creeks and in the Clear Fork Brazos River. The overlying Quaternary deposits apparently provide recharge to the member and make it a reliable source of ground water near and west of its outcrop or subcrop.

The Bullwagon dips west-northwest into the subsurface at approximately 40 feet to the mile, and is present in the subsurface within Jones County west of the outcrop. The downdip limits of usable quality water are not known; however, fresh to slightly saline water may be encountered in some areas as much as 8 miles west of the outcrop.

Examination of scattered samples indicates that this unit contains local zones of permeability in the form of fractures or solution channels.

The Bullwagon yields small to moderate quantities of fresh to moderately saline water to wells in the western part of the county (Tables 6 and 8 and Figure 35).

Choza Formation

The Choza Formation rests conformably on the Vale Formation. It is the youngest formation of the Clear Fork Group and consists of semi-persistent beds of gray dolomitic limestones and anhydrite, interbedded, at various levels, with red shales which contain thin argillaceous sandstone units. The anhydrite has been altered to gypsum where water is present. The persistent gray Merkel Dolomite Member is located near the top of this formation. Both the Choza Formation and the Merkel Dolomite Member were originally named by Beede and Waite (1916, p. 49).

The thickness of the Choza Formation within Jones County is approximately 550 feet. The Merkel Dolomite Member is approximately 15 feet in thickness.

The outcrop area of the Choza Formation is approximately 10 miles wide and is a generally north-trending band covering approximately the east one-half of the west one-half of the county (Figure 5). Quaternary rocks cover approximately 50 percent of the formation's outcrop. The Merkel Dolomite Member crops out as a thin band less than 50 feet wide, and forms a persistent escarpment which trends north across the west one-half of the county.

The Choza dips to the west-northwest at about 40 feet to the mile into the subsurface beneath the overlying San Angelo Formation.

The Choza Formation yields water to many wells in western Jones County and the water quality ranges from fresh to moderately saline. Well yields range from small to moderate (Tables 6 and 8 and Figure 35). Well 29-08-802 is the only well inventoried during this study known to produce ground water from the Merkel Dolomite Member of the Choza Formation. Only a small quantity of slightly saline water is produced from this well (Figure 35 and Table 8).

Pease River Group

The Pease River Group is the youngest and uppermost group of the Permian System represented in north-central Texas. This group was named originally by Cummins (1890, p. 188) and it consists largely of conglomerates, sandstones, shales, and gypsum (Table 1). The group is separated from the underlying Choza Formation by a marked erosional unconformity. The group's total thickness within Jones County is approximately 165 feet.

Ground water produced from the various units ranges from fresh to moderately saline in quality and is present in small quantities (Tables 6 and 8 and Figure 35). Almost all of the water produced from this group, within Jones County, is from the San Angelo Formation except a few wells producing from the Blaine Formation.

San Angelo Formation

Resting uncomformably upon the Choza Formation is the lowermost formation of the Pease River Group, the San Angelo Formation. This formation was named by Cummins and Lerch (1891, p. 73-77, 321-325). The unit consists of a nonmarine series of cross-bedded sandstones, conglomerates of chert and quartz pebbles, and red to green shales (Table 1). The approximate thickness of the formation in Jones County is 110 feet.

The San Angelo Formation is exposed in the prominent escarpment formed by the underlying Merkel Dolomite and crops out in a belt, approximately 2 to 5 miles wide, across the west one-third of the west one-half of Jones County (Figure 5). The unit is present throughout Jones County to the west of its outcrop. It dips to the west-northwest at the rate of about 40 feet per mile. The San Angelo is overlain in part by the younger Blaine Formation and Quaternary-age rocks (Figure 5).

The San Angelo Formation is one of the more reliable minor sources of ground water in Jones County and yields water to many wells in the extreme western portion of the county (Tables 6 and 8 and Figure 35). The quality of water ranges from fresh to mainly moderately saline. The quantity of water yielded to the wells is small. The downdip limit of usable quality water within the unit is unknown; however, water suitable for livestock use is known to be present as far west as the Jones County line.

Blaine Formation

Conformably overlying the San Angelo Formation, in parts of northern Texas and western Oklahoma, are the Flowerpot shale and the Blaine Formation, which was originally named by Gould (1902, p. 42 and 47). These two units are not easily separated in Jones County; therefore, for the purposes of this report the term "Blaine" (Table 1) is used to include all Permian sediments in the county above the San Angelo Formation.

In Jones County, these deposits are composed of red to gray gypsiferous shales in the lower part, anhydrite or gypsum and dolomite near the middle of the section, and calcareous sandstone and dolomite in the upper part. Several beds of sandstone, dolomite, and anhydrite or gypsum appear to be lenticular. This makes them difficult to trace into the subsurface. There is approximately 55 feet of these deposits present.

The Blaine crops out in a belt, 3 to 4 miles wide, which trends northeast across the extreme northwest corner of the county (Figure 5).

The formation dips west-northwest into the subsurface beneath beds of Quaternary age at about 40 feet per mile. The unit is present in the subsurface underlying all of the northwest corner of the county.

Unreliable supplies of ground water occur in the thin dolomite beds and calcareous sandstones on or near the outcrop.

A few wells produce water from the Blaine. They yield small quantities of water, which ranges from slightly saline to moderately saline in quality (Tables 6 and 8 and Figure 35).

Quaternary Systems

Rocks of the Quaternary System occur as isolated patches covering an estimated 80 percent of the surface of Jones County (Figure 5). They are separated from the underlying Permian beds by a marked erosional unconformity and dip very gently to the east-southeast (Figures 36 and 37).

The sediments are comprised of nonmarine clays, sandstones, gravels, and sometimes conglomerates (Table 1).

The rocks of this age contain most of the ground water in Jones County. The water quality ranges from fresh to moderately saline; most of the water, however, is of slightly saline quality (Tables 6 and 8 and Figure 35). Well yields range from small to moderate.

The series representing this age are the Pleistocene Series and the younger, Recent Series.

Pleistocene Series

Seymour Formation

The Seymour Formation was named by Cummins (1893, p. 181-190). The unit in general caps the southeast-trending interstream areas or divides between the major streams (Figure 5). It occurs, also, in many areas as isolated patches, suggesting that it was originally a sheet-type deposit which covered the entire surface of the county.

The Seymour, within Jones County, consists generally of nonmarine deposits of clays, silts, sands, caliche, gravels, and conglomerates (Table 1). Please consult the "Availability of Ground Water in Jones County" section of this report for a more detailed discussion of the lithology of this formation. Although the individual beds are discontinuous, except for isolated areas, a fairly consistent deposit of sands, gravels, and conglomerates is present near the base of the Seymour Formation over most of Jones County. This basal unit is best developed in the area between the towns of Anson and Hawley and between Truby and Nugent (Figures 35, 39, and 40). Almost all of the water obtained from the Seymour is derived from this basal unit.

The thickness of the formation varies from 0 to a maximum of 115 feet.

Van Siclen (1957, p. 54) states that the Seymour Formation is questionably of middle Pleistocene age. Ogilsbee and Osborne (1962, p. 19) discussed the occurrence of a volcanic ash bed in the basal portion of the Seymour about 12 miles north of Munday, in Haskell County. Sidwell and Bronaugh (1946, p. 15) have established that all but one of the Pleistocene ash deposits in Texas occurred during one ash fall. A correlation of these deposits has been made with the Pearlette ash, which has been established as early Yarmouth (Middle Pleistocene interglacial time) by Frye and others, (1948, p. 501). These findings further suggest a middle Pleistocene age for the Seymour Formation.

Gordon (1913, p. 30) states that the character of the materials found in the Seymour Formation suggests that it was derived from the Tertiary beds which outcrop along the escarpment of the Llano Estacado northwest of this area. The author has viewed these beds and is also of the same opinion. Gould (1906, p. 29) also referred to the presence of waterworn *Gryphaea* shells of Lower Cretaceous age in the gravels at the base of the Tertiary deposits. It is possible that some of the isolated patches of the postulated Seymour are actually erosional remnants of Tertiary deposits. The general character of the deposits suggests that the beds were deposited by streams. Johnson (1901, p. 655) states that the heterogeneous distribution of the various units which characterize the Quaternary in the High Plains is the result of branching streams in a desert habitat. Van Siclen (1957, p. 47-60) postulated that during Pleistocene times, following the removal of all post-Permian sediments, streams were depositing sediments, thought derived and carried from the west, over a large area of north-central Texas. He thought the deposits were controlled by repeated cycles of terrestrial alluviation and erosion caused principally by climatic changes associated with the advance and retreat of glacial ice sheets in the northern United States.

The Seymour Formation is the major ground-water source in Jones County. The geology map (Figure 5) shows the extent of the Seymour Formation in the county, and Figure 10 outlines the areas in which the Seymour is generally capable of yielding water to wells. Capabilities of the various areas will be discussed in the "Availability of Ground Water in Jones County" section of this report. The location of the wells, and the water quality and quantities, are shown on Figure 35 and in Tables 6 and 8.

Water in the Seymour Formation usually is slightly saline; however, it ranges from fresh to moderately saline (Table 8).

Well yields generally range from small to moderate. One well (30-18-518) yields water in large quantities (Table 6).

Recent Series

Recent Alluvium

The basal part of the flood-plain deposits of the Clear Fork Brazos River and California Creek within Jones County is composed of silt, sand, and gravel (Table 1). It appears that these deposits were derived, for the most part, from the Seymour Formation and were transported to their present position by existing streams. These sediments were erratically deposited and they are very discontinuous. The porosities and permeabilities vary greatly and, therefore, the yields of wells also have a wide range. The most favorable sediments for irrigation-water development are the more permeable deposits which can be found in oxbows of former streambeds. Several areas of irrigation have been developed on these alluvial deposits.

The Recent alluvium deposits are unconformably in contact with the Seymour Formation and with the underlying beds of Permian age. There may be, locally, drainage from these deposits into more porous Permian beds below. There is also drainage from the Seymour into the Recent alluvium.

The geologic map outlines the principal deposits of Recent alluvium (Figure 5). Alluvium is present as a strip approximately 1 mile wide along the Clear Fork Brazos River and California Creek in Jones County. Alluvium is also present along numerous tributaries of these streams but is not shown on the geologic map in all cases. Water is produced from the Recent alluvium typically by shallow, dug wells.

The alluvium as a whole provides a reliable source of ground water in Jones County. The quality ranges from fresh to moderately saline. Much of this water is high in sulfate content (Table 8). Yields of wells range from small to moderate (Table 6).

GENERAL PRINCIPLES OF GROUND-WATER OCCURRENCE

The occurrence of ground water in north-central Texas and Jones County is erratic, the aquifers are limited and discontinuous, and the yields of wells, in general, are small (less than 100 gpm) to moderate (100 to 1,000 gpm). Even though these conditions exist, the ground-water occurrences conform to the same fundamental principles as those in any other area.

Hydrologic Cycle

The water available for use by man—whether as rain, water from wells, or stream discharge—is captured in transit, and after its use and reuse, is returned to the hydrologic cycle from which it came. This cycle is illustrated in Figure 7. Graphically, this figure shows the continuing movement of water from the oceans through evaporation to precipitation and its return, either

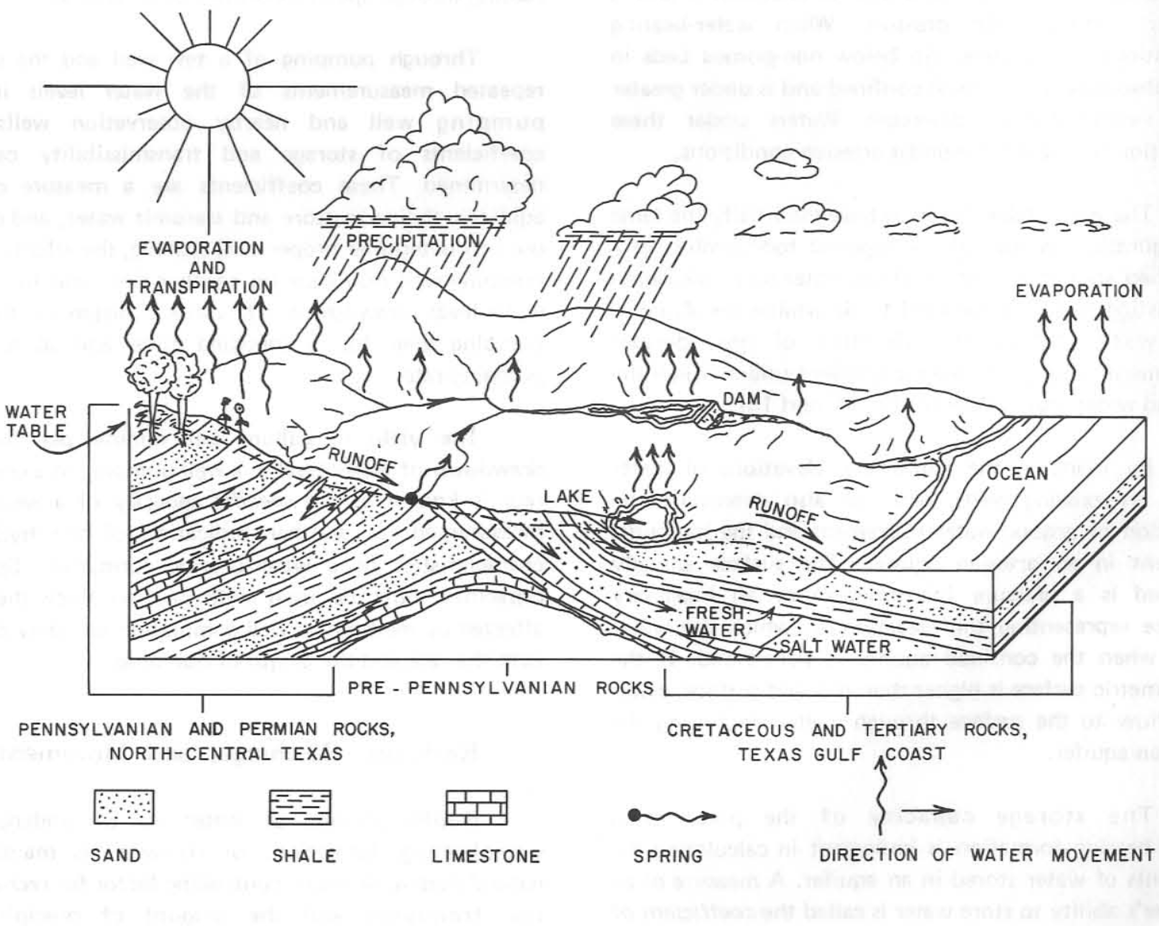

Figure 7.—The Hydrologic Cycle

directly or indirectly, to the ocean. Ground water is the part of the returning water which has entered the subsurface and filled the void spaces of the porous rocks which are within the zone of saturation. The source of all fresh ground water is precipitation, and only a small percentage of the precipitation actually becomes ground water.

As water moves downward under gravity through porous rocks, it first enters the *zone of aeration* in which unsaturated voids contain both air and water, and later it enters the *zone of saturation* where all of the pore spaces are filled with water. The upper surface of the zone of saturation is called the *water table,* and the water below the water table is termed *ground water.* Occasionally, water in its downward movement encounters impermeable beds above the normal water table and is trapped, forming what is referred to as a *perched water table.*

An *aquifer* is a formation, group of formations, or part of a formation that is water bearing (Meinzer, 1923, p. 30).

Water-table conditions exist where the upper surface of the zone of saturation is unconfined and is under atmospheric pressure. When water-bearing formations, or aquifers, dip below non-porous beds in the subsurface, the water is confined and is under greater than atmospheric pressure. Waters under these conditions are said to be under artesian conditions.

The water table tends to have essentially the same configuration as that of the regional topography. In a specified aquifer, elevations of the water table, measured in existing wells, can be used to determine the shape of the water table, the direction of ground-water movement, and the hydraulic gradient under which the ground water moves (Figures 13, 14, and 15).

By mapping the subsurface elevations of water levels in existing wells, one can also determine the direction of ground-water movement and the hydraulic gradient in an artesian aquifer. The surface actually mapped is a pressure (piezometric) or an imaginary surface representing the elevation to which the water rises when the confined aquifer is penetrated. If the piezometric surface is higher than the land surface, water will flow to the surface through wells penetrating the artesian aquifer.

The storage capacity of the pores of a water-bearing formation is important in calculating the amounts of water stored in an aquifer. A measure of an aquifer's ability to store water is called the *coefficient of storage* and is the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Coefficients of storage for artesian aquifers are very small in comparison to those of water-table aquifers as they reflect the elastic properties of the artesian aquifers. Under water-table conditions, the coefficient of storage is essentially the same as the *specific yield* which is defined as the ratio of the volume of water yielded to the volume of the aquifer which was dewatered (After Stearns, 1928, p. 144).

The field *coefficient of permeability* is the flow of water in gallons per day at the prevailing temperature through a cross section of 1 square foot of the aquifer under unit hydraulic gradient.

The *coefficient of transmissibility* is a measure of an aquifer's ability to transmit water and it is important in computing the amount of water available on a continuous basis. It is defined as the amount of water, in gallons per day, which will flow through a vertical column of aquifer 1 foot wide under a 45-degree slope or gradient (After Theis, 1938, p. 889-902). Given a known hydraulic gradient and the coefficient of transmissibility, one can calculate the amounts of water passing through specific portions of an aquifer.

Through pumping of a test well and the use of repeated measurements of the water levels in the pumping well and nearby observation wells, the coefficients of storage and transmissibility can be determined. These coefficients are a measure of the aquifer's ability to store and transmit water, and can be used to determine proper well spacing, the effects that a pumping well may have on another well, and to predict water-level drawdowns at various distances from a pumping well for a specified time and at a given pumping rate.

The yield in gallons per minute per foot of drawdown of water level in a well pumping at a constant rate is known as the *specific capacity* of a well. This measurement is another indication of the hydraulic characteristics of a water-bearing formation. Specific capacities must be used with caution since they are affected by methods of well completion and they change with the rate and the length of pumping.

Recharge, Discharge, and Movement

Replenishment of water to an underground water-bearing formation, or recharge, is mainly by natural means. A major controlling factor for recharge is the frequency and the amount of precipitation. Precipitation, in the form of rain, sleet or snow, and the seepage from lakes or streams on an aquifer's outcrop, aid in natural recharge. The rechargeability of an aquifer depends upon the type of topography, and the amount and kind of vegetative cover on the outcropping rocks, the condition of the soils, and the permeability of the rocks involved. Minor amounts of artificial recharge may be accomplished by running water over an aquifer's permeable outcrop or by pumping water into the water-bearing unit through wells. If recharge does not equal discharge, over a long period of time, the aquifer will be progressively drained. If recharge is greater than discharge, then water will be taken into storage and progressively fill the aquifer.

Discharge is the process by which water is removed from an aquifer. As in the case of recharge, the discharge of water from a water-bearing formation is also by natural and artificial means. Natural discharge occurs as flow from springs, effluent seepage, interformational leakage, transpiration by plants, and by evaporation. Artificially, water is discharged through wells by pumping.

The movement of ground water is generally very slow and is from areas of recharge to areas of discharge. The governing factors which determine the rate of movement are the permeability of the aquifer and the hydraulic gradient. With low permeabilities (example: 10 gallons per day per square foot) and a very low gradient of much less than 1 degree, the rate of flow would be less than 1 foot per day. Under ideal conditions of high permeabilities and gradient, field tests have reported velocities of greater than 100 feet per day. Todd (1959, p. 53), states, however, that the normal range is from 5 feet per year to 5 feet per day. Artificial discharge through pumping wells can alter the direction of movement and the velocity of the natural flow of ground water. In most areas of north-central Texas, ground-water movement is not constant in rate or direction. This is due to the wide variance in the lithology, extent, porosity, permeability, and structure of the water-bearing units.

Water-Level Fluctuations

Locally, measurements of the depth to water in wells indicate the position of the water table under water-table conditions, or of the piezometric surface under artesian conditions. When there is an absence of withdrawal, or the influence of pumping is nil, the measurement is termed a *static water level.* When the measurement is made in a pumping well, the water level is termed a *pumping level.* For water-table aquifers, changes in water levels reflect changes in the ground-water storage. The changes may be on a local or regional basis. Regional changes over a long period of time reflect a change in the recharge-discharge relationship.

Often water-level fluctuations of a minor nature are reflections of earthquakes, tidal forces, and changes in atmospheric pressure.

The most significant changes are the result of heavy pumping. Depending on the reservoir characteristics of an aquifer and the rate of withdrawal, various sizes of *cones of depression* are formed around the well bores of pumping wells. These cones are formed by the drawdown of the water table or the piezometric surface and are in the shape of an inverted cone having its apex at the pumped well (Figure 8, well A). These cones will expand until they encounter a recharge source equal to the discharge rate. If the cone does not encounter a recharge source, it will continue to expand until it encounters the cone of depression of another pumping well, as is the case in highly developed irrigation areas, and may combine with it and form a large, regional cone of depression in the piezometric surface or the water table (Figure 8, wells A+B).

CHEMICAL QUALITY

Only small amounts of mineral matter are present in precipitation, whether it be in the form of sleet, snow, or rain. However, upon reaching the land surface, water dissolves minerals from the soils and rocks through which it moves. This accounts for the wide differences in the chemical quality of water in different formations. In general, the concentration of dissolved solids increases with the depth of the aquifer.

Ground water may be subjected to contamination from various sources. Contamination may result from the improper disposal of sewage or industrial wastes. It also may result from disposal of brine, which is produced with hydrocarbons, or by leakage from abandoned or producing oil wells.

Table 8 is a tabulation of 895 chemical analyses of water from wells and springs in Jones County. The sampled wells are indicated on Figure 35 by a bar over the well number. Table 2 lists the principal mineral constituents found in ground water, and discusses their source and significance and the physical properties of natural waters.

Quality Criteria or Standards

The degree and type of mineralization of ground water determines its suitability for municipal, industrial,

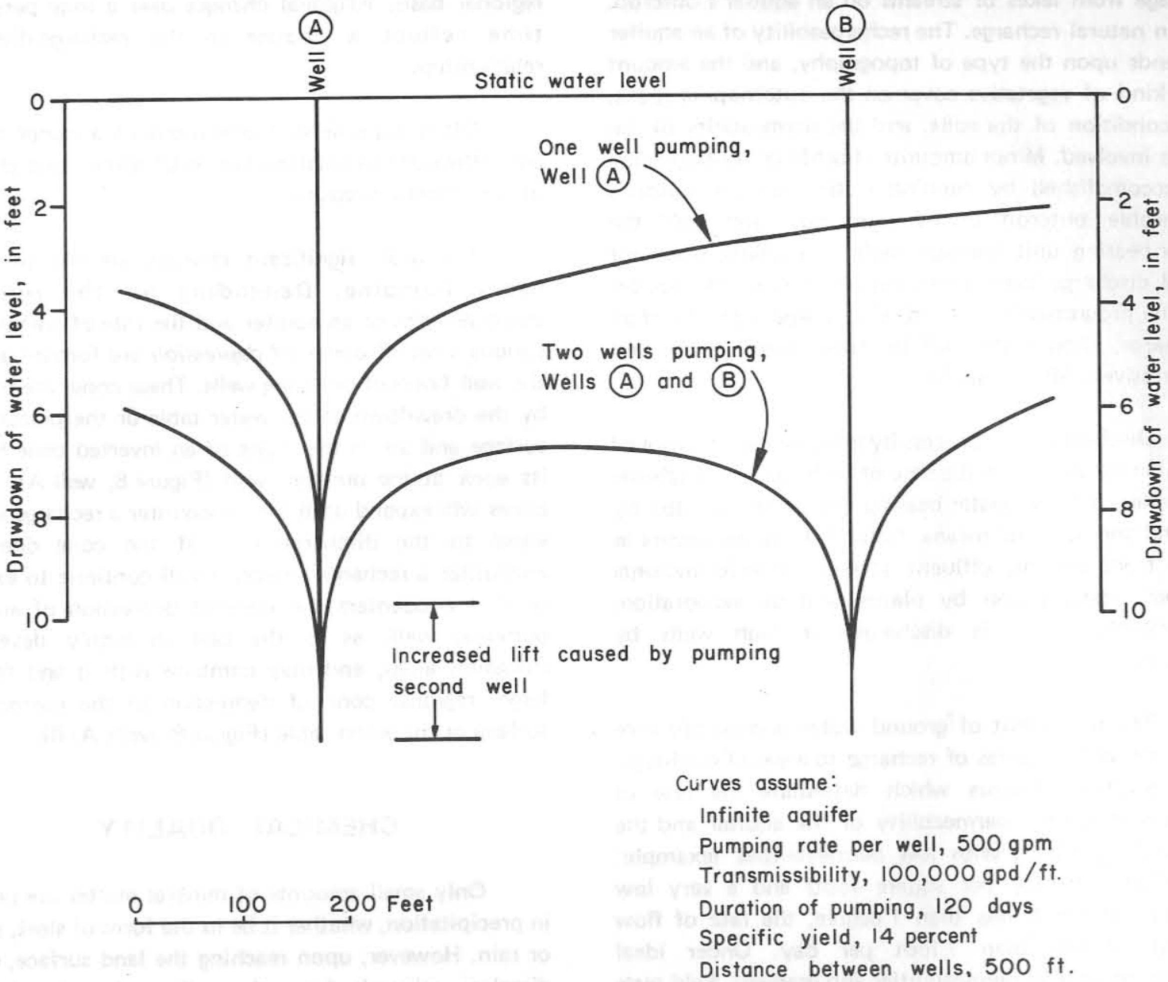

Figure 8.—Idealized Cross Section Showing Drawdown Interference Between Two Pumping Wells

irrigation, and other uses. Several criteria for water-quality requirements have been developed through the years which serve as guidelines in determining the suitability of water for various uses. Subjects covered by the guidelines are bacterial content; physical characteristics, including color, taste, odor, turbidity, and temperature; and the chemical constituents. Water-quality problems associated with the first two subjects can usually be alleviated economically. The neutralization or removal of most of the unwanted chemical constituents is usually difficult and often very costly.

The total dissolved-solids content is usually the main factor which limits or determines the use of ground water. Winslow and Kister (1956, p. 5) used an excellent, and very applicable, general classification of waters based on the dissolved-solids concentration in parts per million (ppm). The classification 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

In recent years most laboratories have begun reporting analyses in mg/l (milligrams per liter) instead of ppm. These units, for practical purposes, are identical unless the dissolved-solids concentration of water reaches or exceeds 7,000 units (ppm or mg/l). The concentrations of chemical constituents reported in this report, other than for oil-field brines, are in mg/l (Tables 2, 3, and 8). Most of the chemical concentrations are below 7,000 mg/l and therefore the

Table 2.—Source and Significance of Dissolved-Mineral Constituents and Properties of Water

(Adapted from Doll and others, 1963, p. 39-43)

CONSTITUENT OR PROPERTY	SOURCE OR CAUSE	SIGNIFICANCE
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 mg/l. High concentrations, as much as 100 mg/l, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 mg/l stain laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. U.S. Public Health Service (1962) drinking water standards state that iron should not exceed 0.3 mg/l. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (sea hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and Potassium (K)	Dissolved from practically all rocks and soils. Found also in oil-field brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefullness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon-dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. U.S. Public Health Service (1962) drinking water standards recommend that the sulfate content should not exceed 250 mg/l.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in oil-field brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water. U.S. Public Health Service (1962) drinking water standards recommend that the chloride content should not exceed 250 mg/l.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual (Maier, 1950, p. 1120-1132).
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. U.S. Public Health Service (1962) drinking water standards suggest a limit of 45 mg/l. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding (Maxcy, 1950, p. 271). Nitrate shown to be helpful in reducing inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.

In most waters, the salt concentration is not high enough to impair or retard the growth of plants. It is the salt accumulation in the soil which causes saline conditions that are injurious. However, as the salt concentration in irrigation waters increases, the salinity hazard or the tendency of salts to accumulate in the soil also increases.

The U.S. Salinity Laboratory Staff (1954, p. 69-82) prepared the diagram shown in Figure 9 which is an excellent guide for estimating the relative salinity hazard of various waters for irrigation. It is based, partly, on various salinity classes which are determined by the conductivity in micromhos per centimeter at 25°C which is shown on most chemical analyses. The classes are shown on the horizontal scale of Figure 9 and a discussion of them follows (Lyerly and Longenecker, 1957, p. 13-14):

C1) Low-salinity water—can be used for irrigation of most crops on most soils, with little or no development of soil salinity. Care must be exercised only in soils having extremely low permeability.

C2) Medium-salinity water—can be used if moderate leaching occurs. Plants with moderate salt tolerance can usually be grown without special salinity control practices.

C3) High-salinity water—cannot be used on soils with restricted drainage. If used, plants with good salt tolerance should be selected, adequate drainage should be provided, and special management for salinity control should be practiced.

C4) Very high-salinity water—is not ordinarily suitable for irrigation. If used, water must be applied in excess to permeable soils with adequate drainage, and crops must be highly salt-tolerant.

Physical conditions of the soil are markedly affected by an increase in exchangeable sodium. For that reason, it is necessary to consider the sodium hazard of irrigation water. Accumulations of sodium in the soil may be injurious to plants sensitive to sodium. The total salt concentration, as well as the sodium-adsorption ratio, (SAR, described in Table 2) influence the sodium hazard. A high SAR in irrigation water causes soil structure breakdown. The affected soils tend to form a hard crust and become impermeable to water and air movement. This usually results in crop damage, cultivation difficulties, and drainage problems (Hem, 1959, p. 247). Table 8 gives the SAR calculations for all

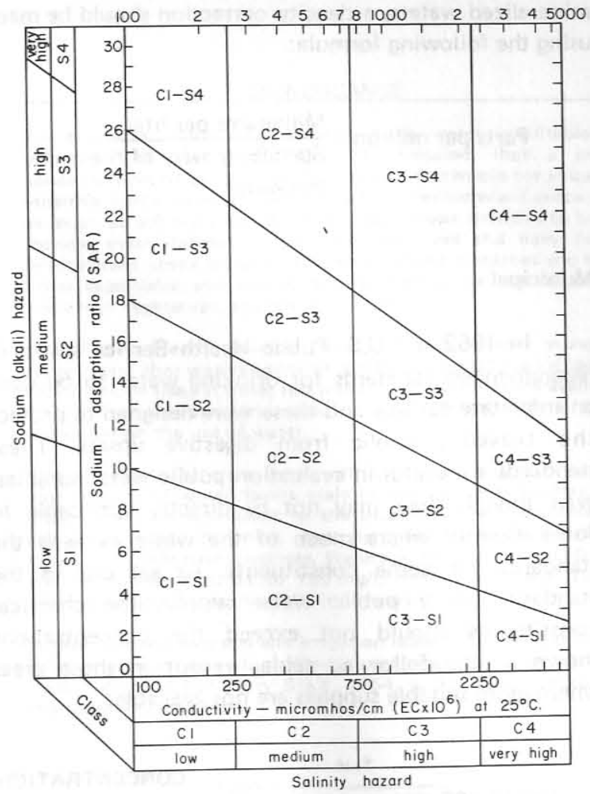

Figure 9.—Diagram for the Classification of Irrigation Waters

water samples that were analyzed in Jones County. Using these calculations, and the value of the conductivity, also shown in Table 8, one can determine the sodium hazard on Figure 9. The sodium-hazard classes as shown on the vertical scale of Figure 9 are as follows (Lyerly and Longenecker, 1957, p. 14-15):

S1) Low-sodium water—can be used with little danger of development of harmful levels of exchangeable sodium on almost all soils. Some stone-fruit trees and other sodium-sensitive crops may accumulate sodium which could be injurious.

S2) Medium-sodium water—is recommended to be used on coarse-textured or organic soils having good permeability. In the absence of gypsum in the soil, this water will present an appreciable sodium hazard in fine-textured soils with high cation-exchange capacity under low-leaching conditions.

S3) High-sodium water—will require special management as it may produce harmful levels of exchangeable sodium in most soils;

however, this is not the case in gypsiferous soils. Organic additions, high leaching, and good drainage are needed.

S4) Very high-sodium water—is usually unsatisfactory for irrigation purposes. Exceptions are water with low and possibly medium salinity, where the solution of calcium from the soil or the use of gypsum or other additives may make the use of this water feasible.

Under most conditions, irrigation waters having a sodium percentage of less than 60, and a low bicarbonate content are probably satisfactory (Table 8). The sodium hazard becomes progressively greater as the sodium percentage increases above 60.

Boron is necessary for good plant growth; however, excessive boron content will render water unsuitable for irrigation. Wilcox (1955, p. 11) stated that concentrations of boron as high as 1.0 mg/l is permissible for irrigation of boron—sensitive crops; as high as 2.0 mg/l on semi-tolerant crops, and as much as 3.0 mg/l for tolerant crops (Table 2). Examples of sensitive crops are deciduous fruit and nut trees and navy beans; semi-tolerant crops include most small grains, cotton, potatoes, and some other vegetables; and tolerant crops are alfalfa and most root vegetables (Doll and others, 1963, p. 39-43). Table 3 lists the boron content on 50 selected wells in Jones County. Most of these wells are presently classified as irrigation wells. The boron content ranged from 0.08 to 5.5 mg/l and the average value for all of the samples was 0.97 mg/l. Discussions of the boron content of water from the various aquifers will follow in subsequent sections of this report.

Following irrigation, as the soil dries the soil solution becomes progressively more concentrated. This condition creates a tendency for the less soluble compounds to precipitate from solution. Both calcium and magnesium carbonates, being less soluble than sodium carbonate, may precipitate with drying. This precipitation results in an increase in the proportion of sodium in solution. The bicarbonate ion is the source of carbonate which makes possible the above precipitations.

The conditions favoring precipitation and the extent to which calcium and magnesium carbonates will precipitate are not fully understood. However, water containing 1.25 to 2.5 me/l (milliequivalents per liter) of residual sodium carbonate (RSC; see Table 2) are considered marginal and those containing greater than 2.5 me/l probably are not suited for irrigation use (Wilcox, 1955, p. 11)

Treatment of Water

Water that does not meet the requirements of a municipal or industrial user commonly can be treated by various methods so that it will become usable. Treatment methods include softening, aeration, filtration, cooling, dilution or blending of poor and good quality waters, and the addition of chemicals. The limiting factor in treatment is economics. Each water may require different treatment practices and the treatment should be designed for that particular water. However, once treatment is established it probably will not have to be changed as the chemical characteristics of uncontaminated ground water remain fairly constant.

AVAILABILITY OF GROUND WATER IN JONES COUNTY

Primary Aquifer

Seymour Formation

The primary aquifer of Jones County is the Seymour Formation. This formation provides water for all uses including irrigation. It is the major source of irrigation water.

Extent of the Aquifer

The Seymour Formation is present as scattered patches covering approximately 75 percent of the county (Figure 5), but is not water-bearing throughout its entire extent. In some areas the Seymour has a very thin saturated thickness and cannot be considered a reliable ground-water source. Figure 10 indexes for discussion purposes those areas in which the Seymour is generally capable of yielding water to wells.

Area A, covering approximately 126 square miles and outlined on Figure 10, is the area of greatest saturated thickness (Figure 11) and is the principal source of Seymour ground water in Jones County. Other areas outlined on Figure 10 which contain less water but support limited irrigation activities are areas B, C, D, E, and F. Areas G through O are believed to be very limited and unreliable sources of ground water. Area P possibly contains small amounts of water. Many other small,

Table 3.—Boron Concentration of Water from Selected Irrigation Wells

(Analyses in milligrams per liter)

Analyses performed by the Texas State Department of Health

WELL	DEPTH OF WELL (ft)	BORON CONCENTRATION (mg/l)
VALE FORMATION		
30-25-101	120	0.25
BULLWAGON DOLOMITE MEMBER OF VALE FORMATION		
30-09-922	60	2.5
17-505	68	1.1
509	60	1.1
25-110	82	2.1
CHOZA FORMATION		
30-09-703	80	1.3
SAN ANGELO FORMATION		
29-15-902	190	0.36
16-405	110	1.1
SEYMOUR FORMATION		
29-23-606	37	0.9
30-01-704	40	2.8
02-602	24	.9
03-507	101	2.0
17-323	45	.36
337	29	.5
403	75	.96
17-512	40	.52
605	70	.63
621	51	.56
709	34	.28
802	31	.8
18-111	40	.25
112	62	.27
225	65	.45
303	73	.32
334	60	.4
401	69	.12
424	68	.2
SEYMOUR FORMATION—CONTINUED		
532	54	.2
610	78	.23
612	73	.36
712	68	.2
19-401	46	.16
402	60	.08
501	57	.31
701	42	.09
712	46	.39
817	29	2.2
25-303	28	1.2
304	16	.8
27-106	28	.20
RECENT ALLUVIUM		
30-01-707	38	2.4
17-707	23	1.9
817	24	.41
826	30	1.5
831	18	2.0
911	17	1.4
915	76	2.9
916	70	5.5
919	23	.8
27-614	24	.58
SEYMOUR AND VALE FORMATIONS		
30-17-335	50	0.27
26-104	100	2.9
SEYMOUR FORMATION AND BULLWAGON DOLOMITE MEMBER OF VALE FORMATION		
30-25-804	115	0.32

isolated areas of Seymour Formation in the county are not known to yield water to wells.

Geologic Characteristics

The Seymour, within Jones County, consists of unconsolidated to semi-consolidated, nonmarine deposits of reddish-orange and gray clays; cross-bedded fine silts and white or tan to red sands; buff to white nodules of caliche, usually near the surface; and in the basal portion, cross-bedded, interstratified, discontinuous lenses of orange clay, sand, and coarse gravels or conglomerates. The conglomerates are composed of well rounded pebbles or cobbles of variously colored quartz, quartzite, igneous crystalline rocks, bone fragments, petrified wood, scattered waterworn Cretaceous *Gryphaea* fossils, and pebbles and cobbles of limestone. Referring to sections DD' and EE' (Figures 39 and 40), the formation, in its upper portion, consists generally of sands, sandy clays, clays, caliche, and silts which may be locally water-bearing when the materials are permeable. The sands and gravels found in the basal portion of the Seymour comprise the main water-bearing portion of the formation and generally transmit water readily.

The thickness of the Seymour varies greatly from area to area, and reaches a maximum of 115 feet in area A (Figure 10). The thickness of the basal sands and gravels ranges from 0 to 40 feet (Figure 39 and 40).

The Seymour dips very gently to the southeast (Figures 39 and 40) at an estimated 35 feet per mile and rests on a marked erosional unconformity in contact with the underlying beds of Permian age (Figures 36, 37, and 38).

Figure 12 is a map which depicts the base of the Seymour Formation. This map is an attempt to reproduce the old erosional surface upon which the sediments of the Seymour were deposited.

Within area A (Figure 10) there was ample information to construct a usable map. The indicated topography is hilly to rolling, and the maximum relief appears to be about 75 feet. The structural lows as delineated on Figure 12 reflect old stream patterns which were in existence at the time the Seymour was deposited. There is a direct correlation between the areas of industrial and irrigation well development, the areas of most permeable and thickest gravels in the Seymour Formation, and the structural lows shown on Figure 12. The gravels are best developed in or near the structural lows, and the wells with highest yield (Table 6) and those penetrating the greatest saturated thickness (Figure 11) are also in or very near these structural lows.

When used in conjunction with a topographic map, Figure 12 can also be used to estimate the depth of possible water wells drilled for ground water in the Seymour Formation. The elevation of the land surface is first estimated from a topographic map at the desired location of a water well. The elevation of the base of the Seymour at the proposed well site is then determined from Figure 12. The value as determined from Figure 12 subtracted from the estimated surface elevation of the subject well will give an estimate of the depth to the "redbeds" or Permian rocks.

Ground-Water Source, Occurrence, and Movement

The source of the ground water in the Seymour Formation is precipitation falling on its outcrop area. Only a small portion of the precipitation which falls, however, actually reaches the water table (Figure 7).

Water occurs and is stored in pores or voids between the rock particles. The two fundamental rock characteristics which are important in the occurrence of ground water are *porosity,* or the ratio of the volume of void space to the total rock volume expressed as a percentage, and *permeability,* which is the ability of a porous material to transmit water. The porosity of a rock is dependent upon the shape, size, sorting, and the amount of cementation of the grains. Clays, silts, and soils, which are fine grained, commonly have high porosity; however, they do not readily transmit water because of small size of the voids and low permeabilities. Because of their high porosities (ranging from 40 to 60 percent), the fine-grained sediments are capable of storing large quantities of water. The upper portion of the Seymour Formation generally is composed of the finer grained, well cemented sediments and, therefore, does contain much stored water but does not readily transmit this water. The basal part of the Seymour is usually composed of fairly uniform sands which may have porosities ranging from 30 to 40 percent and sands and gravels which commonly have porosities which range from 20 to 35 percent. The important difference between these sediments and those generally found in the upper part of the Seymour is that the basal portion of the formation has greater permeability and can transmit water more readily. For this reason, greater volumes of water are produced from the basal part of the formation.

The upper surface of the water table is unconfined in the Seymour and is therefore said to be under isolated areas of Seymour Formation in the county are not known to yield water to wells.

Geologic Characteristics

The Seymour Formation in Wilbarger County consists of unconsolidated and poorly consolidated, continental deposits of relatively recent origin. Its major lithologic types are silt and clay, sand, gravel, caliche (which occurs as nodules or as a dense, massive layer near the surface), and basal gravel. The sediments commonly display unmistakable discontinuous lenses of orange clay, silt, and coarser gravels, some conglomerates. The conglomerates are composed of well rounded pebbles and cobbles of various rocks, mainly quartz, quartzite, and some crystalline rocks, bone fragments, petrified wood, limestone, water-worn siliceous (gypsum) sand, and pebbles and cobbles of caliche. Referring to sections D-D' and E-E' (Figures 39 and 40), the formation in its upper portion consists principally of sands, silty clays, clays, caliche and silts which may be locally water-bearing where the materials are permeable. The sands and gravels found in the basal portion of the Seymour comprise the main water-bearing portion of the formation and generally yield water abundantly.

The thickness of the Seymour varies greatly from area to area and reaches a maximum of 115 feet in some areas (Figure 40). The thickness of the basal sands and gravels ranges from 0 to 40 feet (Figures 39 and 40).

The base of the Seymour dips very gently to the southeast (Figures 39 and 40) at an estimated 25 feet per mile and conforms to the regional dip, lying unconformably on eroded surfaces of the red beds of Permian age (Figures 38, 39, and 40).

Figure 12 is a map showing the configuration of the base of the Seymour Formation. This map is an attempt to reconstruct the old erosional surface upon which the sediments of the Seymour were deposited.

Within Area A (Figure 10) there was ample information to construct a reliable map. The indicated topography is that of valleys and the maximum relief appears to be about 75 feet. The structural lows as delineated on Figure 12 reflect old stream patterns which were in existence at the time the Seymour was deposited. There is a direct relationship between the areas of industrial and irrigation well development, the areas of most permeable and thickest deposits in the Seymour Formation, and the structural lows shown on Figure 12. The gravels are best developed in or near the structural lows, and the wells with highest yield (Table 5) and those penetrating the greatest saturated thickness (Figure 11) are also in or very near these structural lows.

When used in conjunction with a topographic map, Figure 12 can also be used to estimate the depth at which water-well drillers will encounter water in the Seymour Formation. The elevation of the land surface at a well site can be estimated from a topographic map at the desired location of a proposed well. The elevation of the base of the formation at the proposed well site is then determined from Figure 12. The value thus determined when it is subtracted from the estimated surface elevation of the proposed well site will give an estimate of the depth to the underlying Permian rocks.

Ground-Water Source, Occurrence, and Movement

The source of the ground water in the Seymour Formation is precipitation falling on its outcrop area. Only a small portion of the precipitation which falls, however, actually reaches the water table (Figure 2).

Water occurs and is stored in pores or voids between the rock particles. The two fundamental rock characteristics which are important in the occurrence of ground water are *porosity*, or the ratio of the volume of void space to the total rock volume expressed as a percentage, and *permeability*, which is the ability of a porous material to transmit water. The porosity of a rock is dependent upon the shape, size, sorting, and the amount of cementation of the grains. Clays, silts, and soils, which are fine grained, commonly have high porosity; however, they do not readily transmit water because of small size of openings and low permeabilities. Because of their high porosity ranging from 40 to 60 percent, the fine-grained sediments are capable of storing large quantities of water. The upper portion of the Seymour Formation generally is composed of the fine grained, well cemented sediments and, therefore, does contain much stored water but does not readily transmit the water. The basal part of the Seymour is usually composed of fairly uniform sands which may have porosities ranging from 30 to 40 percent and sands and gravels which commonly have porosities which range from 20 to 35 percent. The important difference between these sediments and those generally found in the upper part of the Seymour is that the basal portion of the formation has greater permeability and can transmit water more readily. For this reason, greater volumes of water are produced from the basal part of the formation.

The upper surface of the water table is unconfined in the Seymour and is therefore said to be under water-table conditions. In most cases, the water table is a short distance above the basal sands and gravels.

The movement of ground water is down gradient, from the high to low elevations, at right angles to the contours which denote the configuration of the water table. Ground-water movement is in general toward the major streams or their tributaries.

In area A (Figure 10), the ground-water highs are located in the northwest and north (Figures 13, 14, and 15). Ground-water movement away from these highs is mostly to the south and southeast into the Clear Fork Brazos River. There is some movement away from these highs to the north, northwest, or northeast into tributaries of California Creek and the Cottonwood Creek tributary of the Clear Fork Brazos River.

In areas B and F, on the south limits, the ground-water movement is south or southeast into the Clear Fork Brazos River; on the north edge, the movement is north, northwest, or northeast into the tributaries of California Creek; on the east and west limits the movement is to the southeast and southwest, respectively.

In areas C and D the ground-water movement is northward and north-eastward into the Clear Fork Brazos River; on the east and west boundaries the movement is east-southeast and west-northwest, respectively, into the tributaries of the Clear Fork Brazos River.

The ground-water movement in area E on the south and east edge is south and southeast into California Creek, and on the north limits the movement is north and northeast into tributaries of the Brazos River.

Water-Level Fluctuations

Several older residents of Jones County have reported that the ground-water supply in the Seymour has increased or become stronger since the early 1900's. Many other people have also reported marked changes in water levels in this same period of time. Ogilsbee and Osborne (1962, p. 23-24) reported similar change within the Seymour Formation in Haskell and Knox Counties.

A comparison of the water-table maps for the summer of 1953 (Figure 13) and for the winter of 1968-69 (Figure 15) shows water-level rises within area A (Figure 10) ranging from 6 to as much as 35 feet. Within area F rises of 1.9 to 3 feet are reflected for the same period. Scattered water-level measurements in area E indicate rises of as much as 31.5 feet (well 30-03-507) during the same time. Historical water-level data on 22 wells for the 15.5-year period reflect an average net rise of water level of 0.35 foot per year. In well 30-18-510, the water level rose 7.4 feet (average of 1.1 feet per year) from December 1, 1959 to February 10, 1967.

The hydrographs shown on Figure 17 are records of Seymour Formation water-level fluctuations from January 1967 to January 1969. The monthly precipitation of Abilene, Texas is also shown on Figure 17 for comparison with the water-level fluctuations. The hydrographs show noticeable seasonal changes in water levels which correspond to changes in rainfall and irrigation pumpage. The peak water levels generally occur during March, April, May, and June, coincident with increased rainfall and decreased pumpage. There is a general decrease in water levels during the growing season and the hot summer months, and marked water-level declines are caused by irrigation pumpage. Recharge in the irrigation areas by rainfall following periods of pumping illustrated by the hydrographs of irrigation wells 30-18-222 and 402 during August, September, and October of 1967. In these cases there was an increase in rainfall during September with a corresponding rise in water level in the subject wells.

Precipitation records (Figure 3) at Abilene, for the period 1885 to 1968, generally reflect an increase in rainfall during the period from 1885 through 1941. However, during this time there were periods of wet years interrupted by droughts. The State's most severe drought occurred in the early 1950's, and the lowest recorded annual rainfall at Abilene was 9.78 inches in 1956. Following this drought, yearly precipitation fluctuated; however, water levels have continued to rise even though there has been increased pumpage. During this same general period, many of the areas shown on Figure 10 have been completely cleared of heavy mesquite or oak trees and placed in cultivation. Much of area A (Figure 10) has been cleared and placed in cultivation.

The clearing of water-consuming vegetation (phreatophytes); the improved farming practices of terracing, contour plowing, and deep plowing; and the general increase in rainfall for the period from 1885 through 1941, have all been major contributing factors to the general rise in water levels.

In summary, water levels fluctuate in response to precipitation, cultivation practices, and pumpage. The general rise in water levels within the Seymour Formation indicates that the volume of ground water in water table conditions. In most cases, the water table is a short distance above the basal sands and gravels.

The movement of ground water is down-gradient, from the high to low elevations, at right angles to the contours, which denote the configuration of the water table. Ground water moves [illegible] major streams in [illegible].

In area [illegible] located in [illegible] and 15). Ground-water movement [illegible] is mostly [illegible] and southeast into the Clear Fork Brazos River [illegible] movement away from these highs [illegible] northwest, or northeast into tributaries [illegible] Creek and the Cottonwood Creek [illegible] the Clear Fork Brazos River.

[illegible] and [illegible] ground-water movement is north [illegible] Clear Fork Brazos River. [illegible] movement is north, northeast, [illegible] of California Creek [illegible] east and west [illegible] movement [illegible] and [illegible].

[illegible] of the ground-water movement is [illegible] into the Clear Fork [illegible] east and west boundaries the [illegible] southeast and west-northwest, [illegible] tributaries of the Clear Fork [illegible].

[illegible] direction [illegible] and [illegible] on the [illegible] Creek [illegible] River.

Water-Level Fluctuations

Several water [illegible] of [illegible] County have reported that the [illegible] water [illegible] the Seymour has increased [illegible] since the early 1900's. Many other people have [illegible] water levels in the same [illegible] and Osborne (1962, p. 23-24) [illegible] the Seymour Formation in [illegible].

A comparison of the water-table maps for the summer of 1963 (Figure 13) and for the winter of 1968-69 (Figure 15) shows water-level rises within area A (Figure 10) ranging from 6 to as much as 35 feet. Within area F rises of 1.9 to 3 feet are reflected for the same period. Scattered water-level measurements in area E indicate rises of as much as 31.5 feet (well 30-05-507) during the same time. [illegible] water-level data [illegible] wells [illegible] area [illegible] of [illegible] 2.7 [illegible] and [illegible] feet [illegible] 1.1 [illegible] to [illegible] 1968.

[illegible] shown on Figure 17 [illegible] records [illegible] wells [illegible] from January [illegible] 1968 [illegible] precipitation [illegible] is also shown on Figure 17 for comparison with the water-level fluctuations. The [illegible] noticeable seasonal changes in water levels [illegible] to changes in rainfall and irrigation [illegible] water levels generally occur during [illegible] May and June, coinciding with increased [illegible] and decreased [illegible]. There is a general [illegible] water levels during the growing season and [illegible] with [illegible] irrigation [illegible] rainfall [illegible] the [illegible] of irrigation wells 30-13-[illegible] and 402 during August, September, and October of 1967. In these cases there was an increase in rainfall during September with a corresponding rise in water level in the subject wells.

Precipitation records (Figure 3) at Abilene, for the period 1885 to 1968, generally reflect an increase in rainfall during the period from 1885 through 1941. However, during this time there were periods of wet [illegible] by droughts. The State's [illegible] severe [illegible] in the early 1950's, and the lowest [illegible] rainfall at Abilene was [illegible] inches in [illegible] through [illegible] precipitation [illegible] water levels have continued to rise [illegible] though there has been [illegible]. During this same general period, many of the areas shown on Figure 10 have been completely cleared of heavy [illegible] and placed in cultivation. Much of area A (Figure 10) has been cleared and placed in cultivation.

The clearing of water-consuming vegetation [illegible] improved farming practices of [illegible] and deep plowing, and the [illegible] for the period from 1885 through [illegible] have all been major contributing factors to the general rise in water levels.

In summary, water levels fluctuate in response to precipitation, cultivation practices, and pumpage. The general rise in water levels within the Seymour Formation indicates that the volume of ground water [illegible]

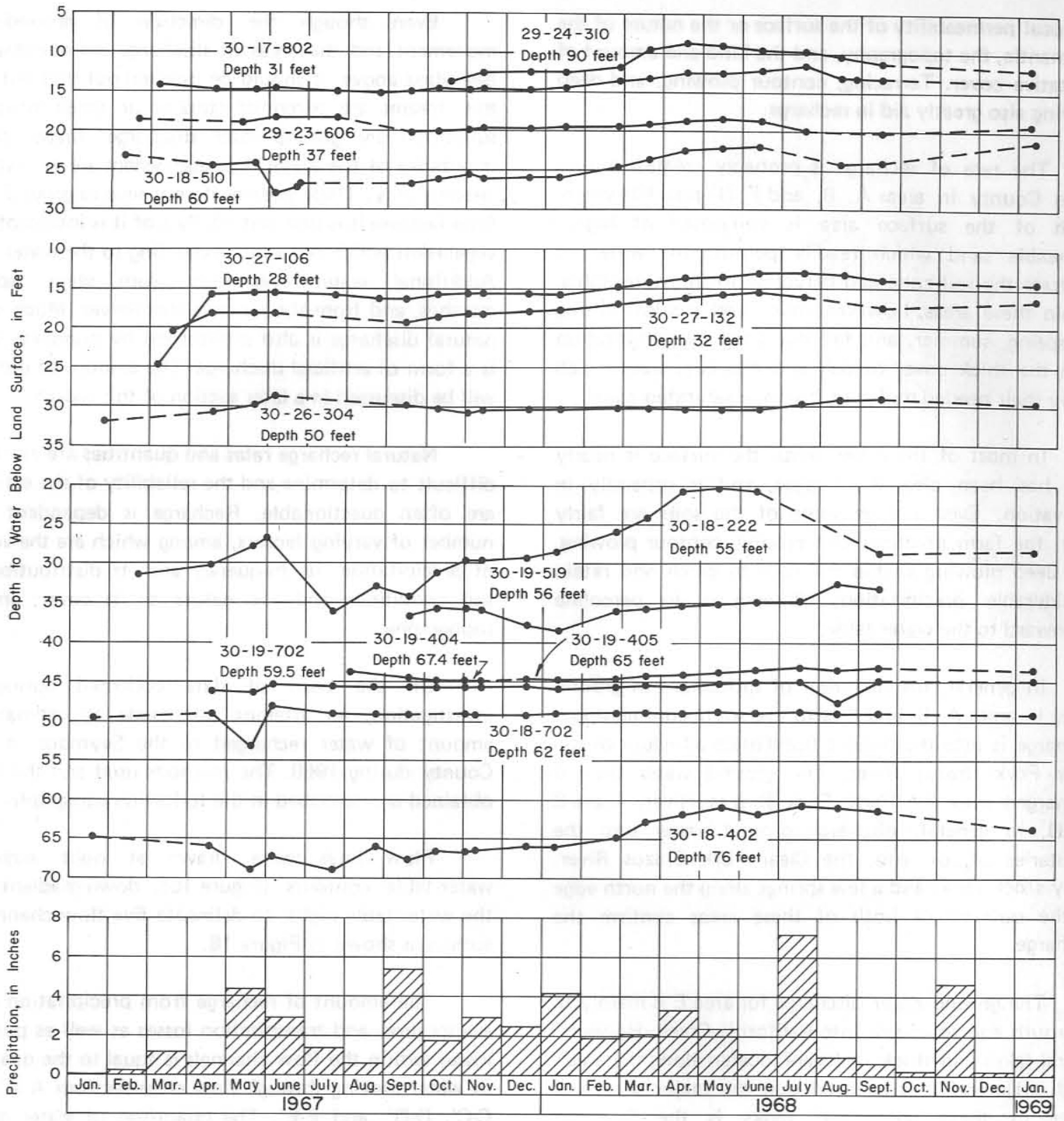

Figure 17.—Water Levels in Observation Wells in the Seymour Formation and Monthly Precipitation at Abilene (Precipitation Data From U.S. Weather Service)

storage has increased. The historical water-level data show an average net rise of 0.35 foot per year from the summer of 1953 to the winter of 1968-69. Using this information, the known areal extent of area A (Figure 10), and the specific yield of 14 percent (determined by pumping test), it is estimated that the amount of ground water in storage in area A increased by about 65,000 acre-feet from the summer of 1953 to the winter of 1968-69. A later section of this report will show that approximately 213,000 acre-feet of water was available from storage in area A during the winter of 1968-69. Data are not adequate for determining changes in storage in other areas of Seymour development.

Recharge and Discharge

The source of all water in storage in the Seymour Formation, as well as the source of recharge to it, is direct precipitation on its outcrop area. Recharge varies, regionally, with the volume and frequency of precipitation. Other determining factors of recharge are the local permeability of the surface or the nature of the soil mantle, the topography, and the kind and amount of vegetative cover. Terracing, contour plowing, and deep plowing also greatly aid in recharge.

The rate of recharge is probably greatest within Jones County in areas A, B, and F (Figure 10) where much of the surface area is composed of highly permeable sand which readily permits the water to infiltrate the soil zone and percolate to the water table. Within these areas, however, much water is lost during the spring, summer, and fall due to evapotranspiration from the thick cover of oak and mesquite trees which derive their needed moisture from the saturated zone.

In most of the other areas, the surface is nearly flat, has been cleared of trees, and is generally in cultivation. Even though some of the soils are fairly tight, the farm practices of terracing, contour plowing, and deep plowing enable the soils to catch and retain considerable precipitation, allowing it to percolate downward to the water table.

In general, the direction of movement of ground water in areas A, B, and F is to the south-southeast and discharge is into the Recent flood-plain alluvium of the Clear Fork Brazos River. The ground water then is discharged into the Clear Fork Brazos River. Areas C and D, in general, discharge ground water into the tributaries of, or into, the Clear Fork Brazos River. Many stock tanks and a few springs along the north edge of the outcrop of both of these areas confirm the discharge.

The ground-water discharge for area E is mainly to the south and southeast into California Creek. However, several lakes and stock tanks are located along the area's north edge and it is believed that the major source of water in these lakes and tanks is the Seymour Formation.

Discharge of ground water from areas G through O is into tributaries of, or directly into, California Creek.

Other minor scattered patches of Seymour which do not contain reliable supplies of ground water probably lose ground water through seepage to the numerous tributaries which have cut through the formation.

Some ground water is believed to be discharged into the Bullwagon Dolomite by interformational leakage where the Bullwagon subcrops beneath the Seymour in areas A, C, D, E, H, and L.

Even though the direction of ground-water movement and the areas of discharge are essentially as described above, it should be pointed out that not all of the streams are perennial streams or those which are supported by ground-water discharge. Many of the tributaries of the major drainage system are wet-weather streams only. These streams do not receive ground-water flow because it is intercepted. Part of it is intercepted by vegetation which has roots extending to the water table. Additional water evaporates from seeps, springs, marshes, and from the streams themselves. Much of the natural discharge is also intercepted by pumpage, which is a form of artificial discharge. The amount of pumpage will be discussed in a later section of this report.

Natural recharge rates and quantities are extremely difficult to determine and the reliability of the estimates are often questionable. Recharge is dependent on a number of varying factors, among which are the volume of precipitation, its frequency and its distribution; the soil conditions and the nature of its cover; and the topography.

On the basis of data collected during this investigation, an attempt was made to estimate the amount of water recharged to the Seymour in Jones County during 1968. The methods used and the results obtained are described in the following paragraphs.

Flow lines were drawn at right angles to water-table contours (Figure 15), down-gradient from the water-table highs, to delineate five flow channels or sectors as shown in Figure 18.

The amount of recharge from precipitation minus evaporation and transpiration losses as well as pumpage losses within the flow channels is equal to the quantities of water moving through flow cross-sections A-A', B-B', C-C', D-D', and E-E'. The quantities of water moving through each cross-section were determined by streamflow measurements at selected points along the Clear Fork Brazos River.

The flow nets were constructed in areas where the two flow lines limiting the area under analysis would terminate at stream-measuring points (Figure 18). Thus the increase in streamflow between the two selected measuring points would be a measure of the volume of water being discharged across each cross-section.

Measurements of low flow were made along the Clear Fork Brazos River during the period January 13 through 17, 1969. At this time, the vegetation was dormant and the temperature was low. This time was selected so that the losses due to evaporation and transpiration would be very low and could be ignored. The analysis was further simplified by the fact that water-level measurements made during the winters of 1967-68 and 1968-69 indicated that there was very slight or no significant net change in the volume of water in storage in the Seymour within area A (Figures 14, 15, and 16). This meant that the recharge during the year was practically equal to discharge and, therefore, adjustment was not needed for change in storage.

Monthly water-level measurements made during 1968 reflected slight water-level rises during the winter and spring months (January-May), and some wells also showed a slight decline during the summer months followed by recovery during the fall months (Figure 17). Within the areas under analysis, however, the water-level fluctuations were slight. It was therefore assumed for computational purposes that water levels, water-level gradients, and thus total discharges in the areas under study were constant.

Areas drained by flow channels 1, 2, 3, 4, and 5 (Figure 18) are 6,560.0, 3,168.0, 2,828.8, 3,148.8, and 979.2 acres, respectively. Flow through cross section A-A', B-B', C-C', D-D', and E-E' was computed to be 340.3, 354.8, 367.8, 144.8, and 181.0 acre-feet per year, respectively. In computing flow through cross section C-C' from flow channel 3. (Figure 18), an allowance was made for a corresponding drainage contribution to streamflow from a major Seymour outcrop on the south side of the river; for all other sections any drainage from the south was considered negligible.

The recharge rate for each of the areas delineated by flow channels 1 through 5 was estimated by summing the flow through the cross section and any pumpage by wells within the area to obtain total discharge, and dividing that discharge by the surface area of the flow channel.

Recharge rates thus computed for areas 1 through 5 are respectively 0.704, 2.232, 1.692, 2.052, and 2.232 inches per year. The average of the five figures is 1.78 inches per year. The rates of recharge as determined above vary widely; however, this is to be expected as geologic conditions also vary widely from area to area. The average recharge figure given above is 6.23 percent of the 28.61 inches of precipitation measured at Abilene in 1968.

If the recharge rate of 1.78 inches per year can be considered representative of all of the Seymour in Jones County, the following volumes of water were recharged to each of the major Seymour areas in the county during 1968:

AREA (Figure 10)	ESTIMATED RECHARGE IN 1968 (acre-feet)
A	12,000
B	2,300
C	3,000
D	3,700
E	8,200
F	2,700
TOTAL	31,900

It is not felt that the above rates of recharge in 1968 are typical as the 1968 rainfall was higher than the mean annual rainfall. Based on the mean annual rainfall of 24.25 inches at Abilene, the average annual recharge to the major Seymour areas in Jones County is approximately 27,000 acre-feet.

In summary, the amount of water available on a long-term basis is limited by recharge, and about 27,000 acre-feet of Seymour ground water is available annually if all of the natural discharge is captured by pumping wells. Theoretically, all of the natural discharge can be intercepted by pumping; however, this would reduce the flow of the streams as has been the case in some parts of the State. An area by area breakdown of the estimated recharge based on the mean annual rainfall is as follows:

AREA (Figure 10)	ESTIMATED AVERAGE ANNUAL RECHARGE (acre-feet)
A	10,200
B	2,000
C	2,500
D	3,100
E	6,900
F	2,300
TOTAL	27,000

Chemical Quality

Located and inventoried during this investigation were 624 wells and 19 springs which produce, or have produced, water of usable quality from porous sand, gravel, and conglomerate of the Seymour Formation (Table 6 and Figure 35). These wells are mainly in areas A, B, C, D, E, and F with scattered wells being located in areas G through O (Figure 10). Most of the wells were in use at the time of the inventory (Table 6), supplying water for domestic, livestock, irrigation, industrial, and municipal purposes.

During this study 413 water samples were collected for chemical analysis from wells completed in the Seymour Formation. Five of these wells were also deriving some of their water from other formations. A tabulation of these analyses is shown in Table 8. The range in dissolved-solids content of water samples from the Seymour wells is tabulated below:

RANGE IN DISSOLVED SOLIDS (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
500 or less	29	7.0
501 to 1,000	135	32.7
1,001 to 1,500	92	22.3
1,501 to 2,000	58	14.0
2,001 to 3,000	47	11.4
over 3,000	52	12.6

Concentration ranges of the principal chemical constituents are as follows:

Calcium	8 to 2,600 mg/l
Magnesium	3 to 1,220 mg/l
Sodium plus Potassium	1 to 5,500 mg/l
Bicarbonate	1 to 2,200 mg/l
Sulfate	<4 to 2,610 mg/l
Chloride	2 to 12,400 mg/l
Fluoride	<0.1 to 9.8 mg/l
Nitrate	<0.4 to 1,490 mg/l

It is apparent from these ranges that the quality of Seymour ground water in Jones County is highly variable. However, the waters are usually of a much better quality than waters in the younger, Recent alluvium (Figure 19) or in the older, Permian rocks. More complete discussion of some of the major chemical constituents follows.

Only 7 percent of the collected Seymour water samples were of a quality which would be acceptable for use on public conveyances. Most Jones County residents have been drinking waters containing a higher concentration of dissolved solids than the recommended 500 mg/l without any apparent ill effects. However, it is generally recommended that waters used for drinking contain less than 2,000 mg/l. Seventy-six percent of the samples collected had a dissolved-solids content of less than 2,000 mg/l. With the exception of wells 29-24-909, 30-18-316, 30-18-803, and 30-26-504, all of the sampled Seymour waters were suitable for livestock consumption and contained less than 10,000 mg/l dissolved solids which is the recommended upper limit for livestock waters (Figure 35 and Table 8).

The sulfate content of Seymour waters ranged from less than 4 to 2,610 mg/l. Approximately 28 percent of the collected water samples exceeded the 250 mg/l sulfate content recommended as the maximum by the U.S. Public Health Service (1962, p. 7). This is the explanation for the "gyppy" taste since concentrations of sulfate in excess of the recommended amount cause the water to have a disagreeable taste. When the sulfate concentrations exceed 750 mg/l the water may have a laxative effect (U.S. Public Health Service, 1962, p. 33-34). However, one evidently becomes acclimated to the use of these waters in a short period of time. Thirty-nine samples (10 percent) contained sulfate concentrations in excess of 750 mg/l. There appears to be a correlation between sulfate content in the Seymour ground waters and the geology. Greater concentrations of sulfate generally occur at the edge of the Seymour outcrop and in the structural lows at the base of the Seymour Formation (Figure 12). Less gypsiferous water usually is located over the known ground-water highs (Figures 14 and 15). Waters in areas of Seymour development other than area A of Figure 10 usually contain higher sulfate content. Much of the sulfate may have been derived from the Permian rocks with which the Seymour Formation is in contact.

Chloride is present in most natural waters, and it is present in varying quantities in ground water collected from the Seymour Formation. The concentration of chloride ranged from 2 to 12,400 mg/l in samples collected from the Seymour during this investigation. The following tabulation gives a more complete breakdown of the chloride ranges of the Seymour Formation (the tabulation does not include wells which are producing ground water from more than one formation):

RANGE IN CHLORIDE CONTENT (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
0– 250	180	44.1
251– 500	97	23.8
501– 550	14	3.4
551–1,000	65	15.9
1,001–2,000	31	7.6
Over 2,000	21	5.2

It is evident from the above table that the waters in 55.9 percent of the wells sampled contained more than the recommended upper limits for chloride of 250 mg/l as recommended by the U.S. Public Health Service (1962, p. 7). These waters would probably taste of chloride and would not be desirable for human consumption.

The amount of chloride an aquifer contains naturally, on a regional basis, is difficult to determine. For that reason, it is difficult to determine when ground waters have been altered or contaminated from oil-field brines which are very high in chloride. However, of a total of 408 water samples collected from wells which yield water exclusively form the Seymour Formation, 356 samples are felt to have been unaltered or altered only slightly by chloride from oil-field brines and/or sewage contamination. The average for these 356 samples was 340 mg/l of chloride, which suggests that regionally the native quality ground water in the Seymour Formation has a high natural chloride content.

Even though the Seymour possibly has a high regional chloride content, this does not account for all of the high chloride concentrations found in the ground water. Hem (1959, p. 118) stated that in areas where nitrate is derived from organic pollution, the high nitrate may be accompanied by high chloride concentrations. The Seymour, in fact, does have this condition. Therefore, many wells listed in Table 8 having high nitrate content possibly have high chloride content due to this association.

Abnormally high chloride content in ground waters is usually interpreted as being derived from oil-field brines which are characteristically high in chloride. Such brines will also usually have high sodium concentrations. Admittedly ion exchange may occur in solution; however, only those water samples with both high sodium and an associated high chloride content will be considered in this report to have been probably altered by brines (Hem, 1959, p. 221). A comparison of those waters with high chloride and their location with respect to existing oil fields indicates there is, locally, some relationship. However, several wells sampled were located in oil fields with no indication of their ground water having been altered. Other wells located outside of existing fields are possibly altered by leakage from nearby oil tests.

Waterlogged conditions are thought to exist southeast of the city of Stamford in area E of Figure 10. Much of the high chloride concentration within this area could be a result of prolonged evaporation of the ground waters. In waters affected by evaporation, other chemical constituents as well as chloride should show corresponding increases in concentration.

There is no obvious relationship between the areas of high chloride content in the Seymour waters and the nature of underlying rocks with which they may have been in contact.

Alteration of native-quality water has occurred in some areas of the Seymour Formation, and historical water-quality data, where available, are included in Table 8 for comparison with the more recent data to indicate the locations and amount of alteration which has occurred. A total of 21 wells sampled in earlier investigations in 1944, 1953, and 1963 were resampled during this investigation. Of these wells, seven exhibited slight improvement in overall water quality. Four of the wells showed a significant improvement over the earlier samples. Seven showed indications of slight deterioration of overall quality, and only three reflected significant worsening of quality. The waters of several wells are thought to have been altered due to the presence of oil-field brines as indicated by abnormally high chloride and also high sodium content. The dissolved-solids and chloride content of waters from seven wells and five seeps believed to be possibly contaminated are as follows:

WELL	DISSOLVED SOLIDS (mg/l)	CHLORIDE (mg/l)
29-24-909 (seep)	11,300	6,100
30-10-719 (seep)	3,000	1,030
30-18-310 (seep)	3,140	2,240
30-18-316 (seep)	23,200	12,400
30-18-424	18,900	11,330
30-18-803	12,600	7,900
30-19-103	10,700	6,200
30-19-401	2,380	1,000
Do.	994 (July 6, 1953)	215
30-19-521	3,550	1,880
30-19-803	5,330	2,660
30-19-813	8,730	3,590
30-26-504 (seep)	16,400	9,100

Seeps 29-24-909, 30-10-719, 30-18-310, and 30-18-316 are located at the approximate contact of the Seymour Formation. An abandoned oil field is shown on the well-ownership map to be located approximately 1,000 feet up-gradient from seep 29-24-909. It is possible that one of the abandoned wells in this field is a contamination source. In the case of seep 30-10-719, the ownership map indicates that an abandoned oil test is situated approximately 700 feet northwest and up-gradient from the subject seep. A possible source of the apparent alteration of seep 30-18-310, as reflected on the ownership map, is an abandoned oil test located approximately 200 feet from and along strike with the seep. Seep 30-18-316 is located approximately 700 feet down-gradient from an old oil test, as reflected by available ownership data. Wells 30-18-424, 803, 30-19-103, 401, and 521 are all located within the confines of producing oil fields. Alteration of ground waters in these wells is possibly from nearby up-gradient producing oil wells which may be leaking or from those which have inadequate surface casing. Wells 30-19-803 and 813 are both located down-gradient from old oil tests, as shown on ownership data. These wells are located approximately 350 feet southeast of an old test and approximately 650 feet northeast of an old test, respectively. Seep 30-26-504 is located at the approximate contact of the Seymour Formation. Since water from this seep contains high concentrations of several chemical constituents, including an abnormally high nitrate value of 500 mg/l, it is felt that this area may be waterlogged. The seep is also down-gradient from several old, abandoned oil tests. Possibly the water-quality alteration here results from more than one cause.

Other well waters listed in Table 8 have abnormally high chloride associated with high calcium and magnesium content, possibly the result of ion exchange. The cause of alteration in these wells is not known.

Fluoride occurs in varying concentrations in ground waters collected from the Seymour Formation. Ranges in this constituent were from less than 0.1 to 9.8 mg/l. The average fluoride content in 408 samples collected from the Seymour was 1.4 mg/l. Based on climatic conditions, a lower limit of 0.7 mg/l, optimum of 0.8 mg/l, and an upper limit of 1.0 mg/l of fluoride has been recommended for drinking water in Jones County (U.S. Public Health Service, 1962, p. 8). A summary of the fluoride analyses is as follows:

RANGE IN FLUORIDE CONTENT (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
0.0–0.7	159	39.0
0.8–1.0	58	14.2
1.1–1.5	46	11.3
> 1.5	145	35.5

Only 53.2 percent of the water samples analyzed fell below the recommended upper limit of 1.0 mg/l. Those waters which contain greater than 1.0 mg/l fluoride may cause mottling of the teeth (Table 8).

Of the total of 413 water samples collected from wells producing partly or entirely from the Seymour Formation, 136 samples or 32.9 percent contained nitrate in excess of the recommended limit of 45 mg/l (Table 8). Many of the samples contained an unusually high amount of nitrate and one sample contained 1,490 mg/l. A breakdown of the ranges is shown in the following table (only wells producing wholly from the Seymour are included):

RANGE IN NITRATE CONTENT (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
0– 45	280	68.6
45–100	58	14.2
101–200	38	9.3
201–300	15	3.7
301–400	10	2.5
401–500	2	0.5
Over 500	5	1.2

Many of the wells containing excessive nitrate are possibly contaminated due to the effects of sewerage from nearby septic tanks or aninal wastes from barnyards. This would account not only for high concentrations of nitrate but also for part of the increase in chloride since the two are associated (Hem, 1959, p. 118).

Abnormally high nitrate concentrations often occur in ground waters over wide geographic areas, and these are difficult to explain. It has been suggested that the leaching of soil and humus in old mesquite groves, which have been converted to farm lands, is the cause of high nitrate in certain areas of California (Huberty, Pillsbury, and Skoloff, 1945, p. 14-15). Another explanation for high nitrate is that it may be due to the leaching of nitrate from grasslands after they were put into cultivation. Nitrogen, bound in organic form, is believed to be highest in soils under grass vegetation. Organic nitrogen in such soils decreases rapidly due to mineralization when these lands are placed in cultivation. One or both of these explanations may be the cause of the high nitrate content of waters in the Seymour Formation, since much of the area was formerly in grassland or covered by mesquite groves.

Some of the high nitrate in the ground waters may be due to the extensive use of nitrogen fertilizers in the areas of cultivation which are underlain by Seymour. Research to date has not been conclusive enough to fully evaluate the effects of fertilizers on ground water. The Texas A&M Water Resources Institute is conducting research on this subject.

Any water containing nitrate in excess of 45 mg/l is not recommended for human consumption (Table 8). Adults can tolerate much more nitrate than babies, but prolonged illness or death can occur when the nitrate concentration is large enough and consumed over a long enough period of time. Burden (1961) concluded that the average lethal dose for a 140-pound adult is between 80 and 300 milligrams of nitrate per kilogram (2.205 pounds) of body weight. Or in other words, death is likely when 80 to 300 mg/l of the body weight is nitrate. Burden further concluded that the maximum recommended limits for nitrate in livestock water should not exceed 220 mg/l. Consulting the ranges in nitrate tabulated above, it is apparent that approximately 31.4 percent of the tested Seymour waters are not considered safe for human consumption, containing more than 45 mg/l nitrate (U.S. Public Health Service, 1962, p. 47-50). Slightly less than 8 percent of the waters sampled are also not recommended for livestock use (Table 8).

Within Jones County, nearly all wells in the Seymour produce very hard water, no areal variation of hardness was noted. Only one sample analyzed well (30-10-303) was soft water. Waters from four wells contained from 61 to 120 mg/l total hardness and are classified as moderately hard. Water from four other wells would be termed hard water. The balance, or 97.8 percent, of the collected samples were of very hard waters.

The boron content of 32 samples from selected wells in the Seymour Formation (Table 3) ranged from 0.08 to 2.8 mg/l. A tabulation of the ranges for the Seymour Formation is as follows:

RANGE IN BORON CONTENT (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
0.0 to 1	28	87.50
1.1 to 2	2	6.25
2.1 to 3	2	6.25

Boron is necessary for crop growth; however, excessive amounts will render waters unsuitable for irrigation. Boron concentration as high as 1.0 mg/l is permissible for irrigation of sensitive crops such as deciduous fruit and nut trees; as high as 2.0 mg/l on semi-tolerant crops such as most small grains, cotton, potatoes, and other vegetables; and as high as 3.0 mg/l for tolerant crops such as alfalfa and most root vegetables. The main crops grown in Jones County are cotton, corn, grain sorghums, oats, wheat, and peanuts. Almost all of these crops can tolerate a boron content up to 2 mg/l. Therefore, irrigation waters from the Seymour generally can be applied without concern for their toxicity due to boron, to most of the crops grown in the county.

Figure 20 classifies the quality of representative Seymour Formation irrigation waters, using the system developed by the U.S. Salinity Laboratory Staff (1954, p. 69-82), based on the salinity hazard as measured by the specific conductance and the sodium (alkali) hazard as measured by the SAR (sodium-adsorption ratio). The specific conductance and SAR for all Seymour waters sampled are shown in Table 8. Figure 20 reflects that all but 13 samples of Seymour ground water plotted fall within salinity-hazard classes C_2, C_3, and C_4, and sodium-hazard classes S_1, S_2, and S_3. An additional 44 samples analyzed had a conductivity greater than

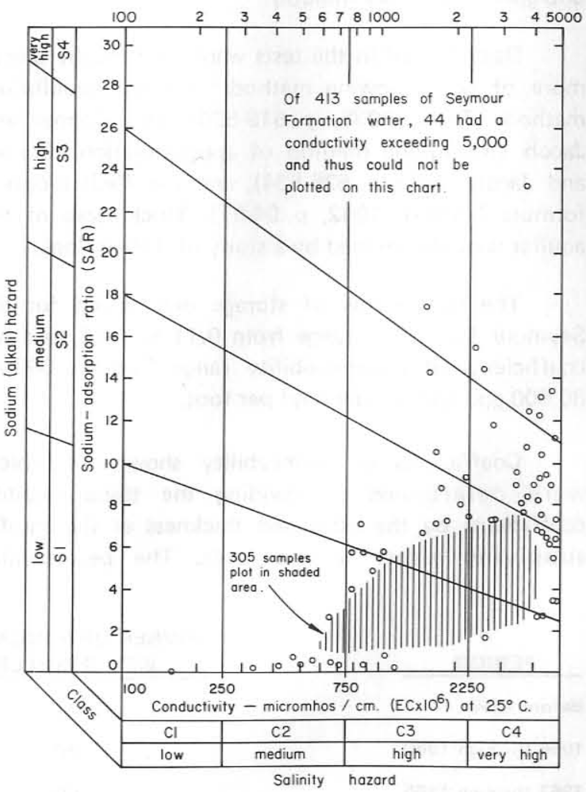

Figure 20.—Classification of Seymour Formation Waters for Irrigation

5,000 and consequently could not be plotted on the classification chart. Detailed discussion of limitations for using irrigation waters of these classes is given in the earlier "Quality Criteria" section of this report.

Under most conditions, irrigation waters having a sodium percentage of less than 60 and a low bicarbonate content are probably satisfactory (Table 8). A total of 369 (89.3 percent) of 413 Seymour samples collected and analyzed had a sodium percentage of 60 or less. The sodium hazard becomes progressively greater as the sodium percentage increases above 60. Forty-four Seymour samples contained a sodium percentage greater than 60.

Hydraulic Properties of the Aquifer

Aquifer tests were conducted on three irrigation wells in the Seymour Formation to determine the aquifer's coefficients of storage, permeability, and transmissibility. For definitions of these physical properties of an aquifer, consult the "General Principles of Ground-Water Occurrence" section of this report.

Results of the tests are shown on Table 4. The measured yields of these wells ranged from 183 to 308 gpm (gallons per minute).

Data derived in the tests were analyzed by one or more of the following methods: the non-equilibrium method (Theis, 1935, p. 519-524), the Cooper and Jacob straight-line method of approximation (Cooper and Jacob, 1946, p. 526-534), and the Theis recovery formula (Wenzel, 1942, p. 94-97). Thicknesses of the aquifer were determined by a study of drillers' logs.

The coefficients of storage determined for the Seymour Formation range from 0.11 to 0.18, and the coefficients of transmissibility range from 30,000 to 80,000 gpd (gallons per day) per foot.

Coefficients of permeability shown in Table 4 were determined by dividing the transmissibility coefficients by the estimated thickness of the aquifer supplying water to the wells. The permeability coefficients range from 1,220 to 4,690 gpd per square foot.

Well Production and Performance

Specific capacities of the three irrigation wells tested are listed in Table 4 and ranged from 21.4 to 24.8 gpm per foot of drawdown.

An additional 29 power-yield tests were run on irrigation wells pumping from the Seymour, and the measured yields on these ranged from 18.4 to 308 gpm. A tabulation of the yields of these wells is shown on Table 5.

Of the total of 248 irrigation wells inventoried that produce from the Seymour Formation, the range in yield was from 10 gpm to greater than 1,800 gpm (Table 6). The saturated thicknesses in these wells ranged from as low as 4 feet to greater than 30 feet in some cases. Wells near the center of area A (Figure 10) usually have saturated thicknesses greater than 10 feet. The wells with larger yield have near, or in excess of, 20 feet of saturated thickness. Wells near the edge of the Seymour Formation outcrop usually have lower saturated thicknesses.

History of Development

Prior to 1954, the use of ground water for irrigation within Jones County was on a very small scale. Winslow, Doyel, and Gaum (1954, p. 9) reported that probably not more than 20 irrigation wells were in use prior to that date. All of the wells reportedly had yields of 100 gpm or less. Subsequent investigation has revealed that a total of 31 irrigation wells had been drilled by 1954.

During this investigation 291 irrigation wells were inventoried. Of these, 148 wells were completed in the Seymour Formation. As of January 1, 1969, there were 115 active irrigation wells in use and 33 wells not being used. A breakdown of the development of irrigation wells in the Seymour Formation is as follows:

PERIOD	NUMBER OF IRRIGATION WELLS DRILLED	PERCENT OF TOTAL	CUMULATIVE PERCENT
Before 1956	31	19.8	19.8
1956 through 1960	20	12.7	32.5
1961 through 1965	66	42.0	74.5
1966 through 1968	40	25.5	100.0

Table 4.—Results of Pumping Tests of Selected Irrigation Wells in the Seymour Formation

WELL	SATURATED THICKNESS (FEET)	DATE TEST BEGAN	SPECIFIC CAPACITY (GPM/FT)	COEFFICIENT OF STORAGE	COEFFICIENT OF PERMEABILITY (GPD/FT²)	COEFFICIENT OF TRANSMISSIBILITY (GPD/FT)	YIELD (GPM)
29-23-606	16.9	May 10, 1967	21.4	0.18	4,690	80,000	308
30-17-802	18.7	Aug. 29, 1968	24.8	—	2,890	54,000	236
30-18-206	24.5	July 29, 1968	21.6	.11	1,220	30,000	183

The pre-1954 irrigation wells in the Seymour Formation concentrated in two main areas (Figure 35), one approximately 3 miles southeast of Hawley and the other 2 miles south of Funston. Both of these locations are within area A of Figure 10. These irrigation areas have since been enlarged and have proven to be two of the most reliable irrigation areas of Jones County.

Present-day development of Seymour irrigation wells is still located mainly in area A; however, areas B, C, D, E, and F also have scattered, minor concentrations of irrigation (Figures 35 and 10).

The development and use of ground waters from the Seymour Formation for industrial and municipal purposes has been very limited. During this study 43 wells in these catagories were inventoried which pumped waters from the Seymour (Table 6 and Figure 35). Ten of the wells also derived part of their waters from other formations. Forty-one wells were classified as industrial. All of these wells, except one, were used as water-supply sources for oil test drilling (15 percent), in waterflood operations (60 percent), gas plant operation (15 percent), or other oil-related activities (10 percent). Well 30-10-804 is used in the operation of a cotton gin. The following tabulation reflects the history of development of industrial wells:

PERIOD	NUMBER OF INDUSTRIAL WELLS DRILLED	PERCENT OF TOTAL
Before 1956	6	15.0
1956 through 1960	24	60.0
1961 through 1965	6	15.0
1966 through 1968	4	10.0

Only two municipal wells producing ground water from the Seymour were inventoried during this study. Well 30-18-423 provided water for the Pleasant Grove Church and well 30-25-506 provided water for 11 families within the confines of an oil field. These wells were drilled in 1967 and 1942, respectively.

Well Construction

Of the 624 wells inventoried as producing from the Seymour Formation, most were either hand-dug or drilled. They range in depth from 8 to 200 feet. The 200-foot well was originally drilled as a geophysical test hole and later was completed as a fresh-water well producing from the Seymour Formation at a lesser depth. The estimated maximum depth to the base of the Seymour is 115 feet.

Most of the dug wells are used for domestic purposes or for watering livestock. They are generally about 3 to 4 feet in diameter and lined with native stone, brick, or concrete rings. The more recently drilled domestic and livestock wells have small diameter, galvanized sheet-metal or steel casing, 5 to 8 inches, and are cased to the bottom of the well. The galvanized sheet-metal casings are perforated opposite the water-bearing sands. The steel casings were almost always torch-slotted.

Industrial and irrigation wells are larger in diameter, 8 to 30 inches, and are usually cased to the bottom of the hole. In most cases, the hole was reamed to 36 inches, the casing was torch-slotted opposite the water-producing sands and gravels, the casing was set on the bottom, and the hole outside the casing was then filled with small pea-sized gravel. In some instances, where centrifugal pumps were used, the upper 12 to 15 feet of the hole would be cased with oil drums or 36-inch concrete rings. This was done to create a cellar in which to place the pump and to reduce the lift height. The lower part of the hole was completed as described above.

Most of the wells were developed by pumping.

Utilization and Pumpage

Domestic and Livestock

A total of 440 livestock and domestic wells and 19 springs producing ground water from the Seymour Formation were inventoried during this study (Table 6 and Figure 35).

Pumping of ground water from the Seymour Formation for domestic and livestock uses is relatively small. Since many farms have stock tanks for livestock water supplies, it is difficult to arrive at a pumpage figure for this category. The estimated total pumpage from the Seymour for domestic and livestock wells for the period from 1954 through 1968 is about 10,000 acre-feet. The 1968 pumpage for these uses is estimated at 760 acre-feet.

Irrigation

During this investigation, 148 irrigation wells were inventoried which were producing or had produced

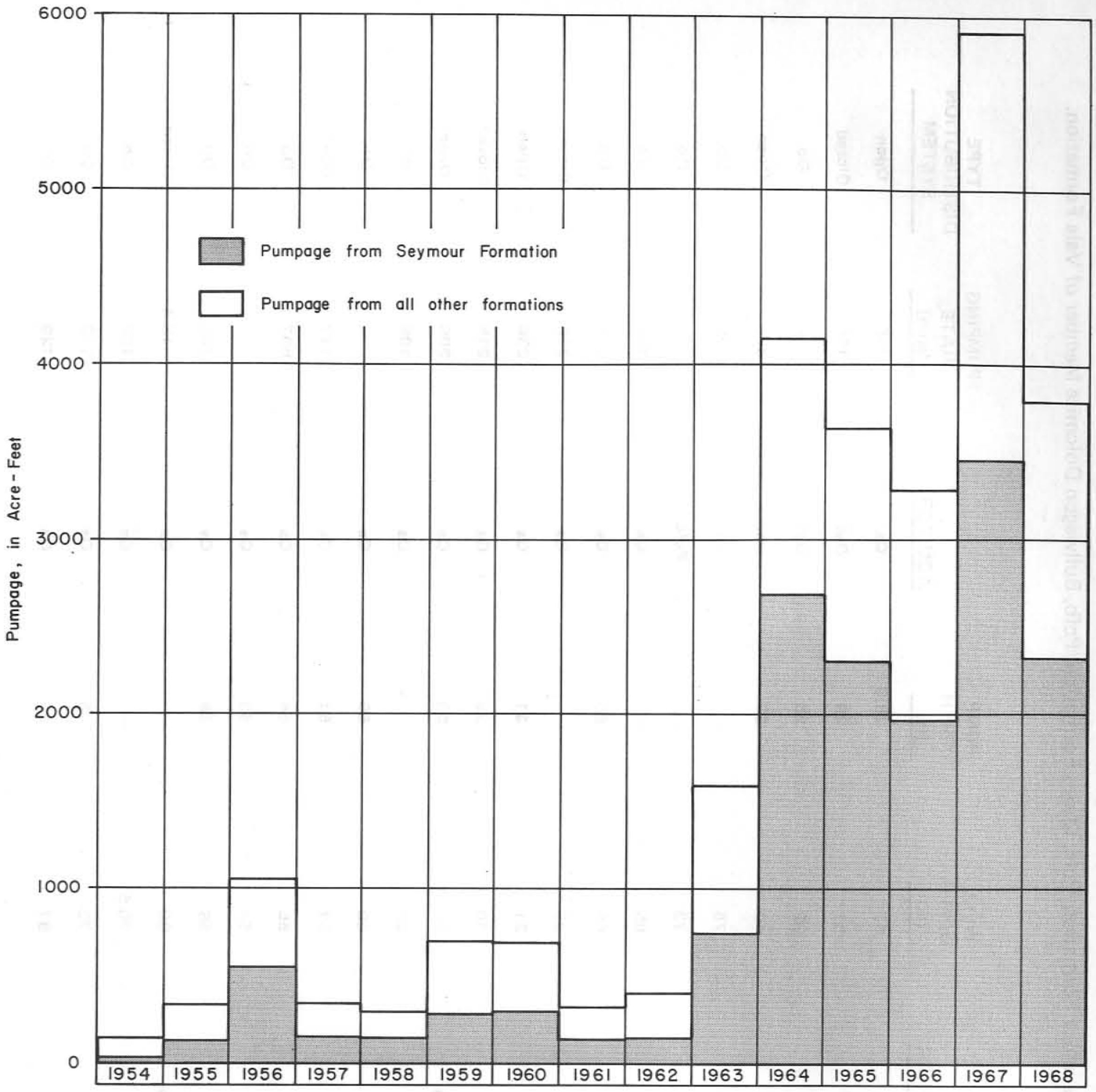

Figure 21.—Pumpage of Ground Water for Irrigation, 1954 Through 1968

water from the Seymour Formation. The yields ranged from 10 to greater than 1,800 gpm (well 30-18-518), with most of the irrigation yields ranging from 100 to 300 gpm (Table 5).

Water is applied for irrigation by sprinkler systems or in furrows. Very limited pre-planting irrigation is applied during the winter and early spring months.

Irrigation pumpage figures from this formation are estimated at 15,370 acre-feet for the period from 1954 through 1968 (Figure 21). The 1968 irrigation pumpage was estimated at 2,320 acre-feet. Approximately 80 percent of this total, or 1,870 acre-feet, was pumped in area A of Figure 10. The next largest irrigation pumpage area is area D which contains eight irrigation wells (Figure 35). Except for well 30-25-304, none of the wells were in existence prior to 1963. The 1954 through 1968 irrigation pumpage in area D was estimated to be 430 acre-feet. Approximately 5 percent or 115 acre-feet of the 1968 Seymour Formation irrigation was estimated to have been pumped from

Table 5.—Yields of Selected Irrigation Wells

Water-bearing unit: Qal, Recent alluvium; Qs, Seymour Formation; Pcfc, Choza Formation; Pcfb, Bullwagon Dolomite Member of Vale Formation.

WELL	TYPE PUMP	HORSEPOWER	WELL DEPTH (ft)	PUMP DEPTH (ft)	AQUIFER	PUMPING RATE (gpm)	TYPE DISTRIBUTION SYSTEM
29-23-606	Turbine	5	37	28.6	Qs	308	Open
24-501[a]	do	25	31	29	Qal	169	Closed
502[a]	do	3	32	28	Qal	—	Do.
805	do	5	40	37	Qal	324	Open
30-09-108[b]	Submersible	5?	75	—	Pcfc	90	Do.
109[b]	do	5	73	—	Pcfc	—	Do.
17-701	do	3	65	—	Qs	152	Do.
702	do	3	65	65	Qs	217	Do.
801	Centrifugal	20	39	—	Qs	276	Closed
802	do	15	31	31	Qs	236	Open
812	Turbine	10	30	29	Qs	215	Closed
18-202	do	7½	53	53	Qs	306	Open
205	Submersible	5	56	—	Qs	108	Do.
206	—	—	60	60	Qs	—	Do.
207	Turbine	5	51	51	Qs	177	Open
226[c]	do	15	55	54	Qs	657	Do.
228[c]	do	10	54	53	Qs	—	Do.
301	Submersible	5	58	58	Qs	105	Do.
417	do	1½	80	—	Qs	18.4	Closed
425	Turbine	10	50.5	—	Qs	162	Do.
509	Submersible	5	78	75	Qs	113	Do.
514	Turbine	15	87	83	Qs	129	Do.

Table 5.—Yields of Selected Irrigation Wells—Continued

WELL	TYPE PUMP	HORSEPOWER	WELL DEPTH (ft)	PUMP DEPTH (ft)	AQUIFER	PUMPING RATE (gpm)	TYPE DISTRIBUTION SYSTEM
601	do	5	78	78	Qs	124	Do.
19-801[d]	do	5	30	near 30	Qs	141	Do.
816[d]	do	5	29	near 29	Qs	–	Do.
817[d]	do	7½	31	near 31	Qs	–	Do.
25-202	do	15	85	75	Pcfb	231	Do.
303	Submersible	3	32	–	Qs	73.6	Do.
304	Centrifugal	1	15.8	–	Qs	20.9	Open
306	do	1	60	–	Qs	50.0	Do.
26-309	Turbine	7½	40	near 40	Qs	200	Do.
27-103	do	5	33	33	Qs	180	Do.
114	do	3	40	near 40	Qs	73	Closed
142	do	5	32	32	Qs	200	Open
143	do	3	32	32	Qs	137	Do.
146	Submersible	3	38	near 38	Qs	168	Do.

a Wells pumping together.
b Do.
c Do.
d Do.

area D. Irrigation pumpage in other areas is very small and there are no large concentrations of the wells.

Industrial

Industrial pumpage from the Seymour Formation is used for waterflood operations, the drilling of oil and gas wells, the processing of natural gas products, and in a laundry. There are no accurate records of pumpage available for these uses. However, it is estimated that industrial use of ground water in Jones County is approximately 77 acre-feet per year.

A total of 41 industrial wells which produced from the Seymour Formation were inventoried during this study. Only 10 of these wells produced from the Seymour alone.

Municipal or Public Supply

None of the towns in Jones County secure their water supply from the Seymour Formation. Insofar as known, only two wells classified as public supply produce water from the Seymour. Well 30-18-423 supplies a church, and well 30-25-506, producing water from the Seymour and the Bullwagon Dolomite, provides water for several families living within the confines of an oil field. No estimate of the amount of pumpage has been made.

Theoretical Effects of Pumpage

Pumping water from wells completed in an aquifer such as the Seymour Formation can have widespread effects on water levels. Water levels in the immediate vicinity of the wells decline as water is removed from aquifer storage. The amount of decline is greatest at the pumped well and becomes progressively less with distance from the well, thus forming a "cone of depression" in the water table with the apex of the cone being at the pumped well.

Continued pumping removes more water from storage, causing the cone of depression to expand. Expansion of the cone will continue until it intercepts some source of recharge. This recharge may be from a stream, from the percolation of precipitation from the surface, from another aquifer in contact with the pumped aquifer, or any source of recharge equal to the pumping rate.

Factors which determine the extent of the cone of depression are the aquifer's transmissibility and storage coefficients, the pumping rate, and the length of time the well is pumped.

Using hydraulic properties of the Seymour as determined from 3 aquifer tests and the non-equilibrium formula (Theis, 1935), theoretical declines in the water table were calculated at various times and distances from a well which was pumping at a constant rate. Figures 22, 23, and 24 graphically show the theoretical effects of such a pumping well on water levels at various distances from the well after times up to 360 days. Data used in the computations for Figure 22 are based on the aquifer characteristics determined from a 48-hour aquifer test. This test was conducted July 29, 30, and 31, 1968 on well 30-18-206 located on the Charles M. Herndon farm about 2 miles south of the Funston community (Figure 35). Figure 23 is based on characteristics which were determined from an aquifer test conducted on the A. J. Teal farm 1 mile north of Truby. The well tested was 30-17-802 and the test was run August 25 through 30, 1968. Figure 24 was constructed using assumed aquifer coefficients and was prepared to illustrate the theoretical drawdowns in areas where the transmissibilities and pumping rates are likely to be less than in the tested areas.

Figures 22-24 show that the greatest amount of drawdown occurs in the first few days of pumping and that the water levels are affected at relatively large distances from the pumping well. Figure 22 illustrates, under the assumed condition, that water levels are affected up to 1 mile in all directions from the pumping well after 30 days. The drawdown as shown on Figures 22-24 is directly proportional to the rate of pumping; therefore, the effects of different pumping rates can be determined. For example, if the assumed pumping rate is 400 gpm instead of 200 gpm (Figure 23), the drawdown would be twice that indicated. Or, if the assumed pumping rate is only 100 gpm then the drawdown would only be one-half that indicated.

Figure 25 illustrates the theoretical drawdown that would occur at various distances from a pumped well after 1 day of pumping at various rates. Identical aquifer characteristics were used to construct this figure and Figure 22.

The amount of interference that will theoretically occur between two or more pumping wells and the effects of well interference on water levels are shown by the distance-drawdown graphs of Figures 22, 23 and 24. These figures also demonstrate the importance of well spacing.

When several wells produce from the same water-bearing formation such as the Seymour, and they

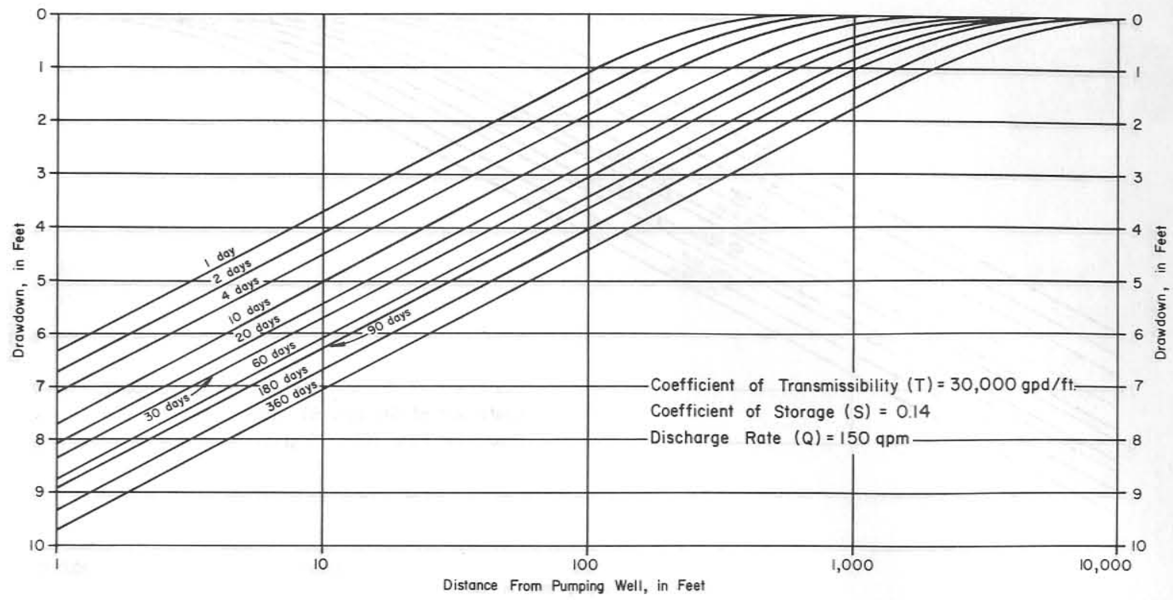

Figure 22.—Relation of Decline in Water Levels to Time and Distance as a Result of Pumping From the Seymour Formation

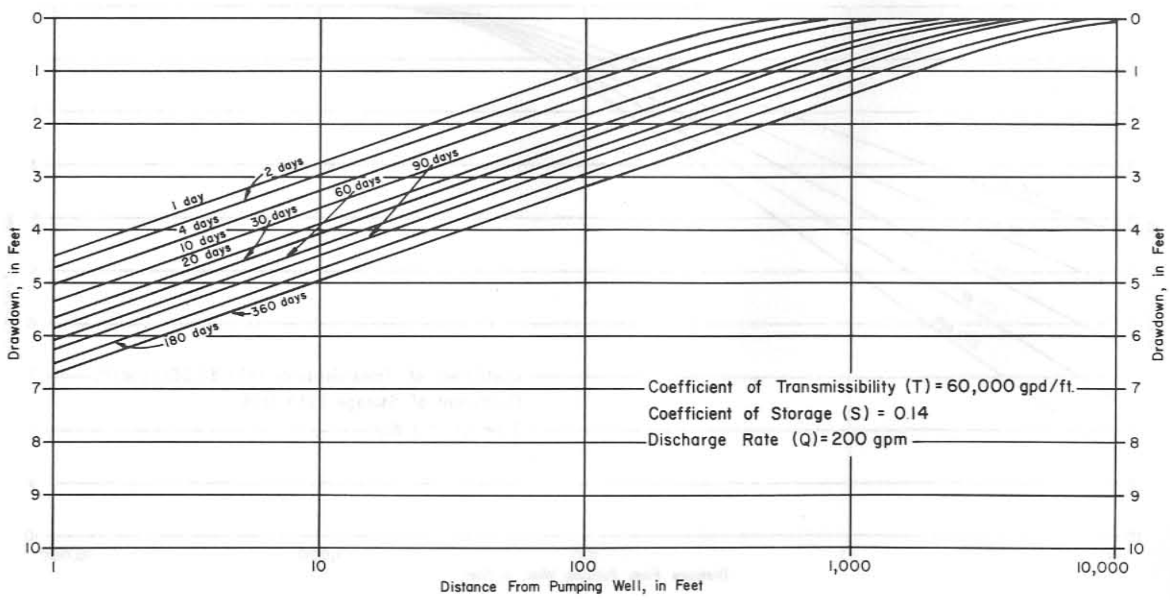

Figure 23.—Relation of Decline in Water Levels to Time and Distance as a Result of Pumping From the Seymour Formation

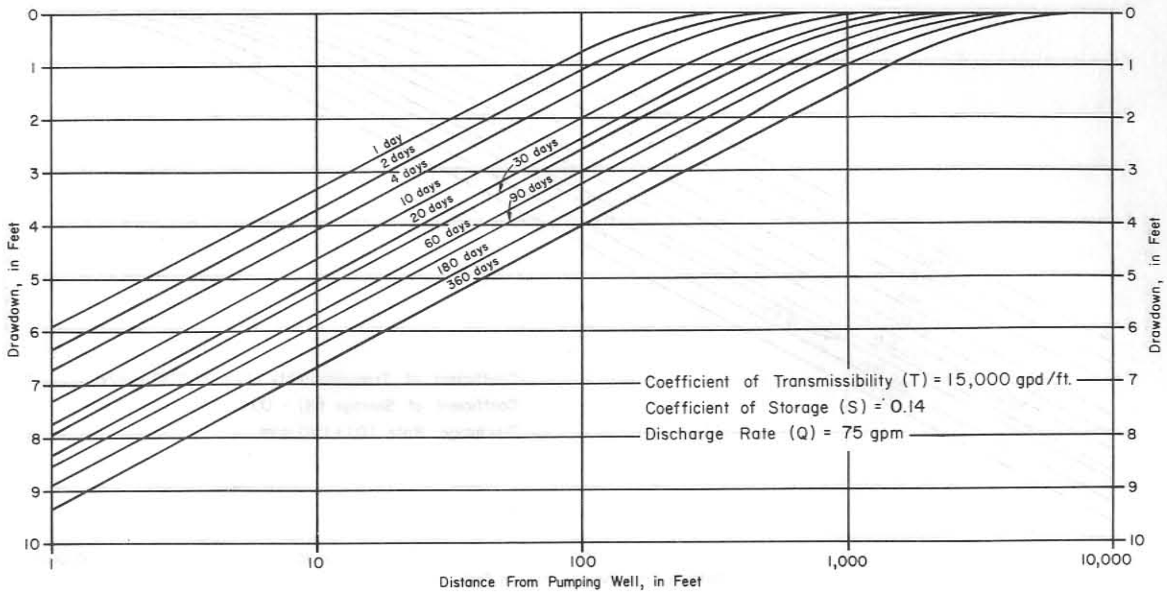

Figure 24.—Relation of Decline in Water Levels to Time and Distance as a Result of Pumping From the Seymour Formation

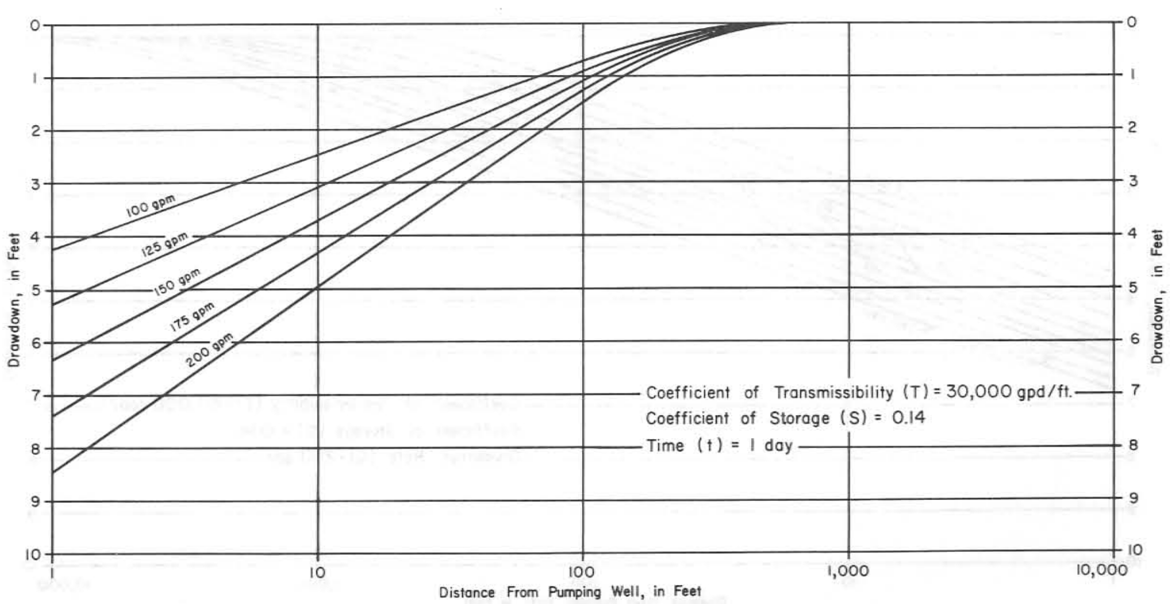

Figure 25.—Relation of Decline in Water Levels to Distance for Various Rates of Pumping From the Seymour Formation

are spaced too closely, their cones of depression overlap and the wells are said to "interfere". When this condition exists, the pumping of one well lowers the water level in nearby wells. The drawdown at any point in the area of influence caused by the discharge of several wells is equal to the sum of the drawdowns caused by each well individually. This is important in that wells spaced too closely will result in lower pumping levels and a decline in the yield of each well as it competes for water. Assume that two wells are spaced 100 feet apart, each pumping 150 gpm, and that they have the same aquifer characteristics as those used to construct the distance–drawdown graph shown on Figure 22. The graphs show that after 4 days the drawdown in each well caused by its own pumping is 7.1 feet. The water level 100 feet away from a pumping well would be 1.9 feet (Figure 22). Thus, the total drawdown in each well would be 7.1 feet caused by its own pumping plus 1.9 feet caused by the pumping of the other well, or 9.0 feet. From this it can be seen that the curves are useful to demonstrate the extent of the cone of depression, the effect of pumping on water levels with time, and also the effects of well spacing.

Basic assumptions were made in the construction of the graphs. It was assumed that all water pumped is withdrawn from storage. It was further assumed that the aquifer has infinite areal extent, is homogeneous, is isotropic, and has a constant thickness.

Never in nature do the assumed conditions of homogenity and infinite aquifer extent occur. The Seymour of Jones County has a limited extent and has definite boundaries. The aquifer is not homogeneous but consists of sands, gravels, and clays of various permeabilities and porosities. The aquifer also varies in saturated thickness. Boundary conditions caused by the physical limits of the aquifer or by changes in its permeability and saturated thickness will result in greater drawdowns than those illustrated by the graphs.

The curves presented on Figures 22, 23, 24, and 25 are not applicable to all parts of the Seymour Formation and should, therefore, not be used to predict the effects of pumping on water levels except where aquifer coefficients of storage and transmissibility are the same as those used in constructing the graphs. The graphs, however, are based on aquifer characteristics determined from actual aquifer tests conducted during this study. It is thought that the transmissibilities used to construct these curves probably encompass the range of actual transmissibilities which will be encountered in most of those areas in which the Seymour is productive.

Ground Water Available for Development

Several hydrologic and economic factors determine the amount of water available for development from the Seymour Formation of Jones County. The major hydrologic factors are the rate of recharge to the aquifer, the ability of the aquifer to transmit water, and the volume of water in storage. The main economic factors are the number and cost of wells required to produce the maximum amount of water.

The amount of water in storage within the Seymour Formation is determined by the areal extent of the water-bearing unit, its saturated thickness, and its porosity.

The Seymour Formation in Jones County occurs as several separate, isolated deposits (Figure 10). The most important and largest of these is area A. This area is currently the most extensively developed, contains the greatest saturated thickness, and probably has the greatest potential for additional development in the county.

A saturated thickness map (Figure 11) was prepared from information shown on the water-table map of the Seymour Formation for the winter of 1968-69 (Figure 15) and the contour map at the base of the Seymour Formation (Figure 12). The total volume of saturated deposits in area A was computed to be about 1,523,600 acre-feet. The saturated thickness is greatest (76 feet or more) in a north-trending channel running through the approximate center of area A.

The data derived from 3 aquifer tests conducted on wells pumping from the Seymour Formation indicated an average specific yield of 14 percent. If the average specific yield of 14 percent is representative, then only about 213,000 acre-feet of water is theoretically available in storage in area A. To dewater area A completely would be impractical because the yields of wells fall off rapidly as the saturated thickness of the aquifer is greatly reduced. It also would require constant year-round pumpage. This is not economically feasible nor is there a need for the water during the fall and winter months.

Areas B, C, D, and E (Figure 10) contain lesser amounts of ground water in storage, however, in areas C and D, available data are not sufficient to assign meaningful storage values. Assuming that 14 percent specific yield is also representative of these areas, then the estimated quantity of water in storage within area B is 28,000 acre-feet, and in area E, 109,000 acre-feet. Unknown but smaller amounts of ground water are also present in other isolated Seymour deposits.

The amount of water that can theoretically be developed annually is limited by the amount of recharge to the aquifer. During years of drought, discharge can exceed recharge with the deficit being pumped from storage. This condition can exist only temporarily, or until the supply in storage is exhausted. Fortunately droughts are eventually interrupted by years in which precipitation is normal or above normal. During periods in which recharge exceeds discharge, ground water previously removed from storage is partly or completely replaced.

Area A, consisting of slightly more than 126 square miles, contains 80,851 acres. If this area received 1.51 inches of recharge annually, based on the mean annual rainfall at Abilene, then 10,200 acre-feet of water would be recharged to area A yearly. Theoretically, this amount would be available for development by wells. It would be impractical to intercept all of this water. To do this would require capture by wells of all natural discharge. Natural discharge, in part, supports vegetation growth and streamflow. It is possible to capture enough of this discharge during the summer months, however, to reduce all of the local streamflow.

The largest use of water is for irrigation which is confined mainly to the spring and summer months. Year-round pumping is both uneconomical and unnecessary. During the fall and winter months much natural discharge would not be captured.

It does not seem unreasonable to assume that two and one-half times the 1968 pumpage of area A, which was approximately 2,350 acre-feet, or 6,000 acre-feet could be developed yearly from that area alone.

Even though considerable additional amounts of water could be developed from the Seymour in Jones County under conditions existing at the time of this study, maximum development would require numerous low-capacity wells. The saturated part of the formation is relatively thin over much of the area (Figure 11) and in these areas the formation will not produce large quantities of water from single wells. Only in the areas of thickest saturation should wells producing more than 200 gpm be expected.

Many areas of the Seymour of Jones County have a very limited extent as well as little saturated thickness. During prolonged drought, with reduced recharge and declining water levels, well yields may decline and, if the drought is of very long duration, wells may fail. This would normally be expected to occur first in the areas of less saturated thickness (Figure 11).

Possible Areas of Future Development

As a general rule, the most desirable areas for development of a Seymour ground-water supply coincide with those areas of greatest saturated thickness (Figure 11). In these areas, the basal sands and gravels which are thickest and most permeable are generally associated with the structural lows or "valleys" in the erosional surface upon which the Seymour was deposited (Figure 12). It appears that the most promising areas for future development are generally those in which the saturated thickness exceeds 30 feet, although apparently reliable irrigation wells have been developed in areas having less than this amount. In times of drought, excessive pumping may result in failure of wells having a thin saturated thickness.

Within area A (Figure 10) there are several locations where the saturated thickness of the Seymour equals or exceeds 30 feet. Area E is the only other area in which present data indicates a saturated thickness of 30 feet or greater.

The most favorable locations for future development are in area A. There are four significant areas, of limited extent, within area A, which have a saturated thickness of 30 feet or greater. One area is located directly north from Hawley for a distance of 5½ miles and is about 1½ miles wide. The approximate areal extent is about 8 square miles. The maximum saturated thickness is 70 feet. Prior to any development within this area, the chemical quality of water in nearby wells should be checked using Table 8 as water of poorer quality is present in some localities within this area. A second area, located west of U.S. Highway 83-277, east of Farm Road 707, and about 5 miles due south of Anson, is about 12 square miles in extent and contains a maximum saturated thickness of 70 feet. A third area is located about 4 miles southeast of Anson and just east of U.S. Highway 83-277. The maximum saturated thickness of this area is 40 feet and the areal extent is about 6 square miles.

None of these favorable areas are extensively developed by wells other than domestic and livestock wells.

Another area, located 4 miles west of Nugent, has been partly developed. The area has a saturated thickness greater than 30 feet and is about 3 square miles in area. There are presently irrigation wells within this area, and well spacing should be considered in choosing locations of new irrigation wells.

Within area E (Figure 10), an area of potential irrigation development 5 miles due east of Stamford has an areal extent of about 8 square miles. The maximum saturated thickness is 46.5 feet. A previous section of this report discussed waterlogging in this approximate vicinity. Limited irrigation development in this area could cause a water-level decline and, therefore, reduce some of the waterlogging problem.

Secondary Aquifers

(Discussed in Order of Importance)

Bullwagon Dolomite Member of Vale Formation

The second most reliable source of ground water in Jones County is the Bullwagon Dolomite Member of the Vale Formation. This unit provides water for all uses including limited developments of irrigation and public supply.

The "Geology" section of this report discusses the geologic characteristics and extent of the aquifer.

Ground-Water Source, Occurrence, and Movement

Ground water in the Bullwagon is derived mainly by the infiltration of stream runoff, and by interformational leakage from water-bearing deposits of Quaternary age which overlie the Bullwagon.

The water occurrences in this formation are believed to be confined to local zones of permeability, in fractures and solution channels, at or near the outcrop. The areas most favorable for well development are near the Clear Fork Brazos River and its tributaries.

Water in the Bullwagon is generally under artesian conditions. The movement of ground water within the aquifer is downdip and toward discharge areas. Natural discharge areas are unknown. Several domestic, stock, irrigation, industrial, and public-supply wells are pumping from this aquifer and some movement is toward these areas of discharge (Figure 35 and Table 6).

Water-Level Fluctuations

Limited historical data are available on this aquifer concerning water-level fluctuations. However, seven wells completed in the Bullwagon Dolomite were measured in the summer of 1953 and again in late 1967 or early 1968. The wells exhibited a net rise in water level during this period, ranging from 6.97 feet in well 30-09-613 to 14.40 feet in well 30-09-305 (Table 6 and Figure 35). Historical water-level data are also available on three wells measured during the summer of 1960 and again in late 1967 or early 1968. The wells measured were 30-09-506, 30-09-901, and 30-09-902. Their water levels also indicated a net rise, of 0.86, 4.87, and 12.30 feet, respectively. It should be pointed out that in all of the above cases, except well 30-09-506, summer water levels were compared with winter water levels. Well 30-09-506 was measured on both occasions during the winter months and was more representative of the actual amount of change in water level.

The rise in the water level since 1953 has occurred in spite of that fact that the number of producing irrigation wells completed in the Bullwagon has increased from 4 to 49 wells during this period.

Recharge and Discharge

Recharge to the Bullwagon Dolomite is dependent on the rainfall. Much of the recharge is from the streams which cross its outcrop. Interformational leakage from Quaternary deposits overlying the Bullwagon provides additional recharge. Precipitation falling directly on the very limited outcrop provides some recharge. Information is lacking with which to estimate the amount of recharge; however, recharge has exceeded discharge as reflected by a net rise in water levels since 1953.

Areas of natural discharge and the amounts are not known. Artificial discharge is through the many wells which pump from this aquifer.

Chemical Quality

One hundred and twenty-four wells inventoried during this study were known to produce or have produced from the Bullwagon Dolomite. These wells are located mainly in the east one-half of the west one-half of the county.

Sixty-seven water samples were collected from wells producing from the Bullwagon Dolomite during this investigation and analyzed for their chemical constituents. These analyses are shown in Table 8. The dissolved-solids content varied widely and a tabulation of only those wells sampled during this study is as follows:

RANGE IN DISSOLVED SOLIDS (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
500 or less	1	1.5
501 to 1,000	15	22.4
1,001 to 1,500	12	17.9
1,501 to 2,000	8	11.9
2,001 to 3,000	16	23.9
Over 3,000	15	22.4

The ground waters produced from the Bullwagon range from fresh to moderately saline; however, 77.6 percent of the samples were fresh to slightly saline in quality.

Only one sample (well 30-10-820) contained less than 500 mg/l of dissolved solids and would be desirable for use on a public conveyance. Approximately 54 percent of the samples contained water of 2,000 mg/l or less dissolved solids. These waters would be suitable for human consumption, although they are of a poorer quality.

Much of the variance in content of dissolved solids can be explained by the location of the wells with respect to the outcrop of the Bullwagon. In general, those wells which are located in or near the outcrop produce waters with a slightly lower content of dissolved solids. Other wells are located within the confines of oil fields, and the waters from many of these wells have a higher chloride value and thus higher dissolved-solids content than those outside the fields. In some of the producing areas the Seymour Formation overlies the Bullwagon and there is believed to be interformational leakage from the Seymour into the underlying Bullwagon. Generally, the Seymour contains better quality ground water than the Bullwagon.

Ranges in the principal constituents are as follows:

Calcium	15 to 640 mg/l
Magnesium	22 to 334 mg/l
Sodium plus Potassium	35 to 1,220 mg/l
Bicarbonate	79 to 1,350 mg/l
Sulfate	31 to 2,980 mg/l
Chloride	38 to 3,130 mg/l
Fluoride	0.4 to 4.4 mg/l
Nitrate	$<$ 0.4 to 840 mg/l

For the quality of water in individual wells consult Table 8.

Ground waters from the Bullwagon are characteristically high in sulfate as are most waters in Permian rocks in north-central Texas (Figure 26). Exceptions are areas near the outcrop or near streams. The average sulfate content of all samples was 845 mg/l. Only 29.7 percent of the collected samples contained less than the maximum recommended upper limit of 250 mg/l (U.S. Public Health Service, 1962, p. 7). Approximately 41 percent of the samples contained greater than 750 mg/l sulfate, which can cause these waters to have a laxative effect on the consumer.

The chloride content of samples collected from the Bullwagon Dolomite ranged from 38 to 3,130 mg/l. Exclusive of those wells which were obviously contaminated, the regional or normal chloride content is estimated to be about 370 mg/l. Only 39.7 percent of the water samples contained less than the recommended upper limit of 250 mg/l (U.S. Public Health Service, 1962, p. 7). In general, there is less chloride present in waters located near the outcrop of this member. The chloride content is locally higher within the producing limits of some oil fields and contamination of these waters is probable.

Fluoride occurs in relative low concentrations in ground-water samples collected from the Bullwagon. However, the recommended upper limit of 1.0 mg/l (U.S. Public Health Service, 1962, p. 8) was exceeded in approximately 35 percent of the samples tested. Ninety percent of the samples contained fluoride in concentrations less than 1.5 mg/l. The average fluoride content of all Bullwagon Dolomite samples analyzed was 1.1 mg/l.

Of a total of 67 water samples collected and analyzed from wells producing from the Bullwagon, 23 wells (34.3 percent) contained nitrate in excess of the recommended 45 mg/l limit (Table 8). It is believed that much of this high nitrate is due to sewage from improperly located septic tanks or animal wastes from barnyards. The nitrate content in the Bullwagon is possibly derived from Seymour water which recharges the unit by interformational leakage. The high nitrate concentration in water occurring in the Seymour Formation is discussed in the chemical quality section for that formation.

Water from wells 30-09-515, 30-10-110, and 30-25-204 contained nitrate in concentrations of 840, 220, and 252 mg/l respectively. Burden (1961) recommended that the nitrate concentrations in water used for livestock should not exceed 220 mg/l. These waters, therefore, should not be used for livestock watering. Well 30-09-515 is located down slope from a cattle feeding enclosure and drainage from this area has possibly caused the high nitrate buildup. Well 30-10-110 is located at a cotton gin. The high nitrate in this case could result from the leaching of humus carelessly placed near the well. Well 30-25-204 is believed to be contaminated by the laterals from a septic tank.

The boron content was determined in four samples from selected wells pumping from the Bullwagon Dolomite Member (Table 3). Two samples each had 1.1 mg/l, one had 2.1 mg/l, and one 2.5 mg/l. If the four samples are representative, then Bullwagon ground water is suitable for irrigating only those crops that are semi-tolerant or tolerant to boron. For a discussion of the type of crops which are tolerant to these concentrations, see the comments under the "Quality Criteria" section.

The percent sodium, specific conductance, and SAR (sodium-adsorption ratio) values for waters from the Bullwagon are shown on Table 8. Plots of representative irrigation waters from this aquifer are shown on Figure 27 to indicate their suitability for irrigation. This figure indicates that all classifiable samples of Bullwagon ground water fell within salinity-hazard classes C_3 and C_4 and sodium-hazard classes S_1 and S_2. For a detailed discussion of limitations for using irrigation waters of these classes, refer to the "Quality Criteria" section of this report.

Usually irrigation waters which have a sodium percentage of less than 60 and an associated low bicarbonate content are suitable for irrigation (Table 8). Only two of the Bullwagon Dolomite water samples (wells 30-09-613 and 30-10-733) had a sodium percentage higher than the recommended limit of 60 percent. The sodium percentage of these samples was 79.3 and 72.9, respectively.

Some alteration of native-quality ground water has occurred within the Bullwagon Dolomite in several areas, and historical water-quality data, where available, are included in Table 8 for comparison with the more recent data to indicate the amount and where the alteration has occurred. Five wells sampled in earlier investigations in 1944, 1952, 1953, and 1956 were resampled during this investigation. Of these wells, well 30-09-901 showed a slight quality improvement over the earlier sample. Two wells (30-02-401 and 30-17-331) exhibited indications of slight deterioration of overall quality. Wells 30-09-902 and 912 reflected significant worsening of quality. For the most part, deterioration or worsening of quality was the result of increase in sulfate content. Well 30-09-912 showed increases in almost all constituents, including nitrate. The increase in chloride content in this well is possibly related to the increase in nitrate.

Table 8 shows that in some water samples a higher than normal chloride content is accompanied by high content of calcium and magnesium but not of sodium; therefore, the chloride in these samples could not be directly attributed to oil-field brines. Ion exchange could have occurred, but this phenomenon is not fully understood. Well 30-25-204 has a nitrate content of 252 mg/l and its high chloride value is believed related to the high nitrate. This well is believed altered by sewage from septic laterals.

Well Production and Performance

A power-yield test was performed on well 30-25-202 and the results of this test are shown on Table 5. The reported yields of irrigation wells pumping from the Bullwagon Dolomite range from 20 to 550 gpm. Most of the wells, however, yield between 20 and 150 gpm. Twenty-six wells or 63.4 percent yield 50 gpm or less.

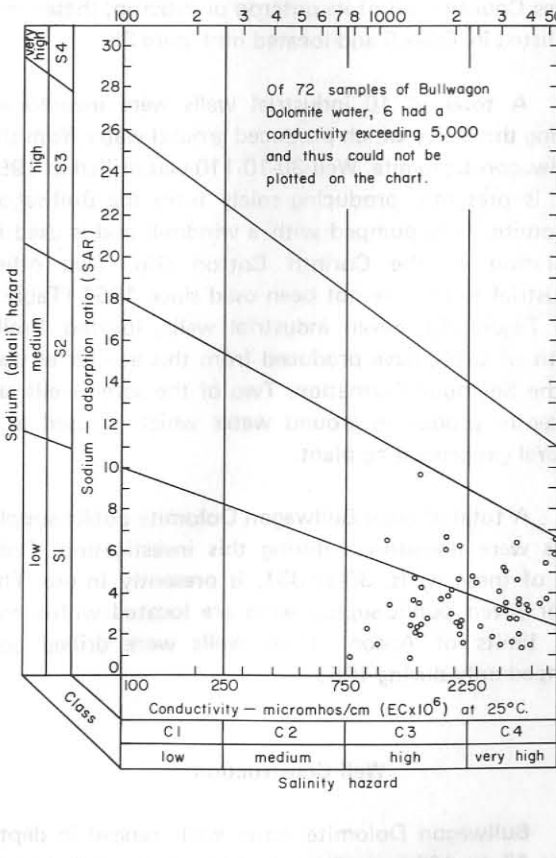

Figure 27.–Classification of Bullwagon Dolomite Waters for Irrigation

History of Development

Domestic and livestock wells have been completed in the Bullwagon for many years. Sixty domestic and livestock wells which pumped solely from this aquifer were inventoried during this study.

Only four known irrigation wells were producing from the Bullwagon in Jones County prior to 1954. In 1968, 49 irrigation wells were known to exist but only 35 were in use. The number of irrigation wells completed in the Bullwagon during various periods of time since 1954 is shown in the following table:

YEAR	NUMBER OF IRRIGATION WELLS DRILLED	PERCENT OF TOTAL
Before 1956	17	34.7
1956 through 1960	9	18.4
1961 through 1965	13	26.5
1966 through 1968	10	20.4

Irrigation wells producing from the Bullwagon are distributed in a rather narrow area throughout central Jones County west of its outcrop or subcrop; these wells are listed in Table 6 and located on Figure 35.

A total of 10 industrial wells were inventoried during this study which produced ground water from the Bullwagon Dolomite. Well 30-10-110 was drilled in 1955 and is presently producing solely from the Bullwagon Dolomite. It is pumped with a windmill and is used in operation of the Corinth Cotton Gin. Two other industrial wells have not been used since 1954 (Table 6 and Figure 35). Seven industrial wells, located 1 mile south of Stith, have produced from this aquifer as well as the Seymour Formation. Two of the seven wells are presently producing ground water which is used at a natural gas processing plant.

A total of eight Bullwagon Dolomite public-supply wells were inventoried during this investigation. Only one of these wells, 30-17-331, is presently in use. The other seven public-supply wells are located within the city limits of Anson. These wells were drilled and pumped only during 1953.

Well Construction

Bullwagon Dolomite water wells ranged in depth from 17 to 120 feet. The general construction of wells producing from this water-bearing unit is essentially the same as for the Seymour Formation.

The dug wells are used mostly for domestic or livestock purposes. Generally, they are about 3 to 4 feet in diameter and lined with native stone, brick, or concrete rings. In some older wells only a limited amount of casing was set and the producing zone was not cased or screened. This has resulted in the caving of the hole and the loss of the well in some cases. This practice has been abandoned on new wells drilled. Recently drilled domestic and livestock wells have small-diameter casing, 5 to 8 inches, and are cased to the bottom of the well with either galvanized sheet-metal or steel. The sheet-metal casings are perforated opposite the water-bearing sands. The steel casings are almost always torch-slotted.

Industrial and irrigation wells are larger in diameter, 8 to 30 inches, and are usually cased to the bottom of the hole. In most cases, the hole was reamed to 36 inches, the casing was torch-slotted opposite the water-producing sands and gravels, the casing was set on the bottom, and the hole outside the casing was then filled with pea-sized gravel.

Most wells of the types described above were developed by pumping.

Utilization and Pumpage

Domestic and Livestock

Many domestic and livestock wells produce from the Bullwagon Dolomite. These are located mainly in the east one-half of the west one-half of the county (Table 6 and Figure 35). The amount of ground water pumped for domestic and livestock use from the Bullwagon is small. The estimated total pumpage for these purposes for the period from 1954 through 1968 is 314 acre-feet. The 1968 estimated pumpage is 22 acre-feet.

Irrigation

Most of the irrigation water from the 49 Bullwagon irrigation wells is applied by sprinkler systems. A small amount of the water is discharged into furrows.

Total pumpage for irrigation purposes for the period from 1954 to 1968 is estimated at 3,876 acre-feet. The irrigation pumpage in 1968 is estimated to be about 599 acre-feet.

Industrial

Well 30-10-110 provides a small amount of ground water from the Bullwagon Dolomite only during the ginning season.

Two other wells, 30-25-801 and 30-25-802, are producing an undetermined amount of ground water from the Bullwagon as well as the Seymour Formation (Table 6 and Figure 35). This water is used at a natural gas processing plant.

Municipal

The city of Anson has one well (30-17-331) which has been used during the period from 1954 through 1968. Water from this well is presently used to fill a public swimming pool. The total estimated pumpage from this well from 1954 through 1968 is 46 acre-feet. The estimated 1968 pumpage is 3 acre-feet.

Possible Areas of Future Development

There probably are undeveloped areas in which ground water can be obtained from the Bullwagon Dolomite. The best potential areas should be along the creeks or the Clear Fork Brazos River and within 1 to 2 miles west of the outcrop of the Bullwagon Dolomite (Figure 5). The water should be less saline, and the depth required for drilling would be more economical, if the wells were confined to the 2-mile limit. The quantity of water available for future development is not known. Yields of wells will usually be 50 gpm or less.

Recent Alluvium

Fairly reliable sources of ground water for domestic, livestock, industrial, and irrigation purposes can be found in the flood plains of the Clear Fork Brazos River and its major tributary, California Creek.

The geologic characteristics and extent of the Recent alluvium aquifer are discussed in the "Geology" section of this report.

Ground-Water Source, Occurrence, and Movement

The source of the ground water is precipitation that falls directly on the alluvium outcrop and the discharge from other water-bearing units into the alluvial deposits along the streams.

The principal occurrences of ground-water supplies in the alluvial deposits are usually found near the major streams.

The movement of the ground water is usually toward the main stream channel where it is discharged into the river or the creek.

Water-Level Fluctuations

Water-level fluctuations within the Recent alluvium vary greatly with rainfall and with the rise and fall of water in the river or creeks. During periods of runoff following rainfall, a temporary rise in the water level occurs due to seepage from the stream into the aquifer. However, when the runoff has passed, the water level in the stream is again below that in the aquifer and the water flows back into the streams.

Recharge and Discharge

The recharge of the Recent alluvium is partly from stream runoff and flooding that results from precipitation upstream. Recharging from stream runoff is usually temporary since most of this recharge is bank storage only and the water flows back into the streams after the runoff recedes. However, during flooding, water often covers the entire floodplain, and at this time considerable recharge takes place. Much recharge also is received by seepage from the Seymour Formation which is extensively in direct contact with the Recent alluvium (Figure 5).

Low-flow studies were conducted in January 1969 along the Clear Fork Brazos River within Jones County in an attempt to determine the recharge rate of the Seymour Formation. A detailed discussion of the findings of these studies can be found in the "Availability of Ground Water" section of this report under the heading "Primary Aquifer, Recharge and Discharge." All of the streamflow measurements made in connection with these studies were made in areas where the Seymour Formation was mapped as being in direct contact with the Recent alluvium. Therefore, the determined recharge rates of the Seymour are also the recharge rates of the Recent alluvium within those specific areas involved (Figure 18).

The determined average recharge rate for five areas was 1.78 inches in 1968, or 6.23 percent of Abilene's 1968 rainfall of 28.61 inches. This 1968 recharge rate should be somewhat higher than that of years in which the annual rainfall is nearer the mean of 24.25 inches as recorded at Abilene.

Discharge from the Recent alluvium is directly into the main channels of the Clear Fork Brazos River, California Creek, and their tributaries.

Chemical Quality

A total of 179 wells and 6 springs were inventoried which produce water entirely from Recent alluvium (Table 6 and Figure 35). Water samples were collected for chemical analysis from 120 of the wells inventoried. A tabulation of the results of these analyses is shown on Table 8. Dissolved-solids content of the samples varied greatly; a tabulation by ranges, considering only those wells sampled during this study, is presented below:

RANGE IN DISSOLVED SOLIDS (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
500 or less	6	5.0
501 to 1,000	16	13.3
1,001 to 1,500	17	14.2
1,501 to 2,000	14	11.7
2,001 to 3,000	32	26.7
Over 3,000	35	29.1

Ranges of the principal mineral constituents are as follows:

Calcium	14 to 840 mg/l
Magnesium	9 to 1,300 mg/l
Sodium plus Potassium	13 to 3,570 mg/l
Bicarbonate	52 to 1,550 mg/l
Sulfate	7 to 8,800 mg/l
Chloride	7 to 5,600 mg/l
Fluroride	0.1 to 5.6 mg/l
Nitrate	< 0.1 to 1,449 mg/l

For data on the quality of waters produced by individual wells consult Table 8.

Based on the range in dissolved-solids content, the ground waters obtained from the Recent alluvium would be classified as ranging from fresh to very saline. However, the above tabulation of ranges in dissolved solids reflects that 81.5 percent of the samples would be classified as slightly to very saline in quality. All of the analyzed samples, with the exception of well 30-17-817, had a total hardness greater than 180 and, therefore, these ground waters would be classified as very hard.

Only 5 percent of the water samples from Recent alluvium wells were fresh water. However, 44.2 percent of the samples contained 2,000 mg/l or less dissolved solids. Although this is water of poorer quality, it would be suitable for human consumption, providing undesirable constituents were low in content.

The wide variance in dissolved-solids content of Recent alluvium waters may be caused by the waters being derived from several sources. The Recent alluvium is in direct contact with the Seymour Formation throughout much of Jones County. The Seymour ground waters recharge the alluvium and are generally of a better quality than other ground waters of the county. In other areas, poorer quality ground waters from Permian aquifers may locally recharge the alluvium. Some of the surface waters which recharge the Recent alluvium are also of poorer quality, having been mineralized by contact with Permian rocks west of Jones County.

There is characteristically a high sulfate content in ground water in the Recent alluvium. Slightly less than 75 percent or 94 of the samples collected and analyzed from Recent alluvium wells contained greater than 250 mg/l sulfate. This mineral constituent would give these samples a gypsiferous or "gyppy" taste. The average sulfate content for 129 samples collected and analyzed during this or previous studies were 971 mg/l.

The chloride content of Recent alluvium water samples ranged from 7 to 5,600 mg/l. Only 33.3 percent or 43 samples contained 250 mg/l or less chloride. Concentrations of chloride greater than this tend to give water a salty taste. The average chloride content for all of the samples was 648 mg/l. It is believed that the regional chloride content in these ground waters is normally high. There is no apparent correlation between the geologic units and the chloride content other than local increases within the limits of producing oil fields.

The recommended maximum upper limit for fluoride content in drinking water within Jones County is 1.0 mg/l. A total of 62 (50.4 percent) of the samples collected and analyzed of Recent alluvium ground waters contained fluoride in this amount or less. The average fluoride content for all of the samples was 1.3 mg/l. The range of this mineral constituent was from 0.1 to 5.6 mg/l. Approximately 72.8 percent of the samples analyzed contained fluoride concentrations less than 1.5 mg/l.

Nitrate concentrations found in Recent alluvium ground waters of Jones County ranged from <0.1 to 1,449 mg/l. Water samples from 33 wells out of a total of 120 collected from the Recent alluvium contained nitrate in excess of 45 mg/l which is the maximum concentration recommended for human consumption. Water from many wells contained excessively high nitrate content. Well 30-09-705 contained 1,449 mg/l. It is not recommended that ground waters containing greater than 220 mg/l be used for livestock consumption (Burden, 1961, p. 429-433). Approximately 3.2 percent of the analyzed Recent alluvium samples contained 200 mg/l or greater nitrate content (Table 8). Much of the high nitrate content found in these ground waters is possibly due to contamination from sewage from improperly placed septic tanks or animal wastes from barnyards. This is the probable explanation for the high nitrate content found in well 30-09-705 (Figure 35). Many wells contain high nitrate content which is probably derived from waters of the Seymour Formation which often have high nitrate concentrations.

The boron content was determined in 10 of the water samples from wells completed in the alluvium (Table 3). The concentration range for this constituent is 0.41 to 5.5 mg/l. A tabulation by ranges is as follows:

RANGE IN BORON CONTENT (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
0.0 to 1	3	30.0
1.1 to 2	4	40.0
2.1 to 3	2	20.0
Over 3	1	10.0

Water from well 30-17-916 contains a boron concentration of 5.5 mg/l. This water would be harmful to crops if used continually for irrigation. The rest of the waters sampled are selectively suitable for sensitive, semi-tolerant, or tolerant crops (Table 2). The percent sodium, specific conductance, and SAR (sodium-adsorption ratio) values for waters from Recent alluvium are shown on Table 8. Plots of representative irrigation waters from this aquifer are shown on Figure 28 to indicate their suitability for irrigation. All but 13 of the samples of Recent alluvium water plotted fell within salinity-hazard classes C_3 and C_4 and sodium-hazard classes S_1 and S_2. An additional 23 samples had a conductivity greater than 5,000 and could not be plotted on the chart. A discussion of the limitations for using irrigation waters of these classes is found in the "Quality Criteria" section.

Out of a total of 126 samples of Recent alluvium waters which were analyzed during this or previous studies, 108 or 85.7 percent had a calculated sodium percentage of 60 or less. Irrigation waters with 60 percent sodium or less and having a low bicarbonate content are usually satisfactory (Table 8). When the percentage is greater than 60, the sodium hazard becomes progressively greater. A total of 18 samples of Recent alluvium waters had a sodium percentage greater than 60 (Table 8).

Alteration of native-quality ground water has possibly occurred in several areas (Figure 33) of the Recent alluvium, and available historical water-quality data are included in Table 8 for comparison with more recent data to indicate the degree and where the alteration has occurred. A total of six wells sampled in earlier studies in 1953 and 1966 were resampled during this investigation. Wells 30-03-704 and 30-27-619 showed slight improvement in overall quality. The other four wells sampled reflected a significant worsening of quality. The deterioration in these samples was mainly due to increase in sulfate and chloride content.

Several water samples contained a high chloride content but not an associated high sodium content (Table 8); therefore, the mineralization of these waters could not be attributed to the presence of oil-field brines. The dissolved-solids and chloride content of waters from seven wells which are believed possibly altered due to oil-field brines are as follows:

WELL	DISSOLVED SOLIDS (mg/l)	CHLORIDE (mg/l)
30-02-706	10,400	2,520
30-02-708	6,860	1,370
30-02-905	10,000	2,730
30-03-901	13,300	3,410
30-10-409	8,800	2,760
30-19-604	17,000	5,600
30-27-619	1,930	850

Well 30-02-706, included in the tabulation above, has an abnormally high dissolved-solids content. The chloride content is also high; however, the sodium content is not as high in relation to the other ions as one might expect in a brine-altered water. The well is down gradient from an abandoned oil test which is located approximately 1,000 feet to the west. It is not known if this is the cause of the alteration. In the immediate vicinity of the above well is well 30-02-708, which is also believed altered. This well is located on a small stream down gradient from several producing oil wells which are located approximately 2,300 feet to the southwest. An abandoned oil test is located approximately 1,400 feet south, and another is located 1,700 feet northwest of the subject well. Any one of these tests could be leaking.

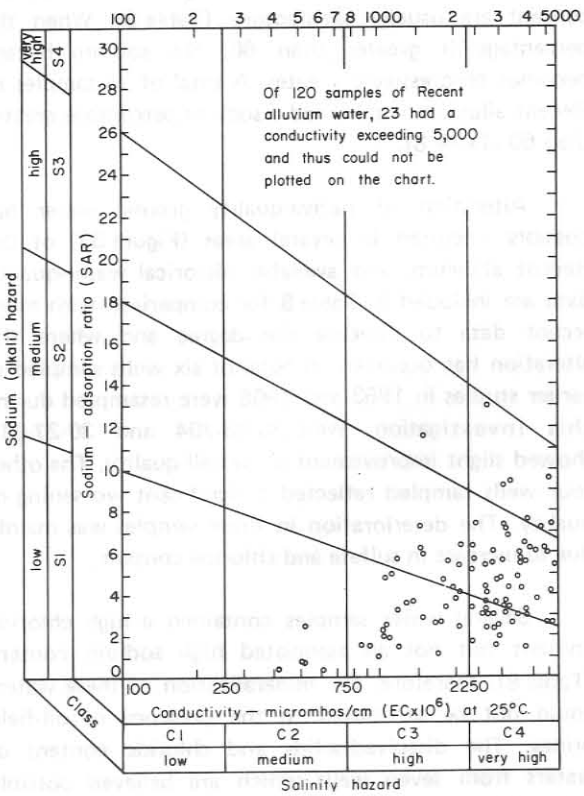

Figure 28.—Classification of Recent Alluvium Waters for Irrigation

Well 30-02-905 contains an abnormally high sodium, chloride, and nitrate content. It is believed that the waters of this well have been altered from an up-gradient barnyard or septic tank. This would account for the 260 mg/l nitrate, as well as much of the high chloride content. It is believed, however, that additional alteration is the result of brine. The location of the brine source is unknown. Seep 30-03-901 is a small flow of very saline water; some natural gas also is seeping, and oil covers the surface. A producing oil well is located upstream, approximately 1,350 feet southwest. Another oil well is located up gradient approximately 1,000 feet. One of these tests, or possibly another, is leaking. Well 30-10-409 is downstream from producing oil wells which according to the well-ownership map, are located 1,800 feet southwest and 2,000 feet to the west. There is no definite brine source; however, one of these wells could be leaking. No definite sources for the alteration of waters in wells 30-19-604 and 30-27-619 are known. There are producing oil wells approximately 1,300 feet west and 1,750 feet northwest and up gradient from 30-19-604. An abandoned oil test is located approximately 3,300 feet southwest and up gradient from well 30-27-619. It is not known if this is the source of alteration or if the well water is being altered by waters from upstream on Deadman's Creek.

Well Production and Performance

The reported yields of irrigation wells producing from the Recent alluvium range from 25 to 400 gpm (Table 6). However, most of the wells yield 50 to 200 gpm. Two power-yield tests were conducted on wells producing from this aquifer (Table 5). Wells 29-24-501 and 502 were pumping together and their combined yield was 169 gpm. Well 29-24-805 had a yield of 324 gpm.

History of Development

Many domestic and livestock wells have been producing from the Recent alluvium for years. One hundred and thirteen domestic and livestock wells and six springs were inventoried during this study (Table 6 and Figure 25).

Eight irrigation wells were producing from this aquifer prior to 1954. A total of 61 irrigation wells were inventoried during this study which were producing or had produced from the Recent alluvium (Table 6). Fifty-one wells are now being used. The increase in the number of wells drilled and producing from the alluvium for irrigation purposes since 1954 is shown in the following table:

PERIOD	NUMBER OF IRRIGATION WELLS DRILLED	PERCENT OF TOTAL
Before 1956	11	18.0
1956 through 1960	5	8.2
1961 through 1965	33	54.1
1966 through 1968	12	19.7

Irrigation wells producing from the alluvium are very dispersed and these are listed in Table 6 and located on Figure 35.

Four Recent alluvium wells are presently being used for industrial purposes. These wells, 29-24-810, 30-19-606, 30-27-622, and 30-27-911, all are used to supply water for oil-field waterflood operations.

No municipal or public-supply wells produce from the alluvium.

Well Construction

Wells completed in the Recent alluvium range in depth from 5 to 83 feet. Their methods of completion are almost identical to those producing from the Seymour Formation.

Most of the dug wells are used for domestic or livestock purposes. These are generally about 3 to 4 feet in diameter and are lined with native stone, brick, or concrete rings. The more recently drilled domestic and livestock wells have small-diameter casing, 5 to 8 inches, and are cased to the bottom of the well with either galvanized sheet-metal or steel. The sheet-metal casings are perforated opposite the water-bearing sands. The steel casings are almost always torch-slotted.

Industrial and irrigation wells are larger in diameter, 8 to 30 inches, and are usually cased to the bottom of the hole. In most cases, the hole was reamed to 36 inches, the casing was torch-slotted opposite the water-producing sands and gravels, the casing was set on the bottom, and the hole outside the casing was then filled with pea-sized gravel.

Most wells of the types described above were developed by pumping.

Utilization and Pumpage

Domestic and Livestock

As has been the case with all other aquifers, pumpage from the Recent alluvium for domestic and livestock purposes is fairly small. The estimated total pumpage for these uses for the period 1954 through 1968 is 215 acre-feet, or an average yearly pumpage of 15 acre-feet. The 1968 estimated pumpage for these uses is 15 acre-feet.

Irrigation

Pumpage for irrigation from the Recent alluvium is estimated at 4,945 acre-feet for the period from 1954 through 1968. The 1954 and 1968 pumpage was approximately 20 and 625 acre-feet, respectively. Other peak irrigation pumpage periods were during droughts or in years of low rainfall (Figures 3 and 21). Increases in pumpage were noted during the years 1956, 1964, and 1967. The estimated pumpage in these years was 106, 823, and 1,067 acre-feet, respectively.

Most of the irrigation water obtained from the alluvium is applied by sprinkler systems.

Industrial

Industrial uses for water from the Recent alluvium have been for water flooding purposes in oil field operations. Four wells have pumped an estimated total of 691 acre-feet of water for these uses from 1954 through 1968. The estimated 1968 pumpage was 54 acre-feet. Insofar as known, water flooding operations which use Recent alluvium ground water began about 1955 and are restricted to three areas. In the Noodle, North Field, located 3½ miles north of Noodle, Bengal Producing Company is using about 28 acre-feet of water per year from well 29-24-810 to waterflood the lower Cisco sands encountered at a depth of approximately 3,670 to 3,780 feet. These operations began about 1956. Schkade Brothers Drilling Company is using three Recent alluvium wells in waterflood operations. Well 30-19-606 provides water for flooding of the Bluff Creek sand at a depth of about 1,700 feet on a Jones County regular lease within the limits of Matilda Field, about 2 miles northeast of Nugent. These operations began about 1955 and use an estimated 14 acre-feet of ground water per year. Wells 30-27-622 and 30-27-911, drilled in 1956 and 1966, are used on two Jones County regular leases about 6 miles northeast of Abilene. Both wells are used to waterflood the Tannehill sand at a depth of approximately 1,700 feet. The annual pumpage from these wells is estimated at 6 acre-feet of water per well.

Possible Areas of Future Development

The most likely areas for future development of irrigation or industrial supplies from the Recent alluvium are in the former oxbows or meanders of the Clear Fork Brazos River or of California Creek. In these areas, the sands and gravels are most likely to be better developed, more permeable, and thus able to transmit water more readily. Yields up to 200 gpm can be expected from wells completed in such areas.

Choza Formation

Within Jones County, ground-water sources of questionable reliability are found in the Choza Formation.

The water-bearing portions of this formation are in semi-persistent beds of gray dolomite which are locally permeable due to fractures and solution channels. Therefore, they are unpredictable as to location, extent, and potential yields.

Water from the Choza Formation is presently being used for domestic, livestock, irrigation, and limited industrial purposes.

Ground-Water Source, Occurrence, and Movement

The source of the ground water is mainly precipitation that falls directly on the formation's outcrop. Some water may be derived by interformational seepage from Quaternary age sediments which cover the Choza in scattered areas.

Useable quality ground water occurs in fractures and solution channels in the dolomictic limestones on the outcrop and probably for some distance downdip.

The natural movement is unknown. Since the ground waters are under artesian conditions, there is movement downdip to the various points of withdrawals by the several wells which produce from the Choza.

Water-Level Fluctuations

The few historical records available suggest that water levels in the Choza Formation have risen since 1953. Net water-level rises measured in wells 29-08-802, 29-32-501, 30-09-407, and 30-17-207 from July 1953 through 1967 were 6.2, 12.2, 6.0, and 0.9 feet, respectively.

Recharge and Discharge

Recharge to the Choza Formation is from precipitation on the outcrop. Limited recharge may also be received by leakage from overlying Quaternary age rocks.

The only known discharge is the withdrawals by scattered wells which produce from the formation.

Chemical Quality

One hundred and forty-five wells were inventoried during this study which produce solely from the Choza Formation (Table 6 and Figure 35). One of these (well 29-08-802) is known to produce from the Merkel Dolomite Member. The wells are located mainly in the west-central part of Jones County.

Ninety-two water samples were collected from these wells and were analyzed by the Texas State Department of Health. A complete tabulation of the results of these analyses is shown on Table 8. The content of dissolved solids ranged from 146 to 42,300 mg/l. Dissolved-solids contents for only the wells sampled during this study are summarized by ranges in the following tabulation:

RANGE IN DISSOLVED SOLIDS (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
500 or less	8	8.8
501 to 1,000	23	25.2
1,001 to 1,500	15	16.5
1,501 to 2,000	9	9.9
2,001 to 3,000	14	15.4
Over 3,000	22	24.2

Ranges in the principal mineral constituents are as follows:

Calcium	25 to 4,660 mg/l
Magnesium	4 to 1,760 mg/l
Sodium plus Potassium	16 to 8,760 mg/l
Bicarbonate	24 to 520 mg/l
Sulfate	7 to 3,170 mg/l
Chloride	7 to 26,300 mg/l
Fluoride	0.1 to 3.0 mg/l
Nitrate	< 0.1 to 300 mg/l

For data on the chemical quality of water in individual wells consult Table 8.

Even though the ground waters collected from the Choza Formation ranged from fresh to brine, 75.7 percent or 69 of the samples would be classified, based on the dissolved-solids content, as fresh to slightly saline. The fresher waters are generally located closer to the updip limits of the Choza. A total of 55 of the samples or 60.4 percent contained 2,000 mg/l or less dissolved solids, and would be suitable for human consumption provided the individual mineral constituents are not present in undesirable amounts. Well 29-08-802 is the only well located which is known to produce from the Merkel Dolomite Member of the Choza Formation; its water contained 1,030 mg/l dissolved solids (Table 8). All of the water samples except those from wells 29-16-607, 29-16-609, and 29-32-602 contained less than 10,000 mg/l dissolved solids and, consequently, would be suitable for livestock consumption from this standpoint.

All of the samples analyzed except two (wells 29-24-602 and 30-09-804) contained more than 180 mg/l total hardness and would be classified as very hard water. The water from well 30-09-804 contained a total hardness of 110 mg/l, and from well 29-24-602, 130 mg/l. These waters would be classed as moderately hard and hard, respectively. Hard waters are satisfactory for irrigation, but water with less than 180 mg/l total hardness is preferable for domestic purposes.

As had been the case with other Permian formations, the Choza also generally contains waters with high sulfate content. Only 39 of the samples analyzed or 39.4 percent contained 250 mg/l or less. Any water which contains sulfate in greater amounts than this recommended limit may have a "gyppy" taste (Table 8). The average sulfate content of all samples was 784 mg/l. Approximately 43.5 percent of the samples analyzed contained more than 750 mg/l and, consequently, these waters would tend to have a laxative effect on those not accustomed to them.

The chloride content of ground waters from the Choza Formation ranged from 7 to 26,300 mg/l. Several of the samples analyzed were obviously contaminated by oil-field brines. Excluding those samples which were thought to be contaminated, an average regional chloride content was calculated at 638 mg/l. Even though much of the Choza ground water is naturally high in chloride content, 39.4 percent of the water samples contained 250 mg/l or less. Water with higher concentrations than this will probably have a salty taste.

Choza Formation ground waters contained fluoride in concentrations ranging from 0.1 to 3.0 mg/l. A total of 59 or 59.6 percent of the water samples analyzed contained not more than the maximum recommended upper limit for Jones County of 1.0 mg/l. The average fluoride content of all of the samples analyzed was 1.1 mg/l. Only 15.1 percent of the analyzed samples contained fluoride in amounts greater than 1.5 mg/l (Table 8).

Of a total of 92 water samples, 24 (26.1 percent) contained nitrate in excess of the recommended limit for human consumption, or greater than 45 mg/l. Two wells (29-24-604 and 30-01-406) had abnormally high nitrate content, 265 and 300 mg/l, respectively. It is not recommended that waters used for livestock consumption contain more than 220 mg/l (Burden, 1962, p. 429-433). Possibly the two wells are contaminated by sewage from improperly placed septic tanks or by animal wastes from barnyards. The high nitrate content in water produced by other wells completed in the Choza Formation is likely derived from the soil and humus associated with grasslands or mesquite trees which are present or have been present over the outcrop area.

The boron content was determined in only one well, 30-09-703 (Figure 35), and its value was 1.3 mg/l. This indicates that the water is suitable for irrigating semi-tolerant and tolerant crops. Consult Table 2 for information on the tolerances of various crops to boron.

The percent sodium, specific conductance, and SAR (sodium-adsorption ratio) of waters from the Choza Formation are shown on Table 8. A discussion of the importance of these values is to be found in the "Quality Criteria" section. Plots of representative waters from this formation are shown in Figure 29 to indicate their suitability for irrigation. All but 16 of the water samples plotted fell within salinity-hazard classes C_3 and C_4 and sodium-hazard class S_1. An additional eight samples has a conductivity greater than 5,000 and thus could not be plotted on the chart. A discussion of the importance of these classes can be found in the "Quality Criteria" section.

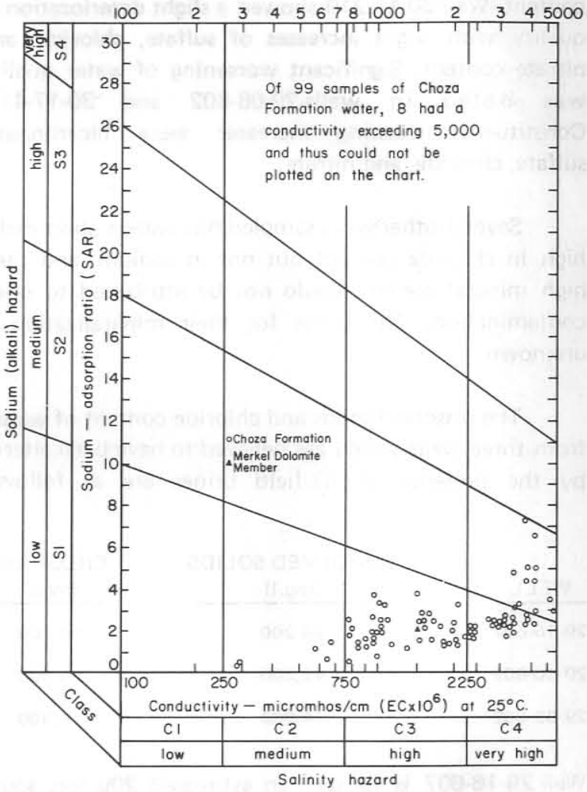

Figure 29.—Classification of Choza Formation Waters for Irrigation

All of the samples of ground water collected and analyzed from the Choza Formation had a sodium percentage of less than 60. Waters with 60 percent sodium or less are usually satisfactory for irrigation when they also have an associated low bicarbonate content (Table 8).

Alteration of native-quality ground water has possibly occurred in several localities (Figure 33) of the Choza Formation, and historical water-quality data, where available, are included in Table 8 for comparison with the more recent data to indicate the amount and where the alteration has occurred. Six wells were resampled during this investigation which had been sampled during an earlier study in 1953. Of these, three samples (wells 30-01-406, 30-17-205, and 209) indicated a significant improvement in overall quality; however, wells 30-01-406 and 30-17-205 had increases in nitrate content. Well 30-17-210 showed a slight deterioration in quality with slight increases of sulfate, chloride, and nitrate content. Significant worsening of water quality was noted in wells 29-08-802 and 30-17-411. Constituents showing increases were bicarbonate, sulfate, chloride, and nitrate.

Several other wells sampled had waters abnormally high in chloride content but not in sodium, and their high mineral content could not be attributed to brine contamination. The cause for their mineralization is unknown.

The dissolved-solids and chloride content of waters from three wells which are believed to have been altered by the presence of oil-field brines are as follows:

WELL	DISSOLVED SOLIDS (mg/l)	CHLORIDE (mg/l)
29-16-607	24,200	14,700
29-16-609	42,300	26,300
29-32-602	14,500	9,300

Well 29-16-607 is located an estimated 200 feet south of, and along strike with, a salt-water injection well. Well 29-16-609 is located an estimated 700 feet southeast and down slope from the same injection well. It is believed that this well may be leaking. Well 29-32-602 is located within the confines of an existing oil-field and down slope from production. In the waters of wells 29-16-607 and 29-32-602, calcium and magnesium make up a greater proportion of the cations, and the sodium content is proportionately less, than might be expected from oil-field brine contamination; possibly this results from ion exchange.

Well Production and Performance

Reported yields for irrigation wells producing from the Choza Formation range from 35 to 40 gpm. The yields of wells 30-09-108 and 109 were measured during this study and they had a combined output of 90 gpm (Table 5).

History of Development

Many older domestic and livestock wells have been producing ground water from the Choza Formation for many years (Table 6 and Figure 35).

Two irrigation wells were producing from the Choza prior to 1954. All of the remaining irrigation wells were drilled in 1965 through 1967. A total of 15 irrigation wells were inventoried during this investigation. Nine of these are presently in use. The irrigation wells producing from this are widely scattered and these are listed in Table 6 and located on Figure 35.

A total of 11 industrial wells were inventoried which were producing, or have produced, ground water from the Choza Formation. The seven presently producing wells were all drilled in 1967 and are used as a supplemental water supply in a waterflood operation (Table 6 and Figure 35). Wells 29-16-606, 29-32-905, and 30-01-603 were drilled and used for the development of oil fields or the drilling of an oil test. They were drilled in 1951 and 1956, respectively. Well 30-17-216 was drilled in 1967 for use as a supply well in a waterflood operation. It has not been used as of 1969.

Well Construction

Choza Formation water wells range in depth from 11 to 800 feet. The 800-foot well (30-01-504) was a seismic shot hole which was converted to a livestock well and was never plugged back. Most of the wells range from 11 to 100 feet in depth. Many older livestock and domestic wells have only a small amount of surface casing of a small size set near the top of the hole. The water-bearing zone is uncased (Table 6).

Utilization and Pumpage

Domestic and Livestock

One-hundred and nineteen domestic and livestock wells, many very old, were inventoried during this study which were producing ground water solely from the Choza Formation (Table 6). Pumpage for these purposes for the period 1954 through 1968 is estimated at 322 acre-feet. The 1968 pumpage is estimated at 23 acre-feet.

Irrigation

Most of the irrigation waters derived from the nine existing wells pumping from the Choza are applied by sprinkler systems. A minor amount is pumped into open furrows.

Irrigation pumpage from 15 irrigation wells which pump or have pumped from this formation is estimated at 1,145 acre-feet for the period from 1954 through 1968. Pumpage for irrigation is estimated at 195 acre-feet during 1968.

Industrial

Eleven industrial wells were inventoried during this study which produced ground water from the Choza Formation. Seven of the wells are presently in production.

Three wells (29-16-606, 29-32-906, and 30-01-604), now abandoned, were used prior to 1954 as water sources during the drilling of oil and gas tests. Well 30-17-216 was drilled for a supplemental water supply well for a waterflood operation; however, as of 1969 it has not been used.

Seven industrial wells (30-17-213 through 215, 217, 218, 220, and 221) are located 2 to 3 miles west and southwest of Anson. These wells are used as a supplemental water supply in a waterflood operation (Table 6 and Figure 35). Production began in 1966 and the pumpage for these wells from 1966 through 1968 is estimated at 50 acre-feet. The 1968 pumpage is estimated at 27 acre-feet.

Possible Areas of Future Development

Areas of possible future development of Choza Formation ground waters are most promising along the creeks which cross the outcrop. Well should be situated west of the easternmost limits of the formation. The ground waters are highly variable in quality from location to location. In general, wells drilled closest to the up-dip limits of the Choza could be expected to normally encounter the freshest quality water; however, the Choza is known to contain fresh to moderately saline ground waters as much as 8 miles west of its easternmost limits. Any wells developed in the Choza would be of questionable reliability. The yields should vary greatly but are expected to be generally less than 50 gpm.

Vale Formation

The Vale Formation as discussed here includes all of the formation exclusive of the Bullwagon Dolomite Member which was discussed as a secondary aquifer in a previous section of this report. The Vale Formation is a fairly reliable source of ground water in Jones County. Water yielded to wells is used mainly for domestic and livestock purposes; however, there is limited use for irrigation. Two wells, now unused, have been used for oil-well drilling.

Ground-Water Source, Occurrence, and Movement

The main source of ground water in the Vale Formation is precipitation falling on its outcrop. Some of the water is derived by interformational drainage from the overlying beds of Quaternary age.

The ground water occurs in the Vale in fractures and solution cavities in the thin dolomite beds at, or near, their outcrop.

The direction of movement of the ground water is thought to be generally toward the local drainageways which cross the outcrop. Some local movement is toward points of irrigation withdrawal.

Water-Level Fluctuations

The water levels in the Vale Formation have risen as substantiated by historical data on nine wells (Table 6). These wells were measured during the summer of 1953 and again at various times during 1967. The range in net rise of water levels was from 2.8 feet in well 30-25-201 to 13.3 feet in well 30-10-905.

Recharge and Discharge

The amount of recharge to the Vale Formation is unknown. The recharge is derived from two sources, precipitation falling directly on the outcrop and interformational drainage from the overlying rocks of Quaternary age.

Data on the areas and amounts of natural discharge are scarce. Spring 30-09-911 flows northward into a tributary of Red Mud Creek. Artificial discharge is by the many wells which pump from the Vale Formation.

Chemical Quality

A total of 119 wells and one spring that are known to produce, or to have produced, ground water from the Vale Formation were inventoried during this investigation (Table 6 and Figure 35). A total of 88 water samples were collected from wells producing from the Vale Formation (exclusive of the Bullwagon Dolomite Member).

A complete tabulation of the chemical analyses is shown on Table 8. The dissolved-solids contents for those wells sampled during this investigation are summarized by ranges in the following table:

RANGE IN DISSOLVED SOLIDS (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
500 or less	3	3
501 to 1,000	18	21
1,001 to 1,500	12	14
1,501 to 2,000	9	10
2,001 to 3,000	16	18
over 3,000	30	34

Ranges in the principal constituents are as follows:

Calcium	3 to 640 mg/l
Magnesium	6 to 770 mg/l
Sodium plus Potassium	2 to 3,470 mg/l
Bicarbonate	9 to 840 mg/l
Sulfate	5 to 4,700 mg/l
Chloride	9 to 5,000 mg/l
Fluoride	0.2 to 5.2 mg/l
Nitrate	<0.4 to 320 mg/l

For data on the chemical quality of water from individual wells consult Table 6.

The ground waters collected from the Vale Formation ranged in dissolved-solids content from 128 to 15,000 mg/l. These waters, therefore, would be classified as fresh to very saline in quality. Only 21 samples contained 1,000 mg/l or less dissolved solids and would be classified as fresh water. Approximately 48 percent of the samples analyzed contained 2,000 mg/l or less and would constitute poorer quality waters suitable for human consumption and domestic uses. It is generally recommended that waters containing greater than 10,000 mg/l dissolved solids not be used for livestock purposes. Six wells contained this amount or greater and it is not recommended that these waters be used for livestock consumption. These wells are 30-10-413, 30-10-422, 30-10-501, 30-10-734, 30-10-803, and 30-25-603. Their dissolved-solids content was 10,700; 10,700; 10,700; 15,000; 12,600; and 10,400 mg/l, respectively.

All of the analyzed samples of ground waters from the Vale Formation contained greater than 180 mg/l total hardness; consequently, they would be classified as very hard. Waters with less than 180 mg/l would be preferable for domestic uses.

The sulfate content of waters from the Vale Formation ranged from 5 to 4,700 mg/l. As with other Permian formations in Jones County, the sulfate content of Vale waters is typically high. Only 34 percent of the samples analyzed did not exceed the maximum recommended sulfate content of 250 mg/l (U.S. Public Health Service, 1962, p. 33-34). A total of 40 percent of the waters analyzed would tend to have a laxative effect on the user as they contained sulfate in quantities of 750 mg/l or greater. The higher sulfate concentrations were generally found in those samples which were abnormally high in chloride, suggesting that some of the high sulfate may be associated, locally, with possible brine pollution (Table 8).

The choloride content of Vale Formation ground waters ranged from 9 to 5,000 mg/l (Table 8). The chloride concentration of this unit is naturally high. The average chloride content for all samples was 827 mg/l, including some samples which are possibly contaminated by oil-field brines. Excluding those samples which are thought to be altered, the estimated regional content of chloride in Vale waters is about 419 mg/l. Only 33 percent of the analyzed samples contained 250 mg/l or less chloride which is the recommended upper limit (U.S. Health Service, 1962, p. 33-34).

The average fluoride content of all Vale ground waters sampled and analyzed during this study was 1.2 mg/l. The recommended upper limit for this constituent in Jones County is 1.0 mg/l. A total of 52 percent of all samples collected during this and previous studies contained this amount of fluoride or less. A total of 78 percent contained 1.5 mg/l or less. The range of this mineral constituent was 0.2 to 5.2 mg/l (Table 8).

Thirty-one water samples contained nitrate in excess of the recommended 45 mg/l limit. Well 30-25-504 contained the highest concentration which was 210 mg/l (Table 8). This well is located in a barnyard and this is believed the source of its contamination. Numerous wells are located down slope from, or along strike with, barnyards and produce water with a high nitrate content that is believed derived from these. Wells 30-02-709, 30-09-429, 30-10-710, 30-10-737, 30-17-914, 30-18-103, 30-18-104, 30-18-108, 30-25-309, 30-25-504, 30-25-505, 30-26-501, and 30-26-702 are all examples of this condition. Additional wells are possibly contaminated due to sewage from improperly located septic tanks or animal wastes from barnyards. In others the excessive nitrate possibly was derived from Seymour Formation ground waters, which locally drain into the Vale and which are high in nitrate content in many areas as discussed earlier. The remainder of the wells, located on the outcrop of the Vale, possibly derived their high nitrate concentrations from the leaching of soils and humus in old mesquite groves which are, or have been, present over most of the outcrop.

The boron content was determined from a water sample from only one well (30-25-101) which produced from the Vale. This well's water contained only 0.25 mg/l boron which should not be harmful to irrigated crops.

The percent sodium, specific conductance, and SAR (sodium-adsorption ratio) of waters from the Vale Formation are shown on Table 8. Plots of representative waters from the Vale are shown in Figure 30 to indicate their suitability for irrigation. All of the water samples plotted, except 11, fell within salinity-hazard classes C_3 and C_4 and sodium-hazard classes S_1, S_2, and S_3. An additional 26 samples had a conductivity greater than 5,000, and one had a SAR greater than 30; these samples could not be plotted on the chart. A discussion of the limitations for using irrigation waters of these classes is found in the "Quality Criteria" section of this report.

Usually, water with 60 percent sodium or less and having a low bicarbonate content is satisfactory for irrigation use. A total of 63 (69 percent) of the samples of Vale Formation water analyzed had a calculated percent sodium of 60 or less. The sodium hazard increases when the sodium percentage is above 60 and extreme care should be exercised in the use of these waters.

Alteration of native-quality Vale ground water possibly has occurred in several areas (Figure 33). Wells 30-10-710 and 30-18-108, which had been sampled for chemical analysis in 1953, were resampled during this investigation to determine any changes in water quality.

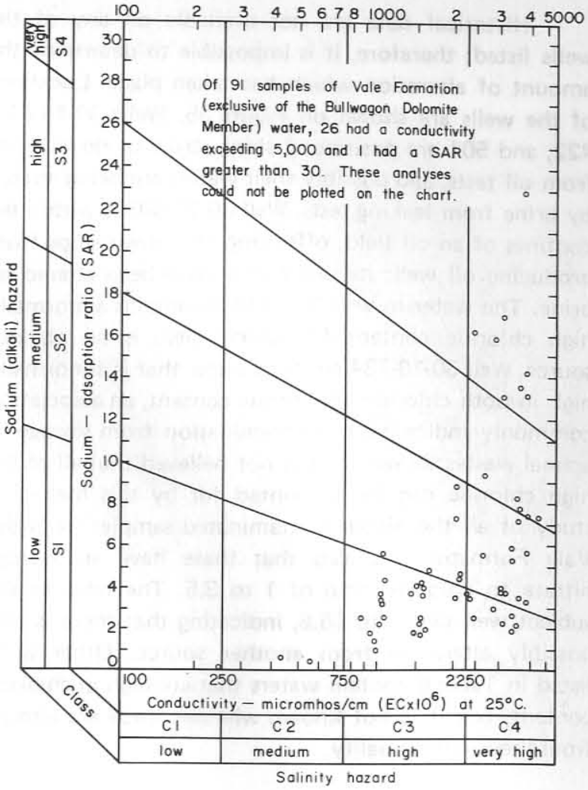

Figure 30.—Classification of Vale Formation Waters for Irrigation

Well 30-10-710 showed significant improvement in overall water quality with decreases in most chemical constituents. Well 30-18-108 reflected slight improvement in quality, with reduction in the concentration of all ions except bicarbonate and nitrate which had slight increases.

Several wells are believed to have been altered by the presence of oil-field brines as they have abnormally high chloride content and an associated high sodium content. The dissolved-solids and chloride content of waters from six wells which are believed contaminated are as follows:

WELL	DISSOLVED SOLIDS (mg/l)	CHLORIDE (mg/l)
30-10-413	10,700	2,560
30-10-422	10,700	3,270
30-10-501	10,700	3,050
30-10-734	15,000	5,000
30-10-803	12,600	5,000
30-25-603	10,400	2,880

Historical data are not available on any of the wells listed; therefore, it is impossible to determine the amount of alteration which has taken place. Locations of the wells are shown on Figure 35. Wells 30-10-413, 422, and 501 are positioned along strike or down slope from oil tests, and possibly their waters are being altered by brine from leaking tests. Well 30-25-603 is within the confines of an oil field, offsetting and down slope from producing oil well; its water may have been altered by brine. The water in well 30-10-803 contains abnormally high chloride content for which there is no obvious source. Well 30-10-734 contains water that is abnormally high in both chloride and nitrate content, an association commonly indicative of contamination from sewage or animal wastes; however, it is not believed that all of the high chloride can be accounted for by this means. A study of all the nitrate-contaminated samples from the Vale Formation revealed that these have an average nitrate to chloride ratio of 1 to 3.5. The ratio in the subject well was 1 to 15.6, indicating that there is also possibly alteration from another source. Other wells listed in Table 8 contain waters that are high in chloride content, but it is not known whether these are altered from their native quality.

Well Production and Performance

Reported yields from irrigation wells producing from the Vale ranged from 25 to 165 gpm (gallons per minute). The yields of wells used for domestic and livestock purposes are considerably smaller, ususally being approximately 20 gpm to as low as 3 gpm (Table 6).

History of Development

Ground water has been produced from the Vale Formation for domestic and livestock purposes for many years (Table 6 and Figure 35).

A total of 12 wells producing, or known to have produced, water for irrigation were inventoried during this investigation. Five of these were drilled prior to 1954. The remainder of the wells were drilled at various times during the period 1954 through 1967.

Only two unused industrial wells completed in the Vale were inventoried during this study. Well 30-10-420 was drilled in 1948 and was used as a water source for the drilling of oil and gas tests. Well 30-09-807 was drilled in 1967 and is to be used, at a later date, as a supplemental water supply in an oil-field waterflood operation.

Well Construction

Those water wells which produce from the Vale Formation range in depth from 9 to 120 feet (Table 6 and Figure 35).

Many earlier drilled wells producing from the Vale are of a small diameter, 3 to 10-3/4 inches, and have only a few feet of casing set near the top of the hole with the water-bearing zone unprotected. Numerous wells have been lost, due to caving, and this practice was abandoned in later drilled wells. There are a few dug wells producing from this formation; these range from 3 to 4 feet in diameter and are lined with native stone, brick, or concrete rings. Those wells drilled in the past few years are similar in casing size, and the methods of completion are similar, to those wells which produce from the Seymour Formation.

Utilization and Pumpage

Domestic and Livestock

One hundred and five domestic and livestock wells and one spring were inventoried during this study which received water from the Vale.

Only a minor amount of Vale ground water is used for domestic and livestock purposes, and pumpage estimates for these uses for the period 1954 through 1968 total about 322 acre-feet. The 1968 pumpage is estimated at 23 acre-feet.

Irrigation

A total of 12 irrigation wells were producing, or had produced, from the Vale Formation. Ten wells were reported as being used.

The total irrigation pumpage from this formation for the period 1954 through 1968 is estimated at 1,010 acre-feet. The 1954 pumpage was about 62 acre-feet. The peak pumpage year was 1957 with an estimated 154 acre-feet. Pumpage declined to a low of approximately 11 acre-feet in 1961, reflecting a reduction in pumpage of the two most used wells, 30-25-101 and 30-25-102. The 1968 irrigation pumpage is estimated at 48 acre-feet.

The irrigation waters pumped from the Vale are applied mainly by sprinkler system; however, some is applied by discharge into open furrows.

Industrial

Only two unused industrial wells, previously discussed in the section or "History of Development" for the Vale Formation were inventoried during this investigation.

There has been no pumpage from these wells during the period 1954 through 1968.

Possible Areas of Future Development

Low-yield wells of fair reliability probably can be drilled in some areas to the west of the Vale's easternmost limit (Figure 5). Yields of generally 3 to 80 gpm can be expected, with a few wells yielding up to a maximum of 165 gpm. Tests should generally be confined to the outcrop area of the formation. It is thought that the most favorable areas for drilling are near the creeks which cross the Vale's outcrop. In such areas, there is a better chance for the development of solution channels necessary for the larger wells yields. These locations are also the areas of most frequent recharge.

San Angelo Formation

Fairly reliable sources of moderately saline ground waters in small quantities, used mainly for livestock purposes, are found in the San Angelo Formation. Limited domestic, irrigation, and industrial uses are made of this water in scattered local areas (Table 6 and Figure 35).

Ground-Water Source, Occurrence, and Movement

The main source of ground water in the San Angelo Formation is precipitation falling on its outcrop. Minor amounts of ground water are derived by interformational drainage from the Quaternary age rocks which overlie the San Angelo just north of the Clear Fork Brazos River (Figure 5).

The less highly mineralized waters within this formation are usually found at or near the east edge of its outcrop but not always. Locally, areas near drainageways may contain better quality water. Higher yield wells should be found in areas of locally higher permeability.

The waters of this formation are under artesian conditions. Movement of the ground water is thought to be generally downdip toward the producing wells. Some ground-water movement is toward the Clear Fork Brazos River and creeks which flow across the outcrop.

Water-Level Fluctuations

Historical data on eight wells, in which the water levels were measured in July 1953 and again in late 1967 or early 1968, indicate net rise in water levels ranging from 1.2 feet in well 29-31-901 to 19.8 feet in well 29-08-401 (Table 6) during the 14-year period.

Recharge and Discharge

The amount of recharge to the San Angelo is unknown. The recharge is derived from, mainly, precipitation falling directly on its outcrop. Limited recharge is believed derived from the overlying Seymour Formation in the area north of the Clear Fork Brazos River (Figure 5).

It is thought that some water is being discharged into the Clear Fork Brazos River where it crosses the outcrop of the San Angelo. Seep 29-08-502 was also an area of natural discharge. At this location, a very small discharge of ground water seeping from a vegetative-kill area drained eastward into a tributary of California Creek.

Chemical Quality

Fifty-nine wells and one seep were inventoried during this invesitgation which were known to produce or have produced from the San Angelo Formation (Table 6 and Figure 35).

A total of 51 water samples were collected from wells producing from the San Angelo. A complete tabulation of the chemical analyses of these samples is shown on Table 8. The dissolved-solids contents, which varied from 319 to 23,100 mg/l, are summarized by ranges in the following table:

RANGE IN DISSOLVED SOLIDS (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
500 or less	3	6
501 to 1,000	8	16
1,001 to 1,500	5	10
1,501 to 2,000	8	16
2,001 to 3,000	7	14
Over 3,000	20	38

The principal mineral constituents ranged as follows:

Calcium	25 to 1,250 mg/l
Magnesium	9 to 2,010 mg/l
Sodium plus Potassium	23 to 4,230 mg/l
Bicarbonate	21 to 920 mg/l
Sulfate	< 4 to 12,000 mg/l
Chloride	9 to 5,000 mg/l
Fluoride	0.3 to 6.4 mg/l
Nitrate	< 0.4 to 1,050 mg/l

For data on the chemical quality of water in individual wells consult Table 8.

Only three samples (6 percent) of San Angelo ground waters analyzed contained 500 mg/l or less dissolved solids and would be classified as freshwaters. A total of 47 percent of the analyzed samples contained 2,000 mg/l or less. This poorer quality water would be acceptable for drinking purposes, providing better quality water was not available. Care should be exercised in the uses of these waters and a check should be made to see that certain mineral constituents are not present in undesirable quantities (Table 8). All of the water samples except three contained less than 10,000 mg/l dissolved solids. This is the recommended upper limit for waters used for livestock consumption. The wells 29-07-901 and 29-07-902 and seep 29-08-502 contained 11,200; 11,600; and 23,100 mg/l dissolved solids, respectively. It is not recommended that these waters be used for livestock consumption.

Only three of the samples collected from the San Angelo contained a total hardness of less than 180 mg/l. These samples were from wells 29-16-501, 29-16-504, and 29-24-103. Their total hardness was 125 mg/l (moderately hard), 140 mg/l (hard), and 107 mg/l (moderately hard), respectively. The range in total hardness was from 107 mg/l (well 29-24-103) to 9,600 mg/l (seep 29-07-302).

The sulfate content of the San Angelo waters ranged from less than 4 to 12,000 mg/l (Table 8). The average for all samples was 1,360 mg/l. Most of the generally high sulfate content is believed to be of natural origin, as the San Angelo characteristically contains gypsum which is the main source of this mineral constituent.

The range in chloride content in San Angelo waters was from 9 to 5,000 mg/l (Table 8). Only 16 (29 percent) of the samples analyzed did not exceed 250 mg/l, the recommended upper limit (U.S. Public Health Service, 1962, p. 33-34). Excluding all apparently altered samples, the regional chloride content of this formation was estimated to be about 392 mg/l. Several well waters contained excessive amounts of chloride and are thought to be altered by the presence of oil-field brines.

The recommended upper limit for fluoride content in drinking water in Jones County is 1.0 mg/l. Only 34.5 percent of the analyzed samples of San Angelo waters contained this amount or less (Table 8). Mottling of the teeth may occur when greater than 1.7 mg/l fluoride is present in ground waters (U.S. Public Health Service, 1962, p. 8). Approximately 49.1 percent of the waters analyzed from this formation contained greater than 1.5 mg/l fluoride.

Out of a total of 51 water samples analyzed from wells producing from the San Angelo Formation, those from 21 wells, and one seep, contained nitrate in excess of the recommended 45 mg/l limit (Table 8). Water containing nitrate concentrations greater than the recommended value is not considered safe for human consumption. It is not generally recommended that waters containing in excess of 220 mg/l nitrate be used for livestock consumption (Burden, 1961, p. 431-433). Several of the samples had abnormally high nitrate amounts. Those waters which contained nitrate in amounts greater than 220 mg/l, and are not recommended for livestock uses, are shown in the following tabulation:

WELL	NITRATE (mg/l)	CHLORIDE (mg/l)
29-08-404	315	1,000
29-08-502 (seep)	357	3,480
29-08-504	294	264
29-08-701	546	432
29-16-201	273	173
29-16-711	1,050	54

Hem (1959, p. 18) indicated that the sources of high nitrate concentrations are also an explanation for part of the increases in high chloride in natural ground waters. This association is well illustrated in the previous tabulation. The average ratio of nitrate to chloride content in the above samples is 1 to 1.9.

Well 29-08-404, listed in the tabulation, is located down slope from a septic tank and along strike from a barnyard. These are thought to be the cause for its high nitrate concentration. Seep 29-08-502, situated approximately at the basal contact of the San Angelo Formation, is down slope from a barnyard which is located about one-quarter mile to the west. The nitrate buildup as well as part of the chloride alteration is believed due to this barnyard. The proportion of chloride in this water, in relation to nitrate, seems higher than can be accounted for by contamination from animal wastes alone; therefore, it is possible that a oil and gas test located approximately 1,800 feet west of the seep may be leaking. Wells 29-08-504, 29-08-701, 29-16-201 and 29-16-711 are all located near or down slope from existing barnyards. Their high nitrate buildup is believed to be a direct result of alteration from these sources. Possibly much of the excessive nitrate content found in many of the other well waters (Table 8) is due to sewage contamination from improperly placed septic tanks or contamination from animal wastes from barnyards. The remainder of those waters which contain very high nitrate are thought to have derived it from the leaching of soils and humus in old mesquite groves or grasslands which are, or have been, present over most of the San Angelo Formation's outcrop.

The boron content was determined in water samples from wells 29-15-902 and 29-16-405, and the concentrations were 0.36 and 1.1 mg/l, respectively. If these samples are typical, it would seem that water from the San Angelo Formation can be used for crop irrigation without toxic effects.

The percent sodium, specific conductance, and SAR (sodium-adsorption ratio) for waters from this formation are shown on Table 8. Plots of representative waters from the San Angelo are shown in Figure 31 to indicate their suitability for irrigation. Figure 31 reflects that all but two of the samples of San Angelo ground water plotted fell within salinity-hazard classes C_3 and C_4 and sodium-hazard classes S_1 and S_2. An additional 17 samples analyzed had a conductivity greater than 5,000 and thus could not be plotted on the chart. A discussion of the importance of these classes is to be found in the "Quality Criteria" section of this report.

Several well waters have abnormally high chloride content and are believed to have been altered due to the presence of oil-field brines. The regional chloride content of San Angelo waters is thought to be about 392 mg/l. The dissolved-solids and chloride content of waters from six wells and one seep believed to be contaminated by brine are listed as follows:

WELL	DISSOLVED SOLIDS (mg/l)	CHLORIDE (mg/l)
29-07-901	11,200	5,000
29-07-902	11,600	4,820
29-07-903	6,200	1,250
29-08-502 (seep)	23,100	3,480
29-15-901	4,350	930
29-16-403	4,990	1,080
29-16-404	4,700	890

The actual amount of alteration in these wells is not known since no previous water-quality data were available on these wells for comparison. Wells 30-07-901 through 903 are all within the city of Hamlin; whether oil and gas tests are near them is unknown as these tests are not generally shown on well-ownership maps within cities. Seep 29-08-502 is believed altered and has been discussed earlier in regard to its high nitrate content. Hydrocarbon production is located updip and east of well 29-15-901. There have previously been saltwater disposal pits in this area. Dry oil and gas tests are located up slope also. Any one of these could be the source of alteration of the waters in this well. Two wells (29-16-403 and 404) are located within the community of Nianda, down slope and 1/2 mile from two oil and gas tests. It is possible that one of these tests is leaking.

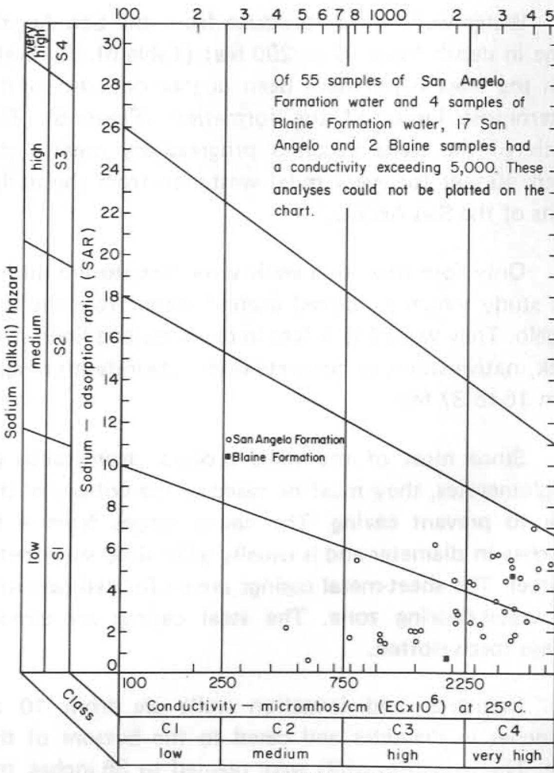

Figure 31.—Classification of San Angelo Formation and Blaine Formation Waters for Irrigation

Well Production and Performance

Reported well yields from the San Angelo Formation are very small for the domestic and livestock wells and range from 30 to 50 gpm for the few irrigation wells (Table 6).

History of Development

Ground water has been produced from the San Angelo Formation for domestic and livestock purposes for many years (Table 6).

Only three irrigation wells were inventoried during this study which derived their waters from the San Angelo Formation. Well 29-16-709 was drilled in 1952. The other two, wells 29-31-902 and 903, were drilled in 1966.

One unused industrial well, which formerly produced from the San Angelo Formation, was inventoried. Well 29-24-407 was drilled in 1940 for a water source during the drilling of an oil and gas test. It has not been used since that time.

Well Construction

Water wells which produce from the San Angelo range in depth from 16 to 290 feet (Table 6). The wells with the least depth have been dug or drilled near the easternmost limits of the formation (Figure 5). The depth of the wells becomes progressively greater (by about 40 feet for every mile) westward from the updip limits of the San Angelo.

Only four hand-dug wells were inventoried during this study which produced ground water from the San Angelo. They were 3 to 4 feet in diameter and lined with brick, native stone, or concrete rings. Their depth ranged from 16 to 37 feet.

Since most of the wells produce from sands or conglomerates, they must be cased to the bottom of the hole to prevent caving. The casing ranges from 4 to 8 inches in diameter and is usually galvanized sheetmetal or steel. The sheet-metal casings are perforated opposite the water-bearing zone. The steel casings are almost always torch-slotted.

Industrial and irrigation wells are from 10 to 18 inches in diameter and cased to the bottom of the hole. The irrigation wells were reamed to 36 inches, the casing was torch-slotted opposite the water-producing zone, the casing was set on bottom, and the hole outside the casing was filled with pea-sized gravel. Few, if any, of the wells were developed by pumping.

Utilization and Pumpage

Domestic and Livestock

Fifty-five domestic and livestock wells and one spring were inventoried during this study. These are used mainly for watering livestock and only minor amounts of ground water are used for domestic purposes.

Estimated pumpage for domestic and livestock purposes for the period 1954 through 1968 is about 2,200 acre-feet. The 1968 pumpage is estimated at 163 acre-feet.

Irrigation

A total of three irrigation wells, all of which were in use, were inventoried as producing from the San Angelo Formation. The total irrigation pumpage from this formation for the period 1954 through 1968 is estimated at 113 acre-feet. The 1968 estimated pumpage is 9 acre-feet. Irrigation waters pumped from the San Angelo are applied by sprinkler systems and by discharge into open furrows.

Industrial

Well 29-24-407 is the only industrial well completed in the San Angelo inventoried during this study. This well was used as a water source in 1940 to drill an oil and gas test. It has not been pumped during the period 1954 through 1968.

Possible Areas of Future Development

Low-yield wells of fair reliablilty can probably be drilled in most areas west of the San Angelo's easternmost limit. Tests should generally be confined to the outcrop area. The waters will usually be slightly saline (1,000 to 3,000 mg/l dissolved solids) to moderately saline (3,000 to 10,000 mg/l dissolved solids) and, therefore, will have limited uses.

Other Water-Bearing Units

Lueders Formation

Small quantities of ground water are yielded by domestic and livestock wells producing from the Lueders Formation. These waters are fresh to slightly saline.

Ground-Water Source, Occurrence, and Movement

The sources of the ground waters found within the Lueders Formation are precipitation that falls on the outcrop, and seepage water from the city of Abilene's sewage disposal facilities which are located in southeast Jones County on Deadman Creek. Water may also seep into the Lueders Formation from Lake Fort Phantom Hill.

Ground waters occur at or near the outcrop area of the Lueders Formation in fractures or solution cavities. The ground-water movement is thought to be toward the local drainageways and, locally, toward producing wells.

Water-Level Fluctuations

No historical data are available on the water levels of this formation. However, since the water levels have been rising in all other water-bearing formations in Jones County, it is probable that they have also been rising in this aquifer.

Recharge and Discharge

The amount of recharge is unknown. Recharge is from those sources which were discussed above.

Since the Lueders outcrops extensively in Shackelford County, to the east of Jones County, there should be local discharge into Deadman Creek and also the Clear Fork Brazos River. This is confirmed by spring 30-12-703 which is discharging ground water into the Clear Fork Brazos River (Figure 35). Springs 30-12-409 and 411 also discharge water into the Clear Fork Brazos River. The amount of aquifer discharge is unknown.

Chemical Quality

Twelve wells and three springs which were producing, or flowing, Lueders ground water were inventoried during this investigation (Table 6 and Figure 35). All are located in the southeast part of Jones County near the Lueders outcrop area (Figure 5).

A total of 12 water samples were collected from wells or springs in this formation. A complete tabulation of the chemical analyses is shown on Table 8. The dissolved-solids contents, for only those wells sampled during this study, are summarized by ranges in the following table:

RANGE IN DISSOLVED SOLIDS (mg/l)	NUMBER OF ANALYSES	PERCENT OF TOTAL ANALYSES
500 or less	1	8
501 to 1,000	3	25
1,001 to 1,500	2	17
1,501 to 2,000	1	8
2,001 to 3,000	3	25
Over 3,000	2	17

The principal mineral constituents ranged as follows:

Calcium	79 to 700 mg/l
Magnesium	17 to 125 mg/l
Sodium plus Potassium	42 to 3,890 mg/l
Bicarbonate	265 to 1,120 mg/l
Sulfate	6 to 9,000 mg/l
Chloride	73 to 2,700 mg/l
Fluoride	0.3 to 5.4 mg/l
Nitrate	$<$ 0.4 to 55.0 mg/l

For data on the chemical quality of water in individual wells see Table 8.

The dissolved-solids content of analyzed samples of Lueders ground water ranged from 285 mg/l in well 30-11-601 to 18,900 mg/l in well 30-11-602 (Table 8). Exclusive of possibly altered samples, these waters ranged from fresh to slightly saline in quality.

All of the samples had a total hardness content greater than 180 mg/l and, therefore, Lueders Formation waters would be classified as very hard.

The sulfate content of Lueders waters ranged from 6 to 9,800 mg/l (Table 8). Generally the sulfate content in these waters is high; only three (25 percent) of the analyzed samples contained less than the recommended limit of 250 mg/l (U.S. Public Health Service, 1962, p. 7).

The range in chloride content in waters from the Lueders Formation was from 73 to 2,700 mg/l (Table 8). Exclusive of probably altered waters, the regional chloride content of Lueders ground water within Jones County is about 193 mg/l.

Only three water samples (25 percent) collected from the Lueders Formation contained fluoride in amounts equal to or less than the recommended upper limit of 1.0 mg/l (U.S. Public Health Service, 1962, p. 8). The range of this mineral constituent was from 0.3 to 5.4 mg/l. The average fluoride value for all samples was 1.9 mg/l. Ground waters from wells 30-11-602, 30-12-411, 30-19-901, and 30-27-202 would probably cause some mottling of the teeth (Table 8).

Out of a total of 12 water samples collected and analyzed from the Lueders Formation, only two contained nitrate in excess of the recommended 45 mg/l limit. These samples were from seep 30-12-411 with 69 mg/l and well 30-27-302 with 55 mg/l nitrate. Seep 30-12-411 is in a limestone quarry 1/2 mile down slope from the city of Lueders. It is thought that the many septic tanks within the city are the probable cause of the high nitrate content in this water. Well 30-27-302 is located down slope from a barnyard and along strike from a corral. It is possible that wastes from either or both of these sources have altered the ground water.

The percent sodium, specific conductance, and SAR (sodium-adsorption ratio) of waters from the Lueders are shown on Table 8. Plots of representative waters from the Lueders are shown on Figure 32 to indicate their suitability for irrigation. This figure shows that all but one of the samples plotted fell within salinity-hazard classes C_3 and C_4 and sodium-hazard class S_1. Two other samples (30-11-602 and 30-27-202) had a conductivity greater than 5,000 and, therefore, could not be plotted on the chart. A discussion of the limitations for using irrigation waters of these classes is found in the "Quality Criteria" section of this report.

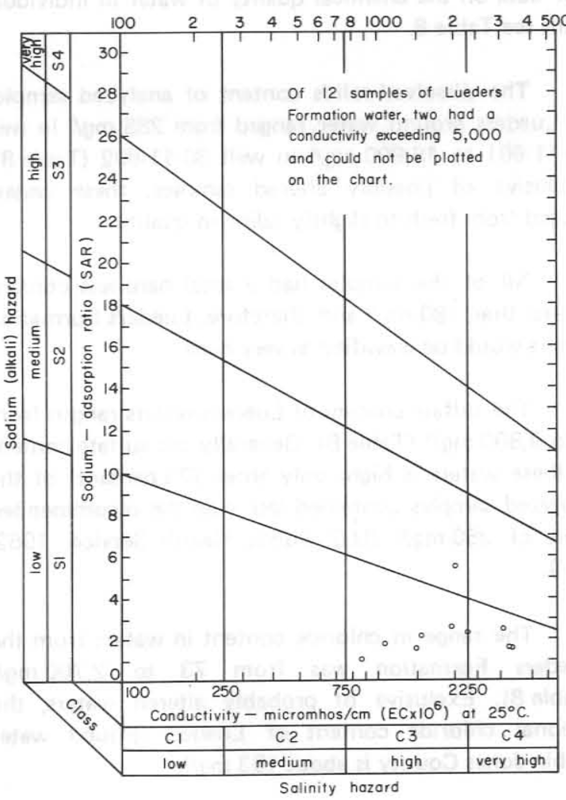

Figure 32.—Classification of Lueders Formation Waters for Irrigation

Out of a total of 12 samples of Lueders water which were analyzed during this investigation, 11 or 92 percent had a calculated sodium percentage of 60 or less. Usually these waters are satisfactory for irrigation use when they have an associated low bicarbonate content (Table 8).

Alteration of native-quality ground water has occurred in two areas of the Lueders Formation where the waters were sampled. It is believed that the water in these areas were altered due to oil-field brine as they contain abnormally high chloride concentrations. Exclusive of two wells thought to be altered, the regional chloride content was determined to be about 193 mg/l. Ground water from well 30-11-602 contained 18,900 mg/l dissolved solids, 1.5 mg/l nitrate, and 2,700 mg/l chloride. There are two nearby oil and gas tests, one located up slope approximately 2,300 feet to the north and the other located up slope approximately 1,700 feet to the southwest, either of which could be a possible cause of this alteration. The water from well 30-27-202 analyzed 4,040 mg/l dissolved solids, less than 0.4 mg/l nitrate, and 970 mg/l chloride. This well is located along strike and 1,400 feet southwest of an oil and gas test which possibly is leaking.

Well Production and Performance

The reported yields of domestic and livestock wells that produce from the Lueders Formation range from 5 to 20 gpm.

History of Development

Very small amounts of ground water has been obtained from the Lueders Formation for domestic and livestock purposes only. The first known development of wells began about 1926, and later well development has been irregular through the years.

Well Construction

The depth of wells which draw water from the Lueders Formation ranges from 8 to 120 feet. Seven of the 12 wells which were inventoried during this study were dug wells. They were 36 to 48 inches in diameter and usually lined with native stone or brick. Those wells which were drilled are cased with 4 to 8-5/8 inch sheet-metal or steel casing which is perforated or torch-slotted opposite the water-bearing interval.

Utilization and Pumpage

Only 12 wells and three springs were inventoried during this study which are known to produce, or have produced, ground water from the Lueders Formation within Jones County. Four wells are used for domestic and livestock purposes. Three wells and two springs are used for livestock purposes. The rest of the inventoried wells are not used.

The ground-water pumpage from the Lueders is believed insignificant and no estimates of the pumpage are made.

Arroyo Formation

The only known ground water found in the Arroyo Formation to date is that in an uncased test hole, 30-04-704 (Table 8 and Figure 35).

This test was drilled in 1967 to a depth of 82 feet and yielded water in small amounts. The reliability of the water-producing zone is unknown. This water had not been used for any purpose to date.

The water contained 4,000 mg/l dissolved solids and would be classified as moderately saline. It would be suitable only for livestock use if present in sufficient quantities.

The total hardness of the water was 1,510 mg/l and, therefore, the sample would be classified as very hard. Concentrations of the various chemical constituents in the water are listed on Table 8.

Blaine Formation

The Blaine Formation is an unreliable source of ground water in Jones County. Five wells (29-08-403, 405, 702, 703, and 29-16-101) were inventoried during this study which produce, or have produced, ground water from the Blaine (Table 6 and Figure 35).

Chemical Quality

Four of the five Blaine wells (29-08-403, 702, 703, and 29-16-101) were sampled. The dissolved-solids contents of these waters were 2,690; 1,520; 5,600; and 5,700 mg/l, respectively. If these samples are representative, then the Blaine waters would be classified as ranging from slightly saline to moderately saline. Only the water from well 29-08-702 would be considered suitable for human consumption, and it contains excessive sulfate content which would have a laxative effect on the consumer. The rest of the waters would be suitable for livestock use.

Ranges in the other principal mineral constituents are as follows:

Calcium	264 to 720 mg/l
Magnesium	39 to 444 mg/l
Sodium plus Potassium	65 to 730 mg/l
Bicarbonate	56 to 401 mg/l
Sulfate	950 to 3,140 mg/l
Chloride	66 to 1,014 mg/l
Fluoride	0.7 to 2.5 mg/l
Nitrate	< 0.4 to 116 mg/l

For a complete tabulation of the chemical analyses of water from individual wells consult Table 8.

All of the analyzed samples of Blaine ground water had a total hardness of greater than 180 mg/l; therefore, they would be classified as very hard waters.

The sulfate content of the Blaine is characteristically high; in the four samples it ranged from 950 to 3,140 mg/l with an average of 2,055 mg/l (Table 8). It is felt that the high concentration of this mineral is natural as the Blaine contains much gypsum and anhydrite from which this constituent is usually derived.

Only one Blaine water sample (well 29-08-702) contained less chloride than the recommended upper limit of 250 mg/l (U.S. Public Health Service, 1962, p. 33-34); its chloride content was 66 mg/l. The range on this constituent for all samples was from 66 to 1,014 mg/l (Table 8).

The fluoride content in Blaine ground waters ranged from 0.7 to 2.5 mg/l with an average value of 1.6 mg/l (Table 8). Only the water in well 29-08-702 would be suitable for human consumption; its fluoride content was 0.7 mg/l which is within the recommended range for this constituent.

Out of a total of four Blaine water samples, only one (well 29-08-703) contained nitrate in excess of the recommended 45 mg/l limit. The nitrate content in this well was 116 mg/l (Table 8). It is not thought that this nitrate content is natural. The well is located within the city of Hamlin and downslope from several dwellings. The distances from existing or former septic tanks or other contamination sources are unknown; however, the water possibly is altered as the result of an improperly placed septic tank or barnyard.

The percent sodium, specific conductance, and SAR (sodium-adsorption ratio) of waters from the Blaine are shown on Table 8. Plots of waters from this formation are shown on Figure 31 to indicate their suitability for irrigation. This figure reflects that two of the Blaine samples fell within salinity-hazard classes C_3 and C_4 and sodium-hazard classes were S_1 and S_2. Two other samples had a conductivity greater than 5,000 and could not be plotted on the figure. For a discussion of the limitations for using irrigation waters of these classes, refer to the "Quality Criteria" section.

Alteration of native-quality ground water has possibly occurred in one area of the Blaine Formation. The water in well 29-16-101 had a dissolved-solids content of 5,700 mg/l, a sodium content of 730 mg/l, and a chloride content of 1,014 mg/l. The chloride content of this water is more than double that of any of the other samples analyzed and it is thought to have been altered. The water is also high in calcium and magnesium content and, therefore, the cause for alteration is not thought to be oil-field brines. No apparent cause for the alteration was found.

Well Construction and Performance

The depth of the five inventoried Blaine wells ranged from 28 to 100 feet. Four of the wells were cased to unknown depths with 6-inch galvanized sheet-metal casing. Well 29-16-101 was cased to an unknown depth with 4-inch steel casing. The methods and depths of casing perforation are unknown.

The yields of all wells that produce from the Blaine Formation are believed to be less than 20 gpm.

History of Development, Utilization, and Pumpage

Three of the five wells inventoried as producing, or having produced, from the Blaine Formation are very old. Well 29-08-703 was drilled about 1950. Well 29-16-101 was drilled in 1964 and has not been used to date. All were drilled as domestic or livestock wells.

Only one of the five wells is presently being used. Well 29-08-703 is used only for household uses other than drinking. The pumpage on this well is very minor.

SURFACE-CASING RECOMMENDATIONS FOR WATER-QUALITY PROTECTION

The Texas Water Development Board provides recommendations to oil and gas operators and the Railroad Commission of Texas concerning the depth to which usable quality ground water should be protected in the drilling for oil and gas. The authority for participation by the Board in this 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 of the Railroad Commission of Texas 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 for oil or gas if the lease or area is not covered by field rules or lease recommendations. The Railroad Commission's Rule 8 requires that all fresh-water strata be protected in drilling, plugging, or production activities.

In carrying out its duties under Rule 13, the Texas Water Development Board maintains 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 program 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 importance 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 Jones 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.

This information is interpreted in the light of available knowledge of the geology and ground-water hydrology available on the area involved.

PRODUCTION AND DISPOSAL OF OIL-FIELD BRINE

Areas of Disposal, Disposal Methods, and Quantities

In 1962 and again in 1968, the Railroad Commission of Texas, the Texas Water Quality Board (formerly the Texas Water Pollution Control Board), the Texas Water Commission, and the Texas Water Development Board (1968) cooperated in the statewide collection and tabulation of information submitted by oil and gas operators concerning the 1961 and the 1967 oil-field brine production and the methods used for its disposal. A summary of these inventories, as they pertain to Jones County, is presented in Table 11.

Figure 33 delineates the areas of disposal, quantities of brine disposal, and methods of disposal within the county.

The areas of disposal, listed numerically 1 through 41 on Figure 33, were determined by outlining the areas of greatest concentration of producing oil and gas wells. No attempt is made in Figure 33 to separate the individual oil or gas fields; however, care was taken not to include parts of a field in more than one area. Statistics on brine disposal for individual oil and gas fields for the years 1961 and 1967 are tabulated in Table 11 by area.

The methods of disposal are by injection, surface pits, or miscellaneous methods. Waters listed as injected are those which are injected into the subsurface through the salt-water injection wells of a waterflood operation, through salt-water disposal wells, or those injected into a non-producing subsurface zone of a presently producing oil well. Waters listed under pits are those which are placed into open surface disposal pits. Waters listed under miscellaneous disposal are those which are disposed of by any other method, mainly through hauling by trucks to salt-water disposal or waterflood injection wells.

As of January 1, 1968, disposal of brine into pits had been discontinued in areas 1, 2, 4, 5, 7 through 12, 14 through 19, 22, 24, 25, 28, 31, 33, 35, 37 through 39, and 41. Disposal into pits had been drastically reduced in areas 3, 6, 13, 20, 21, 23, 26, 27, 29, 30, 32, 34, 36, and 40. In eleven areas the wells that had been producing in 1961 had been plugged by 1967. These areas were 5, 7, 12, 16, 17, 19, 22, 25, 28, 37, and 41. The only area which was producing brine during 1967 which had not produced brine in 1961 was area 4.

The alternate method of disposal, in most cases, has been by injection. A comparison of the volume and methods of disposal in 1961 and 1967 shows that total brine production in the county has increased but the total quantity of brine disposal in surface pits has decreased (Table 11). The total brine production in Jones County in 1961 was 14,817,891 barrels compared to 17,980,990 barrels produced in 1967. The amount disposed of in pits during 1961 was 719,485 barrels or 4.9 percent of the total as compared to 78,344 barrels or 0.4 percent of the total in 1967. Disposal by injection into wells in 1961 was 13,976,463 barrels (94.3 percent) and in 1967 was 17,533,908 barrels (97.5 percent). Miscellaneous disposal in 1961 and 1967 was 121,943 and 368,738 barrels, respectively. This was 0.8 percent of the total in 1961 and 2.1 percent of the total in 1967. For a comparison of the various methods of disposal, area by area and field by field, for 1961 and 1967 consult Figure 33 and Table 11.

Chemical Quality of Produced Brines

Table 9 and 10 are tabulations of the chemical analyses of some oil-field brines in Jones County. The brines have, for the most part, the same ions present that are present in waters from wells used for municipal, industrial, irrigation, and livestock supplies. However, the calcium, chloride, magnesium, and sodium ions are present in much greater concentrations in the brines. The content of dissolved solids is also much higher in the brines, ranging from 48,825 to 207,600 ppm. The concentrations of various ions in the tabulated brines range as follows:

Calcium (Ca)	1,520 to 17,480 ppm
Chloride (Cl)	33,110 to 129,000 ppm
Magnesium (Mg)	210 to 3,720 ppm
Sodium (Na) plus Potassium (K)	15,940 to 56,626 ppm

Produced Brine as a Potential Source of Ground-Water Contamination

Ground water is often subjected to contamination from various sources, and a major potential source of contamination is the improper disposal of oil-field brines. Prior to the advent of the statewide no-pit order, instigated by the Texas Railroad Commission, and which became effective on January 1, 1969, there was possibly considerable ground-water pollution caused by the disposal of produced brines in open, unlined surface disposal pits. Even though much evaporation took place in these pits, if soil conditions were conducive, there was considerable percolation or seepage of these brines downward, to the water table, resulting in the contamination of the native ground water. Occasional overflow of brines from these surface pits may also have contaminated surface waters. With the mixing of these brines with native ground water, there is usually a marked increase in the concentrations of, mainly, chloride and sodium ions in the ground water. These increases are reflected in the analyses of some of the waters in Jones County (Table 8). Figure 33 depicts the location of wells in Jones County which are apparently contaminated.

Contamination may also result when there is leakage from old, abandoned and improperly plugged oil tests, or from improperly cased producing oil wells. In cases such as these, the brines may move up the bore holes of improperly plugged or cased wells into the shallow fresh-water zones, due to both natural pressure in the brine-producing formations and the pressure created by secondary recovery injection operations. The Texas Railroad Commission now has limited funds available for plugging abandoned oil and gas wells or tests which may be leaking brines to the surface or subsurface, or to require plugging of these holes by those responsible. Much work has been done by the Texas Railroad Commission and oil operators to alleviate contamination problems resulting from brine produced with oil and gas.

GROUND-WATER PROBLEMS

Alteration of Native Water Quality

The quality of water derived from various formations in Jones County varies greatly (Table 8). Even with this exhibited wide range in quality, some of the waters sampled during this study appear to have been altered.

Both natural and artificial means contribute to the alteration of the chemical quality of ground water. Alteration occurs naturally when water dissolves minerals from the rocks through which it percolates or over which it flows. In Jones County natural alteration is evidenced by the high sulfate concentrations which are derived from gypsum and anhydrite, and by the high bicarbonate concentrations which are derived from dolomite and limestone. This is particularly true in the case of waters found in the rocks of Permian age. High sulfate concentrations are also very common in water obtained from the Recent alluvium, which is often recharged by waters from overflow of the Clear Fork Brazos River. This river flows over beds of gypsum which outcrop west of Jones County.

Artificial alteration of the quality of ground water may be by biological or chemical means. In wells that are positioned near, or downhill from, septic tanks and livestock feedlots or barnyards, biological contamination of the ground water may be suggested by an abnormally high nitrate concentration in the water. However, relatively high nitrate concentrations may occur in ground waters over wide areas and these are difficult to explain. Huberty, Pillsbury, and Sokoloff (1945, p. 14-15) suggested that the leaching of soil and humus in old mesquite groves, which were converted to irrigated farmlands, is the source of high nitrate in certain areas of California. This may well be the explanation, in some cases, in Jones County.

Alteration of ground water by chemical means may be associated with the operations of the oil and gas industry, or result from improperly constructed industrial waste disposal wells. Produced brines as a potential source of ground-water contamination have been discussed previously.

The locations of numerous wells which show evidence of contamination are shown on Figure 33. This illustration also shows several areas of vegetative kill which are apparently the result of discharge of oil-field brine onto the surface or overflow of brine from surface disposal pits. Figure 34 contains a series of radial-pattern diagrams which compare the relative concentrations of dissolved minerals in native ground water, in water from apparently contaminated wells, and in typical oil-field brines. The percentage of each major chemical constituent—Calcium (Ca), Magnesium (Mg), Chloride (Cl), Sodium (Na), Potassium (K), Sulfate (SO_4), and Bicarbonate (HCO_3)—is plotted on the radial axes and the plots are connected. The patterns thus formed illustrate the similarities and differences between the selected chemical analyses.

Although there are several indications of apparent contamination still evident in Jones County, efforts have been and are being made by the Texas Railroad Commission and the many petroleum operators to eliminate contamination of the surface water, soil, and ground water.

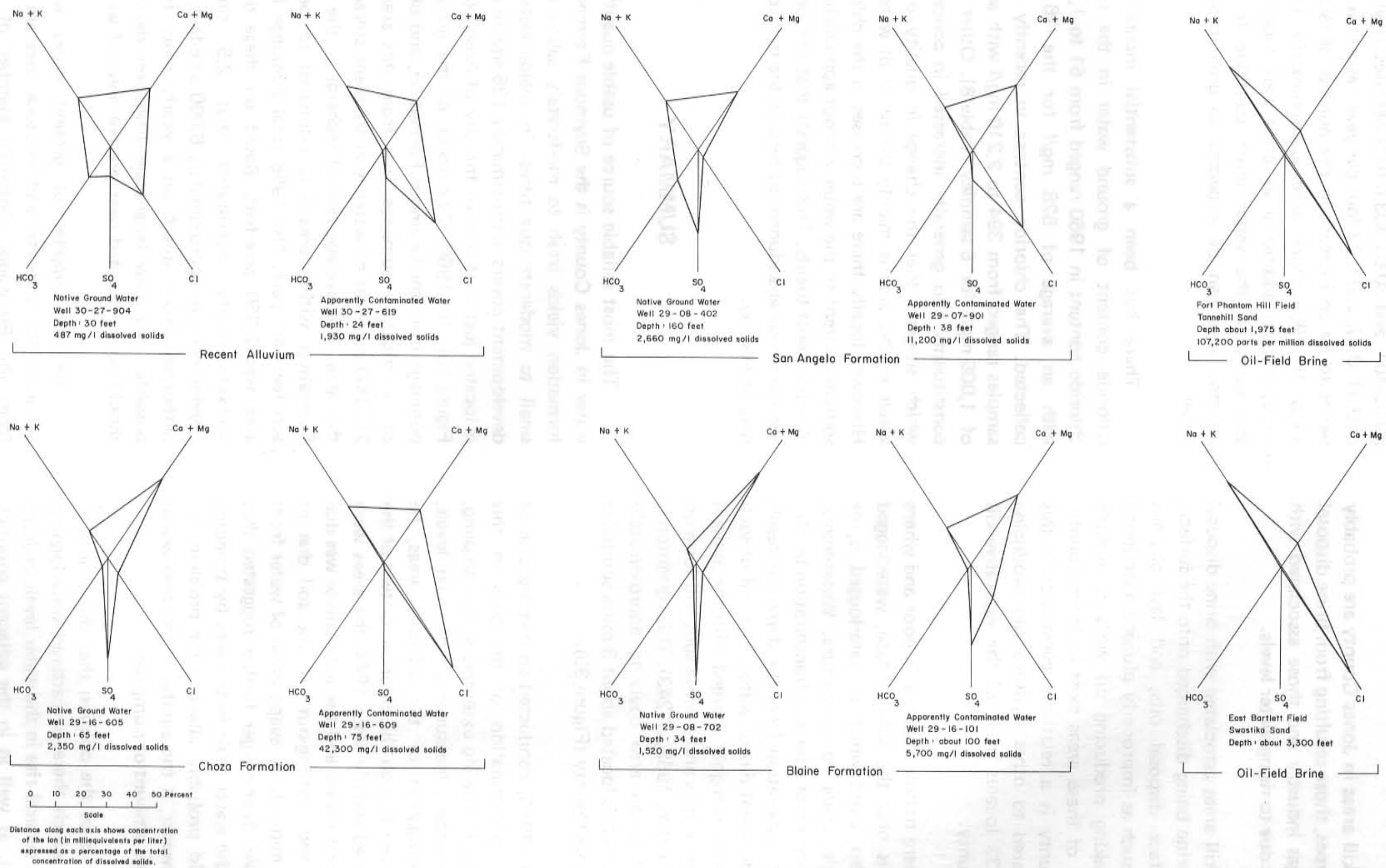

Figure 34

Diagrams of Chemical Analyses of Ground Water and Typical Oil-Field Brines

Areas of Vegetative Kill and Possible Causes

Vegetative-kill areas in Jones County are probably of two distinct types, those resulting from brine disposal by the oil and gas industry and those associated with waterlogged areas due to rising water levels.

Vegetative-kill areas associated with brine disposal can result from brine being discharged onto the surface, overflow of surface disposal pits, and less obvious sources of brine such as improperly plugged abandoned oil tests and leaking producing oil wells or leaking pipelines. Several of these areas exist in Jones County; however, the county is a relatively clean area in this respect as compared to other hydrocarbon producing counties. Figure 33 locates most of the vegetative-kill areas in Jones County.

In areas where natural drainage is poor and where the water table is near the land surface, waterlogged areas may develop. Land which is waterlogged is, or becomes, of little value to agriculture. Water-loving vegetation grows on these sites and transpiration by this foliage and direct evaporation from the damp soil result in the loss of large quantities of water. The soil of such areas, in time, becomes highly charged with the mineral residues from these waters and a white spot will form on the affected land (Hem, 1959, p. 243). This condition is thought to exist in an area covering approximately 10 square miles which is located about 3 miles southeast of Stamford in Jones County (Figure 33).

Shamburger (1960) conducted an investigation of the alleged salt contamination of the soils in this immediate vicinity. Following extensive water sampling, analyses of these waters, measurement of water levels, and general investigation of the affected areas, he concluded that, even though the chloride content of the waters had increased slightly since 1944, the areas were the result of natural causes and the soil damage was due to waterlogging and "salting-out" of the soil due to concentration of minerals by evaporation of water from a high water table. Shamburger further suggested that the lowering of the water table in the area by pumping or ditching would probably alleviate the problem. He was doubtful, however, if the aquifer in this area would sustain a significant amount of pumpage.

The author is of the opinion that the area is, in fact, an area in which there is scattered waterlogging. There has been a general rise in the water levels in Jones County (Table 6), as well as in the adjacent counties. The water levels in this area ranged from approximately 3 to 10 feet below ground level in 1959, and during this study the shallowest water level encountered was 2.08 feet below land surface, in well 30-03-401. Historical water-level data on wells 30-02-808, 30-03-401, and 30-03-603 reflect net rises in water levels of 0.37, 0.47, and 0.22 foot per year, respectively. There seems to be an increase in the number of salt-affected areas. In 1959 there were approximately 15 known areas, and an additional six areas were located during this study. If the water levels continue to rise, the affected area can be expected to grow progressively larger.

There has been a substantial increase in the chloride content of ground water in the area. The chloride content in 1960 ranged from 61 to 1,130 mg/l with an average of 528 mg/l for the 16 samples collected. The chloride content in recently collected samples ranged from 394 to 2,210 mg/l with an average of 1,005 mg/l for 6 samples (Table 8). Other chemical constituents also generally increased in concentration, which suggests that the change in quality of ground water in this area is mainly the result of waterlogging. However, locally there are increases in the chloride and sodium content of the water without appreciable change in other constituents. This suggests that one or more of the numerous abandoned oil tests in the immediate area may be leaking.

SUMMARY

The most reliable source of usable-quality ground water in Jones County is the Seymour Formation. The formation yields fresh to moderately saline waters in small to moderate quantities. Its major water-bearing development covers approximately 126 square miles and is located just southeast of the city of Anson (area A of Figure 10). In 1968, 74 percent of the ground-water pumpage from the Seymour Formation, and 80 percent of its irrigation pumpage, was from this area. About 213,000 acre-feet of water is in transient storage within this area. The average rate of recharge to the Seymour Formation within area A is estimated to be 10,200 acre-feet per year. The 1968 total pumpage from this area was 2,350 acre-feet. Based on these data, it is conservatively estimated that 2.5 times this development, or approximately 6,000 acre-feet, could be withdrawn from area A on a yearly basis. Insofar as possible, any new large-scale irrigation developments should not be located near present areas of withdrawal.

Reliable supplies of ground water which are adequate for domestic and livestock uses are available from the Bullwagon Dolomite Member of the Vale Formation, other units of the Vale Formation, the Choza Formation, and the Recent alluvium. These waters are also used for limited industrial and irrigation purposes. The aquifers yield fresh to moderately saline water in small to moderate quantities.

The San Angelo Formation reliably yields small quantities of moderately saline water which is presently being used mostly for domestic and livestock purposes. The water is also used for irrigation in two small areas.

The Lueders, Arroyo, and Blaine Formations contain unreliable sources of ground waters of fresh to moderately saline quality in small quantities which can be used for domestic and livestock purposes.

The chemical analyses of water samples of this and previous investigations indicate that only a few scattered areas of Jones County produce ground waters that meet the chemical quality standards recommended for public supplies by the U.S. Public Health Services. The waters commonly have a high content of sulfate, nitrate, chloride, and dissolved solids.

Alteration of native-quality ground water in several wells in Jones County has resulted, presumably, from the disposal of oil-field brines into unlined surface pits or from abandoned oil or gas tests which are leaking. Most brine contamination sources are thought to have been eliminated by the statewide no-pit order issued by the Railroad Commission of Texas. However, since contamination in ground water may continue for long periods of time after the sources are removed, it would be advisable to set up a program for periodic resampling of selected wells to check the amounts and extent of the contamination.

In order to further evaluate the future effects of heavy irrigation or industrial pumpage from the various aquifers, a network of 19 observation wells has been established in Jones County in which water levels are planned to be measured and recorded annually by personnel of the Texas Water Development Board.

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Table 6. -- Records of Wells and Springs

All wells are drilled unless otherwise noted in remarks column.
Water level : Reported water levels given in feet; measured water levels given to the nearest tenth or hundredth of a foot.
Method of lift and type of power: A, airlift; C, cylinder; Cf, centrifugal; E, electric; G, gasoline, butane, or Diesel engine; H, hand; J, jet; N, none; Ng, natural gas; T, turbine; W, windmill. Number indicates horsepower.
Use of water : D, domestic; Ind, industrial; Irr, irrigation; N, none; P, public supply; S, livestock.
Water-bearing unit : Kea, Edwards and associated limestones; Ewi, Wilcox Group; Ec, Carrizo Sand; Er, Reklaw Formation; Eqc, Queen City Sand; Ew, Weches Formation; Eb, Bigford Formation; Eep, El Pico Clay; Es, Sparta Sand; El, Laredo Formation; Ecm, Cook Mountain Formation; Ey, Yegua Formation; Ej, Jackson Group; Mc, Catahoula Tuff; Mo, Oakville Sandstone; Ml, Lagarto Clay; Ql, Leona gravel; Qt, terrace gravel; Qal, alluvium.

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
					DIAM-ETER (in.)	DEPTH (ft)			BELOW LAND-SURFACE DATUM (ft)	DATE OF MEASUREMENT			
* 29-07-601	Jake Weir	F. Wallace	1964	30	4	30	Qs	1,748	4.6 6.1	Jan. 30, 1968 Jan. 16, 1969	J, E	S	Water sand reported at 18 feet.
* 602	do	-- Weir	--	25	4	--	Qs	1,749	6.1 9.8	Jan. 30, 1968 Jan. 16, 1969	N	N	--
* 901	Bobby Crowley	Bobby Crowley	1966	38	10	38	Pprsa	1,725	21.7	Feb. 9, 1968	J, E	D	Hand augered. Used only for watering yard. Water sand reported at 34 to 38 feet. Reported yield 4.5 gpm.
* 902	Floyd Cliffton	G. D. Rodgers	1967	40	7	40	Pprsa	1,729	10.7	do	S, E	D	Water not used for human consumption. Water reported from sand and gravel. Yield reported 15 gpm.
* 903	C. R. Crowley	Ed Chapman	1964	50	7	50	Pprsa	1,728	10.5	do	C, E	D	Water not used for human consumption. Water reported from sand and gravel at 30 to 40 feet. Yield reported greater than 10 gpm.
08-401	Mrs. J. W. Hines	--	--	173	8	--	Pprsa	1,748	69.2 49.4	July 30, 1953 Jan. 29, 1968	C, E	S	Water not used for human consumption. Well A-3 of Bulletin 5418. 1/
* 402	George Harrell	--	--	160	8	--	Pprsa	1,758	60.0	do	C, W	N	--
* 403	Louis B. Baker	--	--	37	6	--	Pprb	1,734	9.9	do	N	N	--
* 404	W. B. Walton	F. Wallace	1962?	125	6	125	Pprsa	1,743	15.7	Feb. 6, 1968	C, W	D, S	Water not used for human consumption. Water zone reported at 70 feet.
405	A. W. Gray estate	--	--	40	6	--	Pprb	1,748	--	--	C, W	N	Well possibly caved at 12 feet.
* 501	Otto Steinke	--	--	40	6	--	Pprsa	1,707	21.1	July 14, 1953	C, W	D, S	Water not used for human consumption. Well A-5 of Bulletin 5418. 1/
* 502	do	--	--	Seep	--	--	Pprsa	1,691	(+)	Feb. 5, 1968	N	N	Flows from vegetative-kill area.
* 503	Moore Elevator	--	--	48	6	--	Pprsa	1,762	24.4 9.1	July 11, 1953 Feb. 5, 1968	C, W	D, S	Well A-4 of Bulletin 5418. 1/
* 504	D. O. Waymire	--	1905?	24	--	--	Pprsa	1,733	4.3	Feb. 6, 1968	J, E	D, S	Dug well.
* 601	A. V. Jones and Sons	-- Clark	1950	87	8-5/8	--	Qs	1,675	--	--	N	N	Industrial well formerly used in development of oil field.
* 602	Swenson Land and Cattle Company	--	--	50	7	--	Pcfc	1,637	11.6	Nov. 6, 1967	C, W	S	--
603	do	--	--	30	7	--	Pcfc	1,636	9.6	do	N	N	--
* 604	do	--	--	50	7	--	Pcfc	1,640	12.5	do	C, W	S	--
605	do	--	--	50	7	5?	Pcfc	1,641	14.8	do	N	N	--
* 701	Mrs. B. H. Gardner	--	1914	80	6	--	Pprsa	1,712	23.1 12.5	July 14, 1953 Jan. 29, 1968	J, E	D, S	Water not used for human consumption. Well A-6 of Bulletin 5418. 1/

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- Continued

	WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (ft)	CASING DIAM-ETER (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
*	29-08-702	R. E. Brewer	--	--	34	14 6	1 --	Pprb	1,723	20.3	Feb. 9, 1968	C, N	N	--
*	703	J. O. Priddy	J. O. Priddy	1950?	28	6	--	Pprb	1,704	7.5	do	C, W	D	Water not used for human consumption. Water sand reported at 18 to 28 feet.
*	801	F. L. Adamson	--	--	30	6	--	Qs	1,673	19.0 18.3	Jan. 30, 1968 Jan. 15, 1969	J, E	D, S	Water not used for human consumption.
*	802	Clarence and Marg Hyer	--	1905	17	--	--	Pcfm	1,700	17.2 11.0	July 14, 1953 Jan. 30, 1968	C, E	D	Dug well. Well A-8 of Bulletin 5418. 1/
*	803	M. F. Jones	--	1945	40	6	--	Pprsa	1,698	17.0	Mar. 7, 1968	C, W	S	--
	804	Moore Elevator	--	--	40	6	--	Pprsa	1,705	26.2	do	N	N	--
*	805	do	Jack Leonard	--	78	5-1/2	--	Pprsa	1,709	29.6	do	J, E	S	--
	806	do	do	1965	68	6	--	Pprsa	1,710	32.1	do	S, E	S	Water sand reported at about 35 feet.
*	807	Culberson estate	--	1942	32	--	--	Qs	1,675	15.7	Dec. 11, 1968	N	N	Dug well.
*	901	J. F. Compton estate	F. Hill	1942	41	6	--	Qs	1,668	14.1 2.6 6.5	Mar. 17, 1944 Jan. 30, 1968 Jan. 15, 1969	C, N	N	Well A-7 of Bulletin 5418. 1/
*	902	G. R. Riddle	--	--	20	--	--	Qs	1,640	1.4	Mar. 5, 1968	J, E	D, S	Dug well. Water not used for human consumption.
	903	do	--	1954?	60	6	60	Pcfc	1,645	--	--	C, W	D	Water not used for human consumption. Water reported at 33 feet in streak in the redbeds.
	904	I. B. Ray	--	--	17	6	--	Qal	1,653	10.8	Mar. 5, 1968	C, W	N	--
	15-301	Mrs. Fed Britton	--	1938	100	6	--	Qs	1,756	--	--	C, W	N	Well believed caved at 24 feet.
*	601	Mrs. L. H. McBride	--	--	160	6	--	Pprsa	1,780	77.2 12.0	July 30, 1953 Jan. 30, 1968	C, W	N	Well E-1 of Bulletin 5418. 1/
*	901	D. D. Kerns	D. D. Kerns	1963	50	6	--	Pprsa	1,867	23.9	Jan. 25, 1968	J, E	D, S	Water not used for human consumption.
*	902	A. M. Downey estate	--	--	190	6	--	Pprsa	1,826	19.1 10.3	July 30, 1953 Jan. 25, 1968	C, W	S	Well E-5 of Bulletin 5418. 1/
*	903	L. E. Rector	--	--	290	5-1/2	--	Pprsa	1,817	54.4	Jan. 26, 1968	J, E	D	Water not used for human consumption.
*	16-101	H. D. Lain	Ed Chapman	1964	100?	4	--	Pcfb	1,734	19.4	Jan. 29, 1968	N	N	--
*	201	Josephine Holmes	--	1922	70	6	--	Pprsa	1,746	18.0 14.2	July 11, 1953 Feb. 9, 1968	C, W	D, S	Water not used for human consumption. Well A-10 of Bulletin 5413. 1/
*	202	Mrs. Dave Herbst	--	--	60	6	60	Pprsa	1,741	9.0	do	C, W	D, S	--
*	301	H. L. Ford	--	1941	37	6	37	Pcfc	1,671	11.5	Feb. 8, 1967	J, E	D, S	Nearby core test encountered water at 18, 37, and 52 feet in dolomite(?). Yield estimated 30 gpm.
*	302	Raymond Scifres	--	1963?	31	6	--	Qs	1,684	12.0	Feb. 7, 1968	J, E	D	Water not used for human consumption. Water reported from sand.
*	401	J. J. King	--	1930	31	6	31?	Pprsa	1,779	16.2	Apr. 24, 1967	C, W	S	--
*	402	do	--	1890	37	--	--	Pprsa	1,782	21.6	do	J, E	D, S	Dug well.
*	403	J. L. Weaver	W. C. McBride	--	42	6	--	Pprsa	1,773	20.6 16.5	July 10, 1953 Jan. 25, 1968	J, E	D	Water not used for human consumption. Well E-4 of Bulletin 5418. 1/
*	404	J. E. Brown	Jess Whitaker	1951	42	7	42	Pprsa	1,780	17	do	J, E	D	Water not used for human consumption. Water reported at 28 to 35 feet in sand.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
* 29-16-405	F. E. Gauntt	--	--	110	6	--	Pprsa	1,801	25 27.3	July 13, 1953 Jan. 27, 1968	N	N	Well E-5 of Bulletin 5418.1/
* 406	R. G. McKinney estate	--	1953	50	6	--	Pprsa	1,772	15.3	Jan. 29, 1968	S, E	D, S	Water not used for human consumption. Water reported from sand at about 43 feet. Yield reported 5 to 6 gpm.
* 407	Ina Mae Staton	--	1965	28	6	28	Pprsa	1,751	13.3	Feb. 7, 1968	C, W	S	Water sand reported at 22 to 28 feet.
* 501	Mrs. Frank Taylor	--	--	80	8	--	Pprsa	1,784	14.6	Jan. 30, 1968	C, W	S	Minor water sand reported at about 17 feet, main water at 65 feet.
* 502	Irby Weaver	--	1919?	80	8	--	Pprsa	1,804	27.6	do	C, W	S	Main water reported at 65 feet.
503	W. G. Kelley	--	1952	80	--	--	Pprsa	1,804	28	Jan. 30, 1968	C, E	D, S	Do.
* 504	John Green	--	--	91	6	--	Pprsa	1,772	14.2	Feb. 7, 1968	C, N	N	--
601	J. B. Young	--	--	71	6	--	Pcfc	1,729	45.8	July 10, 1953	C, W	N	Well now caved at 8.5 feet. Well E-2 of Bulletin 5418.1/
* 602	Chittenden estate	--	--	64	5	5	Pcfc	1,717	21.8	Jan. 20, 1967	C, W	S	--
* 603	do	--	--	32	--	--	Pcfc	1,717	22.3	do	C, G	N	Dug well.
* 604	do	P. A. Lynn	1948	65	4	65	Pcfc	1,734	25.9	do	N	N	Formerly supplied Clark and Cowden Oil Company lease house.
* 605	do	do	1961	65	4	65	Pcfc	1,735	25	do	J, E	D	Supplies Clark and Cowden Oil Company lease house.
606	do	do	1951	60	5-1/2	56	Pcfc	1,735	25.8	do	N	N	Formerly used as water source in development of oil field.
* 607	do	Ed Chapman	1967	40	--	--	Pcfc	1,738	32.0	Jan. 26, 1967	N	N	Test hole. Salt water encountered at 31 feet in dolomite.
* 608	do	P. A. Lynn	--	81	6	5	Pcfc	1,748	78.4	Jan. 20, 1967	C, W	S	--
* 609	do	Ed Chapman	1967	75	--	--	Pcfc	1,755	44.0	Jan. 26, 1967	N	N	Test hole. Driller reported good water at 60 feet and salt water invaded well bore overnight.
* 610	do	P. A. Lynn	1960?	59	6	59	Pcfc	1,732	34.1	Jan. 20, 1967	C, W	S	--
701	R. P. Williams	--	--	51	6	--	Pprsa	1,809	18 10.8	July 10, 1953 Jan. 25, 1968	C, W	S	Well E-6 of Bulletin 5418.1/
* 702	J. Noel Weaver	Jess Whitaker?	1948	55	6 5	30 55	Pprsa	1,799	13.7	Apr. 24, 1967	C, W	D, S	Main water reported at 42 feet.
* 703	do	Frank Hill	1952	105	6	60	Pprsa	1,807	26.0	do	J, E	D	Main water reported at 42 to 47 feet. Reported yield 15 gpm.
* 704	do	--	--	33	--	--	Pprsa	1,791	17.0	do	C, W	S	Dug well.
705	do	Ed Chapman	1965	55	4	55	Pprsa	1,812	13.1	do	N	N	Salty water reported at 18 to 26 feet, main water at 42 to 48 feet, both in sandy gravel.
* 706	do	do	1966	60	5-1/2	60	Pprsa	1,812	12.8	do	C, E	S	Main water reported at 39 to 40 feet and 52 to 53 feet. Reported yield 5 gpm.
* 707	Leslie Cory	Leslie Cory	1953	75	6	20	Pprsa	1,839	17.9	Jan. 17, 1968	J, E	D, S	Water reported at 20 to 25, 40, and 60 to 75 feet.
708	do	--	--	60	6	20	Pprsa	1,841	--	--	C, N	N	--
* 709	do	F. Hill	1952	140	10	30	Pprsa	1,835	15.0	Jan. 17, 1968	S, E, 3	Irr	Water reported at about 20, 40, 60, and 85 to 100 feet in sand and gravel. Reported yield 30 gpm.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
* 29-16-710	Milton Carter	--	1954?	50±	6	--	Pprsa	1,887	15.8	Jan. 25, 1968	J, E	D	Water not used for human consumption.
* 711	R. P. Williams	Leslie Cory	1958?	60	5-1/2	--	Pprsa	1,809	10.1	do	J, E	D	Do.
* 801	G. D. Beall	Ed Chapman	1963	55	4	40	Pprsa	1,848	24.1	Apr. 24, 1967	C, W	S	Main water reported at 40 to 46 feet in sandy gravel. Reported yield 10 gpm.
* 802	Homer L. Neal	--	--	46	8	--	Pprsa	1,863	19.6	Jan. 26, 1968	J, E	D, S	Water not used for human consumption. Reported yield 5 to 6 gpm.
803	do	--	--	96	8	--	Pprsa	1,878	46.8	do	C, W	S	--
* 804	J. P. Bingham	--	--	80	--	--	Pprsa	1,867	34.1	do	C, W	D, S	--
* 901	Sam Brooks	--	1953	32	--	--	Pcfc	1,795	17.1	June 20, 1953	N	N	Destroyed. Well E-8 of Bulletin 5418. 1/
902	Joe J. Steel	--	--	62	8	--	Pcfc	1,775	33.4	July 14, 1953	J, E	S	Well E-7 of Bulletin 5418. 1/
23-601	J. T. Jeffrey	G. W. Rodgers	1960	26	12	26	Qal	1,777	16.1 19.7	Aug. 10, 1960 Feb. 23, 1967	T, E, 10	Irr	Water reported from sand and gravel at 12 to 24 feet. Reported yield 207 gpm.
602	A. Darwin Hill	Bob Dennis	1955	65	6	65	Qs	1,806	--	--	C, E	D	Water reported from gravel at 50 to 60 feet.
* 603	do	G. W. Rodgers	1962	35	6	37	Qs	1,809	--	--	C, E	D	Water reported from sand and gravel at 27 to 32 feet.
604	W. C. Sojourner, Jr.	do	1962	32	12-3/4	34	Qs	1,796	21.6 20.9	Jan. 15, 1968 Jan. 10, 1969	Cf, E	Irr	Cased with 48-inch concrete rings to 14 feet; 12-3/4 inch casing from 12 to 34 feet. Reported yield 125 gpm. Water reported from sand and gravel at 17 to 29 feet.
605	J. T. Jeffery	Ed Chapman	1964	29	12-3/4	29	Qal	1,778	16.9	Feb. 23, 1967	Cf, E	Irr	Water reported from sand and gravel at 17 to 28 feet.
* 606	A. Darwin Hill et al.	G. W. Rodgers	1960	37	12-1/2	37	Qs	1,792	18.7 20.4 19.7 18.4 19.3	Feb. 22, 1967 Sept. 18, 1967 Jan. 15, 1968 May 15, 1968 Jan. 10, 1969	T, E, 5	Irr	Water reported from sand and gravel at 16 to 36 feet. Measured yield 307.8 gpm (average for 48 hours). Observation well.
607	J. T. Jeffery	--	--	24	12	24	Qal	1,777	14.6 16.9	July 13, 1953 Feb. 23, 1967	T, E, 15	Irr	Dug well. 1967 water level measured after pumping about 12 hours. Reported yield 150 gpm. Well E-18 of Bulletin 5418. 1/
* 608	Orvel F. Hill	G. W. Rodgers	1963	35	12-3/4	34	Qs	1,820	23.1	do	T, E, 7.5	Irr	Water reported from sand and gravel at 9 to 33 feet.
* 609	Bill W. Ashley	do	1963	41	10	41	Qs	1,798	24.5	do	C, W	S	Water reported from sand and gravel at 22 to 38 feet.
610	do	do	1963	34	12	31	Qs	1,797	20.6 21.0	do May 10, 1967	Cf, E, 10	Irr	Water reported from sand and gravel at 15 to 29 feet. Reported yield 30 gpm.
611	Orvel F. Hill	do	1960	38	12-1/2	38	Qs	1,794	20.7	do	T, E, 15	Irr	Water reported from sand and gravel at 16 to 35 feet. Reported yield greater than 300 gpm.
* 612	do	--	1921?	32	--	--	Qs	1,806	29.4	Feb. 23, 1967	J, E	D, S	Dug well.
613	do	--	--	24	--	--	Qs	1,805	22.4	do	N	N	Do.
901	B. W. Jeffrey	G. W. Rodgers	1959	25	12	25	Qal	1,773	9.7 10.8	Nov. 23, 1959 Feb. 22, 1967	T, E, 10	Irr	Water reported from sand and gravel at 11 to 22 feet. Reported yield 200 gpm.
* 902	A. Darwin Hill	--	1906	80	6	80	Qs	1,801	26.0 26.7 25.8	do Jan. 15, 1968 Jan. 10, 1969	C, W	S	--

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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			
* 29-23-903	A. Darwin Hill and W. W. Hill	--	1923	88	6	88	Qs	1,799	23.6	Feb. 22, 1967	S, E	S	Dug to 45 feet; later drilled to 88 feet and 6-inch casing set from 45 feet to bottom.
* 904	A. Darwin Hill et al.	G. W. Rodgers	1960	29	12-1/2	29	Qal	1,781	12.7	do	T, E, 5	Irr	Water reported from sand and gravel at 8 to 29 feet. Measured yield 200 gpm.
* 905	do	do	--	26	12	26	Qal	1,778	12.1 13.6 12.9 11.5 12.8	do Oct. 9, 1967 Jan. 15, 1968 June 14, 1968 Jan. 10, 1969	C, E, 5	Irr	Dug well, drilled deeper in 1964. Measured yield 180 gpm. Observation well.
* 906	A. J. Hill	do	1960	29	12	29	Qal	1,764	15.0	Feb. 22, 1967	T, E, 15	Irr	Reportedly encountered 15 feet of sand and gravel. Reported yield 300 gpm.
* 907	do	do	1960	31	12	31	Qal	1,770	17.0	do	N	N	Abandoned irrigation well. Water reported from sand and gravel at 16 to 30 feet. Reported yield 300 gpm.
* 908	B. W. Jeffrey	do	1959	22	10	22	Qal	1,778	13.7	Feb. 23, 1967	J, E	D, S	Reported yield 100 gpm.
909	do	do	1962	29	12-3/4	29	Qal	1,771	18.0	do	N	N	Unused irrigation well. Water reported from sand and gravel at 10 to 24 feet. Reported yield 70 gpm.
* 24-101	Dee Cory	--	--	65	8	--	Pprsa	1,861	22.7	Jan. 17, 1968	C, W	N	--
* 102	H. E. Downey	P. A. Lynn	1962	52	6	34	Qs	1,897	16.4 15.8	Jan. 25, 1968 Jan. 15, 1969	C, W	S	Minor amount of water reported at 30 feet, main water at 45 feet.
* 103	do	--	--	16	--	--	Pprsa	1,890	15.7	do	N	N	Dug well.
* 201	Doyle Jacobs estate	--	--	59	6	59	Pcfc	1,810	20.0	Feb. 7, 1967	C, W	S	--
* 202	Mrs. Z. Edgar Boaz	Ed Chapman	1965	60	5-1/2	60	Qs	1,881	34.6 37.8	Oct. 18, 1967 Jan. 15, 1968	C, W	S	Water reported in sand and gravel at 49 to 58 feet. Reported yield 3 to 4 gpm.
* 203	Bill Feagan	--	--	87	6	--	Pprsa	1,890	69.5 49.9 56.9	July 10, 1953 Jan. 25, 1968 Jan. 10, 1969	N	N	Well E-9 of Bulletin 5418.[1] The 1969 water level is possibly a pumping level.
* 204	J. C. Rainwater	--	--	27	--	--	Pcfc	1,794	13.3 2.1	July 9, 1953 Mar. 7, 1968	C, G	S	Dug well. Well E-14 of Bulletin 5418.[1]
205	General American Oil Company of Texas	--	1960	6,245	13-3/8 7	118 6,065	Ch	1,858	--	--	C, N	N	Formerly used as an industrial salt water supply well in the Bartlett oil field waterflood.
* 301	J. M. Arnett	--	1900?	60	5	60	Pcfc	1,828	26.9	Feb. 9, 1967	C, W	D, S	--
302	do	--	--	57	5	57	Pcfc	1,830	33.6	do	C, W	S	--
* 303	do	--	--	25	--	--	Qs	1,819	10.6	do	C, W	S	Dug well.
* 304	do	--	--	30	--	--	Qs	1,800	6.7	do	C, W	N	Do.
* 305	do	--	1950	55	10-1/2	55	Qal	1,782	5.2	do	N	N	Formerly used in drilling oil wells.
* 306	do	--	--	33	--	--	Pcfc	1,820	20.7	do	C, W	D, S	Dug well.
* 307	L. D. Crumpler	--	--	74	--	--	Qs	1,860	21.0 20.3 20.1 18.0	July 9, 1953 Nov. 14, 1967 Jan. 24, 1968 Jan. 10, 1969	J, E	D, S	Dug well. Well E-12 of Bulletin 5418.[1]
* 308	J. M. Arnett	--	--	26	--	--	Pcfc	1,791	13.6	Feb. 9, 1967	C, W	N	Dug well.
* 309	B. F. Higgins	Herring Drilling Company?	1949?	52	6	52	Pcfc	1,778	2.9	Jan. 26, 1968	J, E	D, S	Water not used for human consumption.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
					DIAM-ETER (in.)	DEPTH (ft)			BELOW LAND-SURFACE DATUM (ft)	DATE OF MEASUREMENT			
* 29-24-310	E. O. White	Leland Fikes Oil Company	1953	90	6	90	Qs	1,818	13.8 12.6 8.8 11.2 12.1	Oct. 17, 1967 Jan. 15, 1968 Apr. 17, 1968 Sept. 16, 1968 Jan. 10, 1969	N	N	Formerly used in drilling nearby oil wells. Observation well.
* 311	do	--	1914?	72	6	40	Qs	1,831	40	Oct. 10, 1967	J, E	S	--
* 312	J. C. Rainwater et al.	--	1910?	100	--	--	Qs	1,861	23.0	Nov. 13, 1967	C, W	S	Dug well. Well E-11 of Bulletin 5418.1/
* 313	do	--	1951	85	12	--	Pcfc	1,862	55.6	do	J, E	D, S	Well E-10 of Bulletin 5418.1/
401	A. Darwin Hill	--	1946	65	6	65	Qs	1,818	28.8 34.5 33.9	Feb. 22, 1967 Jan. 15, 1968 Jan. 10, 1969	C, W	N	--
402	do	Robert Higgins	1952	120	6	30	Qs, Pprsa	1,819	36.2 38.6 42.3	Feb. 22, 1967 Jan. 15, 1968 Jan. 10, 1969	C, W	S	Main water reported at 78 feet, from clay beneath a limestone. Reported yield 10 gpm.
* 403	Jim S. Richards	do	1962	50	6	50	Qs	1,815	15.2 8.8	Oct. 17, 1967 Jan. 15, 1969	J, E	D, S	Water reported from sand and gravel at about 30 feet.
404	do	--	--	28	--	--	Qs	1,819	13.5	do	C, W	N	--
405	do	--	--	29	24 6	29 8	Qs	1,825	13.1	Oct. 17, 1967	N	N	Casing: 6-inch from surface to 8 feet, 24-inch from 8 to 29 feet.
406	do	--	--	18	24	18	Qs	1,825	12.5	do	C, W	N	--
* 407	do	J. T. Coates and Son	1940	105	7	67	Pprsa	1,880	63.7	do	N	N	Drilled for a water source for an oil test. Reported yield about 1 gpm.
* 501	H. H. Boaz	Johnson and Henderson	1965	31	14	31	Qal	1,740	20.4	Mar. 7, 1967	T, E, 25	Irr	Water reported in sand and gravel at 22 to 30 feet.
* 502	do	do	1965	32	14	32	Qal	1,745	20.6	do	T, E, 3	Irr	Water reported in sand and gravel at 32 to 29 feet. Reported yield 150 gpm. This well and 29-24-501 have a combined measured yield of 168.9 gpm.
* 503	Mrs. Lela Boaz	--	1935?	30	--	--	Qal	1,748	25.9	do	C, W	S	Dug well. Water reported from sand and gravel.
* 504	do	-- Coates	1942	56	6	56	Qal	1,750	31.0	do	J, E	D, S	Water reported at 40 and 60 feet in sand and gravel.
* 505	do	--	1930?	60	5	60	Qs	1,762	26.7	do	C, W	S	--
* 506	do	--	1920	26	--	--	Qs	1,762	15.0	do	N	N	Dug well.
* 507	Jim S. Richards	Robert Higgins	1964	100	7	100	Pprsa, Qs	1,870	70.2 54.6	Oct. 17, 1967 Jan. 15, 1969	C, W	S	Water reported from sand and gravel at 44 to 59 feet. There were two more breaks with water below 59 feet, both in sand and gravel.
* 508	Mrs. Z. Edgar Boaz	Ed Chapman	1964	65	6 5-1/2	-- 65	Pcfc	1,798	49	Oct. 18, 1967	J, E	D, S	Water reported at about 50 feet.
* 509	do	--	--	34	--	--	Qal	1,770	18.2 13.2	July 9, 1953 Oct. 18, 1967	C, W	N	Dug well. Well E-15 of Bulletin 5418.1/
* 510	do	--	--	8	--	--	Qs	1,779	2.9 2.5 2.0	Oct. 18, 1967 Jan. 15, 1968 Jan. 10, 1969	N	N	Dug well.
* 511	do	--	--	57	--	--	Qs	1,762	39.2 38.7 38.3	do Jan. 15, 1968 Jan. 10, 1969	C, W	S	Dug well.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
* 29-24-601	Hoke Propst	--	--	69	7	69	Qs	1,822	30.9 30.8 31.5	Nov. 21, 1967 Jan. 15, 1968 Jan. 10, 1969	C, W, J, E	D	--
* 602	C. W. Lee	--	--	11	--	--	Pcfc	1,790	6.5	Nov. 21, 1967	N	N	Dug well.
603	do	--	--	42	6	--	Pcfc	1,790	6.4	do	C, H	N	--
* 604	do	--	--	46	6	--	Pcfc	1,798	16.2	do	J, E	D, S	--
605	Hoke Propst	--	1952?	55	6	--	Pcfc	1,745	15.7	do	C, W	N	--
* 606	L. E. C. Boyd et al.	--	--	59	8-1/4	59?	Qs	1,730	18.5 18.8	Nov. 22, 1967 Jan. 16, 1968	C, W	S	Originally a dug well, now cased.
* 701	Dickinson estate	--	--	36	--	--	Qal	1,769	29.4 28.5	July 13, 1953 Jan. 17, 1968	J, E	D, S	Dug well. Well J-1 of Bulletin 5418.1/
* 801	Dr. J. C. Duff and and J. W. Adams	Earl Slick	1951	49	10-1/2	49	Qal	1,765	20.6 10.7	June 20, 1953 Feb. 9, 1967	C, W, S, E, 3	Irr	Former oil test with total depth 5,508 feet; plugged back to 49 feet. Reported yield 78 gpm. The 1953 water level was a pumping level. Well J-3 of Bulletin 5418.1/
* 802	do	--	1952?	44	6	44	Pcfc	1,765	29.4	June 20, 1953	C, E	D, S	Well J-4 of Bulletin 5418.1/
* 803	do	--	--	27	--	--	Qal	1,760	9.0	Feb. 9, 1967	N	N	Dug well.
* 804	Herman A. Reeves	--	--	50	--	--	Qal	1,750	27.0	Feb. 27, 1967	J, E	D, S	Do.
* 805	do	Hollis Davis	1962	40	13	40	Qal	1,745	--	--	T, E, 5	Irr	Water reported from sand and gravel at 24 to 39 feet. Yield measured 324.3 gpm.
† 806	Nueve Operating Company, Incorporated	Sojourner Drilling Company	1962	6,001	10-3/4 7	140 5,802	Ch	1,730	800	July 4, 1968	C, E, 100	Ind	Industrial salt water supply well which was used in an oil field waterflood operation. Yield reported 117 gpm.
* 807	H. H. Boaz	Ed Chapman	1967	60	6	60	Qal	1,750	31.8	Mar. 7, 1967	C, W	S	Water reported from sand and gravel at 48 to 53 feet. Reported yield 10 gpm.
* 808	Mrs. Lela Boaz	Robert Higgins	1961	60	5-1/2	60	Pcfc	1,768	40.8	do	C, W	S	Water reported from clay.
809	do	do	1956	80	6	80	Pcfc	1,756	29.5	do	C, W	N	Do.
* 810	Winston Polly et al.	Fryer and Hanson	1956	83	7-5/8	75	Qal	1,757	28	Mar. 7, 1967	C, G, 16?	Ind	Industrial fresh water supply well used in oil field waterflood. Water reported from a sand and gravel at 75 to 81 feet.
* 901	Dr. J. C. Duff and J. W. Adams	--	--	16	--	--	Qal	1,755	8.4	Feb. 9, 1967	N	N	Dug well.
* 902	do	Shurffleft Brothers	1965	49	5	49	Qal	1,755	9	Feb. 9, 1969	J, E	D	Water reported at 24 to 26 and 43 to 49 feet in gravel.
* 903	Hoke Propst	--	1955?	71	6	--	Qs	1,805	32.8	Nov. 22, 1967	C, W	S	--
904	do	--	1940?	50	6	--	Qs	1,802	35.4 34.9 33.6	do Jan. 16, 1968 Jan. 14, 1969	C, W	N	--
* 905	D. O. Huddleston	--	--	31	8-1/4	--	Qal	1,723	13.8	Nov. 22, 1967	C, W	N	--
* 906	L. E. C. Boyd et al.	--	--	16	--	--	Qal	1,725	14.7	do	N	N	Dug well.
* 907	R. L. Stevenson	--	--	49	6	49	Qs	1,819	15.7	do	J, E, C, W	D, S	Water reported from sand and gravel.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
*	29-24-908	L. E. C. Boyd et al.	--	--	33?	6	--	Qs	1,765	12.7	Nov. 24, 1967	C, W	N	--
*	909	R. L. Stephenson	--	--	Seep	--	--	Qs	1,760	(+)	Jan. 16, 1968	N	N	Flows from vegetative-kill area. Discharge estimated greater than 5 gpm.
*	910	Faye Daniels	--	--	22	--	--	Qal	1,735	17.6	Dec. 11, 1968	C, W	S	Dug well. Water reported from sand and gravel.
*	31-601	Finus W. Cade	--	--	50	6	--	Pprsa	1,921	20.6	Dec. 1, 1967	J, E	D	Water not used for human consumption.
*	602	D. P. Adams	--	1966	60	12 5-1/2	12 60	Pprsa	1,900	3.6	Jan. 5, 1967	N	N	Reportedly water flowed to surface when first drilled.
*	603	H. H. McLeod	Bob Dennis	1954	50	6	50	Pprsa	1,900	17.9	Jan. 5, 1968	J, E	D, S	Water reported at 42 feet. Yield reported 22 gpm.
*	901	Mrs. Donnie Redus	--	--	91	6	--	Pprsa	1,908	16.2 14.0	July 30, 1953 Dec. 1, 1967	C, W	N	Water reported unfit for human consumption. Well J-11 of Bulletin 5418.[1]
	902	Mark M. Williamson	Ed Chapman	1966	20	18	20	Pprsa	1,905	10.4	do	Cf, E, 5	Irr	Water reported from sand and gravel at 15 to 19.5 feet. Yield reported 50 gpm.
*	903	do	do	1966	19	18	20	Pprsa	1,906	10.5	do	Cf, E, 5	Irr	Water reported from sand and gravel at 16 to 19.5 feet. Reported yield 50 gpm.
*	32-101	J. W. Tiner estate	--	--	80	8	80	Pprsa	1,895	24.7 18.2	July 13, 1953 Dec. 1, 1967	J, E	D	Water not used for human consumption. Originally a dug well; deepened by drilling. Water reported at about 40 and 65 to 80 feet. Well J-7 of Bulletin 5418.[1]
	102	Henry Ueckert	Mr. Hurd	1965	200	4	4	Qs	1,820	25	Dec. 21, 1967	C, W	S	Drilled originally as a seismic test hole.
*	103	do	do	1965	200	4	4	Qs	1,822	29.3 30.3 26.1	Dec. 21, 1967 Jan. 17, 1968 Jan. 10, 1969	N	N	Do.
	104	do	do	--	57	5	57	Qs	1,828	30	Dec. 21, 1967	C, W	S	Yield reported 5 gpm.
*	105	Mrs. Zada Beard	--	--	42	--	--	Pcfc	1,795	35	Jan. 17, 1968	J, E	D, S	Water not used for human consumption.
*	106	do	--	--	60	8	--	Pcfc	1,783	24.8	July 13, 1953	J, E	D	Water not used for human consumption. Well J-2 of Bulletin 5418.[1]
*	107	do	Bob Dennis	1956	100	5-1/2	100	Pprsa	1,842	25	Dec. 10, 1968	J, E	D	Water reported at about 54 feet in sandstone.
*	201	Alec Carter	Alec Carter	1948	105	10	105	Pcfc	1,775	11.0 10	Mar. 16, 1960 Feb. 24, 1967	T, E, 5	Irr	Main water reported in dolomite from 90 to 95 feet. Reported yield greater than 140 gpm.
	202	do	do	1947	47	6	47	Pcfc	1,776	9.5	do	C, W	S	Water reported at 30 feet in dolomite streak in the redbeds. Yield reported 20 gpm.
*	203	do	do	1947	105	12	105	Qal, Pcfc	1,778	10.1	do	N	N	Abandoned irrigation well. Main water reported in sand and gravel at 10 to 30 feet; strong water reported at 90 to 100 feet in dolomite. Reported yield 400 gpm.
	204	do	do	1947	105	10	105	Qal, Pcfc	1,770	10	do	T, G, 45	Irr	Main water reported at 10 to 20 feet in sand and gravel; strong water reported at 90 to 100 feet in dolomite. Reported yield greater than 350 gpm.
	205	Dr. J. C. Duff and J. W. Adams	--	1948?	60	4	60	Pcfc	1,771	--	--	N	N	Well is filled with creek debris to within 10 feet of surface.
*	206	do	--	1948?	60	6-1/2	60	Pcfc	1,780	28.4	Feb. 9, 1967	C, W	N	--
*	207	do	--	--	60	5	60	Qal	1,762	9.4	do	N	N	--
*	208	Alec Carter	Alec Carter	1947	47	6	47	Pcfc	1,780	--	--	J, E	D	Main water reported at 30 feet in dolomite streak in the redbeds. Yield reported 20 gpm.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
29-32-209	Herman A. Reeves	--	--	40	--	--	Pcfc	1,825	23.0	Feb. 27, 1967	J, E	N	Dug well.
* 210	Noodle School	Robert B. Higgins	1962	100	5-1/2	100	Pcfc	1,824	68	Nov. 27, 1967	J, E	P	Water reported at 35 to 36, 67 to 68, and 89 to 90 feet in red sand. Reported yield greater than 9 gpm.
* 211	Henry Ueckert	--	1943	57	5	57	Qs	1,824	28.5 27.4 26.7	Dec. 21, 1967 Jan. 17, 1968 Jan. 10, 1969	J, E	D, S	Water reported from sand and gravel at about 38 feet. Reported yield 5 gpm.
* 212	State of Texas	--	--	Seep	--	--	Qal	1,790	(+)	Jan. 17, 1968	N	N	Seep is in north ditch of Farm Road 1812. Discharge estimated greater than 5 gpm.
213	Dugger and Herring et al.	--	1964	3,046	10-3/4 5-1/2	170 3,038	IPsw	1,840	--	--	N	N	Industrial salt water supply well, formerly used in an oil field waterflood operation.
* 214	Travis Farmer	--	1940	60	6	--	Pcfc	1,810	17.8	Dec. 10, 1968	C, W	S	--
301	Dr. J. C. Duff and J. W. Adams	--	1955	54	6	54	Pcfc	1,800	30.5	Feb. 9, 1967	C, W	S	--
302	Carl Jackson	Bob Dennis	1951	120	10	20	Pcfb	1,812	40 28.4	Dec. 10, 1959 Feb. 24, 1967	T, E, 5	N	Unused irrigation well. Water reported at 40 to 42, 75 to 77, and 100 to 102 feet. Well J-6 of Bulletin 5418.1/ Yield reported 60 gpm.
303	Hoke Propst	--	--	50	6	--	Qs	1,810	12.6 13.1 10.9	Nov. 22, 1967 Jan. 16, 1968 Jan. 10, 1969	C, N	N	--
* 304	Finus W. Cade	--	1940?	80	--	--	Pcfc	1,862	--	--	C, E	D	--
* 305	Hoke Propst	--	--	--	6	--	Qs	1,809	14.9	Nov. 24, 1967	C, W	D, S	--
* 306	Mrs. V. E. Eller	--	--	80	6	80	Pcfc	1,827	30	Jan. 17, 1968	J, E	D, S	Well reportedly had a weak upper water bearing zone (cased off) and a stronger lower water bearing zone.
307	Caddie Williams	Robert Higgins	1967	100	7	30	Pcfc	1,837	--	--	N	N	Unused irrigation well. Water reported at 40 to 41, 68 to 72, and 90 to 91 feet in breaks in clay. Reported yield 40 gpm.
308	do	do	1967	80	7	30	Pcfc	1,838	--	--	N	N	Unused irrigation well. Water reported at 40 to 42 and 70 to 75 feet in breaks in clay. Reported yield 60 gpm.
* 309	Mrs. Margret Goode	--	--	80	7	--	Qs	1,828	15.7	Dec. 12, 1968	C, W	N	--
401	H. H. Windham	--	--	52	--	--	Pcfc	1,883	36.7	July 13, 1953	J, E	D, S	Water not used for human consumption. Well J-10 of Bulletin 5418.1/
* 402	Frank Carter	--	--	28	5-1/2	28	Qal	1,842	15.3	Jan. 5, 1968	C, W	S	Water reported from sand and gravel at 25 feet.
* 403	Odell Freeman	--	--	65	6	--	Pprsa	1,919	16.4	do	J, E	D, S	--
501	-- Sharp	--	--	57	--	--	Pcfc	1,840	45.0 32.8	July 13, 1953 Dec. 1, 1967	C, W	S	Well J-8 of Bulletin 5418.1/
* 502	Frank Carter	--	1910	22	--	--	Qal	1,840	17.1 9.4	July 13, 1953 Dec. 1, 1967	C, W	S	Dug well. Well J-9 of Bulletin 5418.1/
* 503	do	--	1950?	57	5-1/2	--	Pcfc	1,859	44	Dec. 1, 1967	J, E	D	--
* 504	Pete Burfiend	Robert Higgins	1965	67	5-1/2	67	Pcfc	1,880	34.1	Jan. 5, 1968	S, E	D, S	Water reported in break in clay at 46 to 47 and 61 to 67 feet. Reported yield 6 gpm.
505	Humble Oil and Refining Company	--	1962	3,032	7	3,010	Pco	1,828	--	--	C, N	N	Unused industrial salt water supply well in Noodle South Oil Field. Reported yield 8 gpm.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
29-32-506	Crown Central Petroleum Corporation	Fletcher Oil and Gas	1967	4,800	10-3/4 7	116 2,135	Pco	1,825	750	Aug. 16, 1968	C, G, 34	Ind	Industrial salt water supply well used in oil field waterflood operation. Yield reported 35 gpm.
* 601	S. C. Herring, Jr.	--	1945?	25	6	--	Pcfc	1,781	10.1	Dec. 19, 1967	C, W	S	--
* 602	do	--	--	68	6	68	Pcfc	1,825	45.6	do	N	N	--
† 603	Roark, Hooker and Roark	--	1950	2,980	10 7	118 2,956	IPsw	1,715	200	July 7, 1968	C, G, 18	Ind	Industrial salt water supply well used in oil field waterflood operation. Yield reported 7 gpm.
† 604	Crown Central Petroleum Corporation	Fletcher Oil and Gas Corporation	1967	3,700	10-3/4 7	105 2,113	Pco	1,848	739	Oct. 4, 1967	C, G, 34	Ind	Water level is a pumping level. Industrial salt water supply well used in oil field waterflood operation. Yield reported 32 gpm.
605	do	Crown Central Petroleum Corporation	1950	4,687	10-3/4 7	114 2,109	Pco	1,827	800	Aug. 16, 1968	C, G, 34	Ind	Industrial salt water supply well used in oil field waterflood operation. Yield reported 35 gpm.
606	Crown Central Petroleum Corporation	Fletcher Oil and Gas Drilling Company	1959	4,797	8-5/8 5-1/2	129 2,186	Pco	1,884	800	do	C, G, 34	Ind	Industrial salt water supply well used in oil field waterflood operation. Yield reported 32 gpm.
* 701	Douglas Reddin	--	--	--	7	--	Pcfc	1,853	15.9	Jan. 5, 1968	J, E, C, W	D, S	--
* 801	Forest Black	--	--	35	6	--	Pcfc	1,799	11.0	do	J, E	D, S	Water not used for human consumption.
* 802	Woodrow Rogers	--	--	19	--	--	Pcfc	1,802	3.1	do	C, W	D	Dug well. Water not used for human consumption.
* 803	do	--	--	60	6	--	Pcfc	1,804	5.8	do	C, W	N	--
* 901	Bill Tarpley	Robert Higgins	1962	60	5-1/2	20	Pcfc	1,806	18	Dec. 12, 1967	J, E	D, S	Water reported at 29 feet, 31 feet (1 gpm), and 55 feet (40 gpm), in slightly sandy clay breaks.
* 902	Otis Foster	do	1963	60	5-1/2	30	Pcfc	1,804	27.3	Dec. 19, 1967	C, W	S	Water level is a pumping level. Minor amount of water reported at 29 and 31 feet; main water reported at 53 feet in slightly sandy clay break. Yield reported 40 gpm.
903	S. C. Herring, Jr.	--	1914?	45	6	--	Pcfc	1,788	20.8	do	C, W	S	--
* 904	do	--	1960?	37	4	--	Pcfc	1,785	5.9	do	N	N	--
* 905	Forest Black	Robert Higgins	1951	64	7	35	Pcfc	1,789	4.7	Jan. 5, 1968	N	N	Unused industrial well, drilled for a water source for the drilling of oil tests.
* 906	LeClair Operating Company, Incorporated	--	1957	5,957	7 4-1/2	4,644 5,730	Ch	1,768	1,200	Apr. 26, 1968	S, E, 100	N	Unused industrial salt water supply well, formerly used in oil field waterflood operation. Yield reported greater than 278 gpm.
* 30-01-401	E. D. Apperson	John Kale	1953?	43	30	11	Pcfc	1,634	32.4 9.5	July 11, 1953 Feb. 5, 1968	S, E, 1.5	Irr	Reported yield 45 to 50 gpm. Well B-44 of Bulletin 5418.[1]
* 402	do	Bill Martin	1967	51	30	11	Pcfc	1,635	12.7	do	N	N	Unequipped irrigation well planned for future use. Water reported from dolomite and gypsum at 30 to 35 feet. Reported yield 50 to 65 gpm.
403	do	Jack Leonard	1967	34	--	--	Pcfc	1,631	10	do	N	N	Unused irrigation well. Water reported at 26 to 27 feet from soft red clay. Reported yield 35 gpm.
404	do	--	--	50	6	--	Pcfc	1,628	26.9	July 11, 1953	N	N	Well B-2 of Bulletin 5418.[1]
405	do	--	--	50	6	--	Pcfc	1,632	10	Feb. 5, 1968	C, W	S	--
* 406	Carl Lunn	--	1945	50	6	16	Pcfc	1,630	20 12.0	July 11, 1953 Feb. 5, 1968	N	N	Reported water zone at 30 feet in a break in shale. Well B-1 of Bulletin 5418.[1]
407	do	--	1947?	50	6	12	Pcfc	1,631	10	do	N	N	--

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
30-01-408	Carl Lunn	--	1928	50	4	--	Pcfc	1,629	12	Feb. 5, 1968	N	N	Water reported from break in shale at 30 feet.
* 501	Mrs. J. E. England	--	1905	60	--	--	Qs	1,644	25	Mar. 17, 1944	N	N	Destroyed. Well B-5 of Bulletin 5418.[1]
* 502	B. R. Baize	--	--	60	6	--	Qs	1,656	9.9 10.4	Jan. 31, 1968 Jan. 15, 1969	J, E	D	Water not used for human consumption.
503	Fred Osment	--	--	80	6	--	Qs	1,639	--	--	J, E	N	--
* 504	E. D. Apperson	--	1940?	800	6	--	Pcfc	1,671	58.7	Feb. 5, 1968	C, W	S	--
* 505	do	--	1958	70	6	70	Qs	1,666	18.2	do	S, E	D	Water reported at about 50 feet. Water not used for human consumption.
* 601	Carl Lunn	--	1952?	52	4	12	Pcfc	1,594	19.7	Feb. 6, 1968	J, E	D, S	Water not used for human consumption. Water reported from a red clay break.
602	do	--	--	20	4	10	Pcfc	1,592	12.5	do	C, W	S	Originally 40 feet deep; recently caved.
603	do	--	1956	76	6	76	Pcfc	1,600	19	do	N	N	Unused industrial well, used as a water source during the drilling of an oil test.
701	G. R. Riddle	--	--	20	--	--	Qal	1,638	5	Mar. 5, 1968	J, N	N	Dug well.
702	Mayfair Minerals, Incorporated	Woodley Petroleum Company	1960	4,090	10-3/4 7	108 3,900	IPcf	1,645	--	--	N	N	Formerly an industrial salt water supply well used in oil field waterflood operation; now used as a salt water disposal well.
703	J. C. Riddle	Ed Chapman	1966	40	12-3/4	40	Qs	1,642	7.8 11.9	Mar. 5, 1968 Jan. 15, 1969	Cf, E, 1	Irr	Water reported from sand and gravel at 30 to 39 feet. Reported yield 60 gpm.
* 704	do	--	1940?	40	6	40	Qs	1,642	6.6	Mar. 5, 1968	J, E	S	--
705	do	Ed Chapman	1967	42	12	42	Qs	1,642	7	do	Cf, E, 1	Irr	Water reported from sand and gravel at 32 to 39 feet. Reported yield greater than 60 gpm.
706	do	do	1967	27	12	27	Qs	1,641	7	do	Cf, E, 1	Irr	Water reported from sand and gravel at 20 to 26 feet. Reported yield less than 60 gpm.
* 707	W. O. Gray	do	1967	38	16	38	Qal	1,621	4.8	Mar. 29, 1968	N	N	Unequipped irrigation well. Water reported from sand and gravel at 18 to 36 feet. Reported yield 85 gpm.
* 801	Lowell L. White	--	--	27	--	--	Qal	1,625	16.9	Dec. 12, 1968	C, W	N	Dug well. Water reported from clay and gravel at about 12 feet.
* 901	Mack T. Claburn	Jack Bradshaw	1959	50	10-3/4	50	Pcfb	1,598	11.2 10.5	Sept. 3, 1960 Feb. 28, 1967	Cf, G, 125	Irr	Pumped with other wells by a central power unit on a manifold system. Water reported from blue shale (limy streaks) at 27 to 31 feet. Reported yield greater than 35 gpm.
902	do	--	--	45	6	45	Qal	1,611	16.4	do	C, W	N	Excavation for livestock tank 50 feet northeast of this well, and in the bottom of California Creek, encountered water at 4 feet in coarse sand and gravel.
* 903	do	Jack Brakshaw	1960	40	10-3/4	40	Pcfb	1,600	9.2	do	Cf, G, 125	Irr	Pumped with other wells by a central power unit on a manifold system. Water reported from limy or dolomitic streaks at 24 to 40 feet. Reported yield greater than 35 gpm.
904	do	do	1960	45	8-3/4	45	Pcfb	1,595	10.3	do	Cf, G, 125	Irr	Pumped with other wells by a central power unit on a manifold system. Water reported from dolomite streaks at 25 to 44 feet. Reported yield greater than 35 gpm.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- Continued

	WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (ft)	CASING DIAM-ETER (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
	30-01-905	Mack T. Claburn	Jack Brakshaw	1960	46	10-3/4	46	Pcfb	1,602	10.7	Feb. 28, 1967	Cf, G, 125	Irr	Pumped with other wells by a central power unit on a manifold system. Water reported from dolomite streaks at 25 to 45 feet. Reported yield greater than 35 gpm.
	906	do	do	1960	37	14 8	4 37	Pcfb	1,591	7.9	do	Cf, G, 125	Irr	Dug well, drilled deeper and cased in 1960. Water reported from dolomite streaks at 25 to 45 feet. Pumped with other wells by a central power unit on a manifold system. Reported yield 80 to 90 gpm.
	907	do	do	1960	45	8-3/4	45	Pcfb	1,594	10.4	do	Cf, G, 125	Irr	Pumped with other wells by a central power unit on a manifold system. Water reported from dolomite streaks at 25 to 45 feet. Reported yield greater than 35 gpm.
*	908	Mrs. A. L. McKeever	--	--	23	--	--	Qal	1,590	14.8	May 30, 1967	C, W	S	Dug well.
	909	Warren B. Tayman	--	--	22	--	--	Qal	1,590	15.8 12.2	July 10, 1953 Feb. 7, 1968	J, E	D, S	Dug well. Well B-13 of Bulletin 5418.[1] Water not used for human consumption.
*	02-401	M. N. McCraw	--	1908?	47	--	--	Pcfb	1,623	26.4 20	Mar. 17, 1944 Feb. 5, 1968	J, E	D	Dug well. Water reported from a break in red shale at approximately 60 feet. Well B-10 of Bulletin 5418.[1]
*	402	Swenson Land and Cattle Company	--	--	9	--	--	Pcfv	1,559	0.6	Nov. 6, 1967	N	N	Dug well.
*	403	C. L. Ely	Ed Chapman	1966	26	24 18	6 26	Qs	1,622	14.8 13.9	Jan. 31, 1968 Jan. 14, 1969	J, E	D	Water not used for human consumption. The 18-inch casing in this well was set from 5 to 26 feet. Water reported from sand and gravel at 18 to 25 feet. Reported yield 20 gpm.
*	404	V. F. Dominey	J. A. Fielder	1941	23	--	--	Qs	1,620	16.5 14.0	Mar. 17, 1944 Jan. 31, 1968	C, W	D, S	Dug well. Water reported from sand and gravel at 15 to 23 feet. Water not used for human consumption. Well B-9 of Bulletin 5418.[1]
	405	M. N. McCraw	--	--	60	14	--	Pcfb	1,624	20.1	Feb. 5, 1968	N	N	Water reported from a break in red shale at about 60 feet.
	406	H. M. Phillips	--	1939	23	--	--	Qs	1,621	16	do	J, E	N	Dug well. Sand and gravel reported at 13.5 to 23 feet, with water encountered at 18 feet.
*	501	W. T. Goree, Jr.	--	--	20	--	--	Qs	1,607	7.1 8.6	June 20, 1967 Jan. 14, 1969	C, W	D	Dug well. Water not used for human consumption.
	502	Bernard Buie	--	1925?	21	6	--	Qs	1,610	20.7 20.2	Feb. 27, 1968 Jan. 14, 1969	C, W	N	--
*	601	Davenport estate, B. P. Davenport, Jr.	--	--	35	6	--	Qs	1,578	22.6 5	Mar. 20, 1944 Mar. 5, 1968	N	N	Well bore now covered with a rock just below the surface. Well C-5 of Bulletin 5418.[1]
*	602	do	-- Balfanz? and Ed Chapman	1951?	24	--	--	Qs	1,578	5.4	do	Cf, J, E	S, Irr	Water reported from sand and gravel at 17 to 22 feet. Owner installs a 3-hp motor and centrifugal pump when he irrigates. Yield reported about 75 to 100 gpm.
*	603	T. A. Halbert	T. A. Halbert	1951	24	12	24	Qs	1,596	16.5	Feb. 27, 1968	N	N	Hand augered. Water reported from dolomite streak(?) in redbeds at 17 to 18 feet. Yield reported 7 to 8 gpm.
*	604	J. C. Kainer	Ed Chapman	1968	60	--	--	Qs	1,591	7.8	do	N	N	Test hole; owner may case and equip later for domestic supply. Water reported from sand and gravel at 16 to 18 feet. Yield reported 2 to 3 gpm.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
30-02-605	Davenport estate, B. P. Davenport, Jr.	Ed Chapman	1968	24	24 12-3/4	8 24	Qs	1,576	3.6 7.7	Mar. 5, 1968 Jan. 14, 1969	N	N	Unequipped irrigation well. Water reported from sand and gravel at 14 to 21 feet. Yield reported 40 gpm.
606	do	--	--	32	--	--	Qs	1,585	2.7	do	J, E	S	Dug well.
* 607	do	Balfanz Construction	1951?	32	--	--	Qs	1,586	2.0	do	J, E	S	Well shares a common motor with well 30-02-607, 10 feet north. Water reported from sand and gravel at 17.5 to 18.5 feet. Well is lined with 36-inch concrete rings.
608	do	do	1951?	32	--	--	Qs	1,586	2	do	J, E	S	Well shares a common motor with well 30-02-608, 10 feet south. Water reported from sand and gravel at 17.5 to 18.5 feet. Well is lined with 36-inch concrete rings.
* 609	do	--	1948?	85	8	--	Qs	1,586	4.9	Mar. 5, 1968	J, E	S	Water reported from sand and gravel at about 40 feet.
701	J. H. Fry	--	--	11	--	--	Qal	1,567	5.2	June 16, 1967	C, W	N	Dug well.
* 702	W. W. Mayfield	--	1932?	41	--	--	Qal, Pcfv	1,571	16.4	do	J, E	D, S	Dug well. Water reported at 22 to 24 feet in sand and gravel and at 41 feet in gray streak in redbeds. Yield reported 4 to 5 gpm.
* 703	do	--	--	13	--	--	Qal	1,565	5.9	do	N	N	Dug well.
* 704	do	Robert Higgins	1965	31	8	31	Qs	1,570	12.3	do	J, E	D	Water reported in sand and gravel at 16 to 25 feet. Originally drilled to 230 feet without encountering water below the main water zone. Yield reported 9 gpm.
* 705	C. R. Taylor	Mr. Lee	1929	80	5	80	Qs, Pcfv	1,572	18.8	do	J, E	D, S	Water reported at 22 feet in sand and gravel and at 65 to 70 feet in break in redbeds. Water not used for human consumption.
* 706	Clinton C. Moss	Slim Wallace	--	40	6	30	Qal	1,582	13.9	June 20, 1967	J, E	S	Water reported in sand and gravel at 35 to 40 feet.
707	do	--	--	13	9	13	Qal	1,581	12.2	do	N	N	--
* 708	do	--	--	15	18 8-1/4	15 15	Qal	1,578	9.0	do	C, W	N	Dug well.
* 709	G. J. Smith	--	1928?	54	6	54	Pcfv	1,609	53.0	do	C, W	D, S	Water-level measurement is a pumping level. Water reported from break in redbeds.
* 710	W. W. Young	--	1932?	22	--	--	Qs	1,564	11.1	do	J, E	D, S	Dug well. Water not used for human consumption.
711	do	Ed Sharp	1967	21	5-1/2	21	Qs	1,570	12.8	June 21, 1967	N	N	Hand augered. Water reported from sand and gravel at 14 to 21 feet.
712	Mrs. Emma Owens	--	1935	83	5	--	Pcfv	1,596	29.8	June 19, 1967	C, E	N	--
* 713	Fred Osburne	--	--	22	6	--	Qal	1,580	8.5	do	N	N	--
* 714	Susie Odstricil	Joe Odstricil et al.	1934	36	--	--	Qal	1,582	18.3	do	C, W	D	Dug well. Water reported from sand and gravel at 33 to 34 feet.
* 715	do	Steve Odstricil	1908?	54	--	--	Qal, Pcfv	1,582	17.8	do	C, W	N	Dug well.
* 801	Cecil W. Bean	--	1908?	60	6	--	Pcfv	1,563	47.4	May 17, 1967	C, W	D, S	Water level may not have been static when measured.
* 802	R. L. Thane	--	1945	11	--	--	Qs	1,591	5.8	May 16, 1967	C, W	N	Dug well. Water reported from gravel at 10 feet.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
* 30-02-803	W. T. Goree	G. R. Breedlove	1943	18	--	--	Qs	1,559	9.2	June 16, 1967	N	N	Dug well. Water reported from sand and gravel at 17 feet. Yield reported 5 gpm.
* 804	Wilson Goree	Wilson Goree	1950?	16	--	--	Qs	1,562	14.8 11.6	July 8, 1953 June 16, 1967	C, W, J, E	D, S	Dug well. Water reported from sand and fine gravel. Well C-10 of Bulletin 5418.[1]
805	C. R. Taylor	Mr. Lundy	1925?	12	--	--	Qs	1,569	11.4 10.8	do Jan. 15, 1969	N	N	Dug well. Specific conductance 188 micromhos/cm^3 at 83°F.
* 806	T. J. Goree	T. J. Goree	1951	12	--	--	Qal	1,560	8.0	June 16, 1967	J, E	D, S	Dug well. Water not used for human consumption. Water reported from sand and gravel at about 10 feet.
* 807	do	M. Waldrip	--	17	--	--	Qal	1,552	12.3	do	N	N	Dug well.
* 808	Joe Benton	Joe Benton et al.	1943	16	--	--	Qs	1,578	13.6 15.4 10.7	Mar. 20, 1944 July 8, 1953 June 19, 1967	J, E	D	Dug well. Water reported from sand and gravel at 8 to 16 feet. Water not used for human consumption. Well C-8 of Bulletin 5418.[1] Specific conductance 5,650 micromhos/cm^3 at 81°F.
809	do	do	1947?	14	--	--	Qal	1,571	9.2	do	J, E	D, S	Dug well. Water reported from sand and gravel in lowermost 2 feet. Water not used for human consumption. Specific conductance 3,275 micromhos/cm^3 at 83°F.
* 810	Mrs. R. B. Buie	--	--	14	--	--	Qal	1,558	9.1	do	N	N	Dug well.
* 901	Wylie W. Cox	--	--	19	--	--	Qs	1,567	9.5	Apr. 6, 1967	Cf, E	D, S	Do.
* 902	do	--	--	17	--	--	Qs	1,566	7.8 8.9	do Jan. 15, 1969	N	N	Do.
* 903	Carl Gared	--	1911	24	--	--	Qal	1,541	19.3	May 29, 1967	C, W	S	Do.
* 904	W. B. Whitley	--	1940	80	6	--	Qs	1,568	57.6 9.7	July 8, 1953 May 21, 1967	C, W	D, S	Water not used for human consumption. Water reported from sand and gravel at about 20 feet and estimated 3 feet thick. Well C-9 of Bulletin 5418.[1]
* 905	Gladys Webb	--	--	45	--	--	Qal	1,544	44.6 13.6	July 8, 1953 May 21, 1967	J, E	D, S	Water not used for human consumption Well C-12 of Bulletin 5418.[1]
906	Alvin Hinze	Mr. Hinze	--	11	6	--	Qs	1,583	10.0	do	C, N	N	Previous depth reported 70 feet; caved at 11 feet.
* 907	do	do	1931?	62	--	--	Qs	1,585	12.8 11.1	July 24, 1967 Jan. 15, 1969	J, E	D, S	Dug well. Water reported from sand and gravel. Water not used for human consumption.
03-401	Ola F. Williams	--	--	24	--	--	Qs	1,558	15.7 2.1 8.6	Mar. 20, 1940 Feb. 27, 1968 Jan. 14, 1969	C, W	N	Dug well. Well C-4 of Bulletin 5418.[1]
* 402	Davenport estate, B. F. Davenport, Jr.	Robert Higgins?	1950?	90	10	--	Qs	1,573	11.5	Mar. 5, 1968	J, E	D, S	Water reported at about 45 feet.
* 501	J. M. Swenson	J. M. Swenson et al.	1948	18	--	--	Qs	1,537	10.1 12.4	June 9, 1967 Jan. 14, 1969	J, E	D	Dug well. Water not used for human consumption. Water reported from sand and gravel at 13.5 to 14.5 feet.
* 502	John E. Newquist	--	1947	21	--	--	Qs	1,513	19.2 19.3	June 9, 1967 Jan. 14, 1969	J, E	N	Dug well. Water reported from sand and gravel at 21 feet.
* 503	H. E. Olson	--	1962	19	--	--	Qs	1,522	13.6	June 12, 1967	N	N	Dug well. Water reported from sand and gravel at 17 feet to bottom.
* 504	do	--	1936	28	--	--	Qs	1,523	16.1	do	C, W, J, E	N	Dug well. Water reported from red sandstone.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- Continued

	WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (ft)	CASING DIAM-ETER (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
	30-03-505	Fred Buerger	--	1945?	44	6	--	Qs	1,531	24.4 6.0	July 29, 1953 Feb. 12, 1968	C, W	N	Well C-2 of Bulletin 5418.[1]
*	506	do	--	1945?	25	--	--	Qs	1,531	5.8 8.1	do Jan. 14, 1969	N	N	Dug well.
*	507	Mrs. Lenore Jackson	--	1928	101	8	--	Qs	1,542	60 27.2 28.5	July 29, 1953 Feb. 12, 1968 Jan. 14, 1969	J, E	D, S	Well C-1 of Bulletin 5418.[1]
*	601	B. W. Thane	--	1940?	17	--	--	Qs	1,499	15.4 10.3	Nov. 29, 1953 Feb. 12, 1968	C, W	S	Dug well. The 1968 water level is a pumping level. Well D-1 of Bulletin 5418.[1]
*	602	Norris Russell	N. M. and Jess Hanson	1937	20	--	--	Qs	1,509	9.8	May 31, 1967	C, W	N	Dug well. Water reported from sand and gravel.
*	603	C. H. Peterson	C. H. Peterson	1941	24	--	--	Qs	1,507	19.7 16.4 14.1	Mar. 20, 1944 May 31, 1967 Jan. 14, 1969	C, W	S	Dug well. Water reported from sand and gravel at 20.5 to 26.5 feet. Well D-2 of Bulletin 5418.[1]
*	604	do	do	1936	30	--	--	Qs	1,507	16.0	do	N	N	Dug well. Water reported from sand.
*	605	Melvin Rosenquist	--	--	29	--	--	Qs	1,514	13.6	May 31, 1967	J, E	S	Dug well.
*	606	W. J. Smith	--	--	22	--	--	Qal	1,692	15.7	Feb. 12, 1968	C, W	S	Do.
*	607	Walter L. Buerger	--	1943	29	--	--	Qs	1,505	19.5	do	J, E	D, S	Dug well. Water reported from sand and gravel at 10 to 26 feet.
	608	B. W. Thane	--	1940?	34	--	--	Qs	1,509	17.0 16.4	do Jan. 14, 1969	C, W	D, S	Dug well. Water not used for human consumption.
*	701	S. A. Olson	--	1918?	17	--	--	Qal	1,526	10.5	June 2, 1967	N	N	Dug well. Water reported from sand.
*	702	E. O. Nauert	--	1920	15	--	--	Qal	1,519	9.0	May 29, 1967	C, W	S	Dug well. Water reported from sand at 21 feet.
	703	Thomas H. McBay	--	--	17	--	--	Qal	1,534	11.5	June 21, 1967	N	N	Dug well.
*	704	Leland Nauert	--	1924	18	--	--	Qal	1,529	19.7 16.1	July 7, 1953 June 21, 1967	J, E	S	Dug well. Well C-13 of Bulletin 5418.[1]
*	801	H. E. Whitworth	--	--	13	--	--	Qal	1,518	7.5	June 2, 1967	N	N	Dug well.
*	802	do	--	--	16	--	--	Qal	1,520	10.0	do	C, W	D, S	Do.
*	803	Mrs. A. B. Shelton	--	1938?	23	--	--	Qs	1,525	16.3	do	J, E	S	Dug well. Water reported from sand and gravel at about 20 feet.
	804	do	--	1938?	21	--	--	Qs	1,524	19.6	do	C, W	N	Do.
*	805	Oliver D. Swenson	Oliver D. Swenson	1943	17	--	--	Qal	1,518	16.9	do	J, E	D	Dug well. Water reported from sand and gravel at 13 to 17 feet.
*	806	Mrs. Carl Ekdahl	--	1924?	24	--	--	Qs	1,517	14.2	May 31, 1967	J, E	S	Dug well.
	807	do	--	--	24	--	--	Qs	1,519	10.0	do	N	N	Do.
*	808	L. W. Larson	--	1920?	28	--	--	Qs	1,522	17.8 17.4	June 9, 1967 Jan. 14, 1969	J, E	D	Do.
*	809	Edgar Shuquist	--	1961	18	10-3/4	23	Qs	1,520	14.8	June 9, 1967	J, E	D	Originally drilled to 25 feet. Water reported from sand and gravel at about 23 feet.
*	901	C. J. Oman estate	--	--	Seep	--	--	Qal	1,505	(+)	Apr. 8, 1968	N	N	Seep of oil, gas, and salt water in vegetative-kill area.
*	04-704	Homer Purcell	--	1967	82	--	--	Pcfa	1,553	11.1	Jan. 16, 1967	N	N	Uncased test hole.

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
*	30-09-101	Helen Baker Propst	Ed Chapman	1965	60	8-5/8	53	Pcfc	1,688	15.4	Jan. 20, 1967	S, E, 5	Irr	Minor amount of water (cased off) reported in sand and gravel at 20 to 22 feet; main water at 35 to 35.5 feet in honeycombed "blue shale" (dolomite?). Yield reported 110 gpm.
*	102	do	do	1966	70	5-1/2	70	Pcfc	1,688	16.0	do	S, E, 3	Irr	Minor amount of water (cased off) reported in sand and gravel at 21 to 22 feet; main water at 56 to 58 feet in "blue shale" (dolomite?). Yield reported 35 gpm.
	103	do	do	1965	70	5-1/2	70	Pcfc	1,688	16.0	do	S, E, 3	Irr	Minor amount of water (cased off) reported in sand and gravel at 20 to 22 feet; main water at 35 to 35.5 feet in honeycombed "blue shale" (dolomite?). Yield reported 45 to 50 gpm.
	104	do	do	1966	70	5-1/2	70	Pcfc	1,688	17.1	do	N	N	Unequipped irrigation well. Minor amount of water (cased off) reported in sand and gravel at 20 to 21 feet; main water at 54 to 56 feet in "blue shale" (dolomite?). Yield reported 35 gpm.
	105	do	--	1946?	35	5	5	Pcfc	1,692	21.6	do	C, W	N	Yield reported 3 gpm.
	106	H. L. Ford	Ed Chapman	1966	68	--	--	Pcfc	1,692	18.7	Feb. 8, 1967	N	N	Uncased test hole.
*	107	do	--	--	37	6	37	Pcfc	1,692	18.7	do	C, W	N	--
	108	do	Ed Chapman	1966	75	8-3/4	75	Pcfc	1,692	16.8	do	S, E	Irr	Water reported in "blue shale" (dolomite?) at 48 to 49 and 69 to 71 feet. Yield reported 50 gpm. This well and 30-09-109 have a combined measured yield of 90 gpm.
*	109	do	do	1966	75	8	73	Pcfc	1,693	18.6	do	S, E, 5	Irr	Minor water seep (cased off) at 2 to 20 feet in red sandy clay; main water in "blue shale" at 35 to 36 feet, 46 to 47, and 72 to 73 feet. Yield reported 50 gpm. This well and 30-09-108 have a combined measured yield of 90 gpm.
	201	C. R. Moss	--	--	80	6	--	Pcfb	1,666	24.5 16.1	July 11, 1953 Jan. 31, 1968	N	N	Well B-16 of Bulletin 5418[1], which showed erroneous location.
*	202	Dr. J. C. Duff	Jack Bradshaw	1956	60	8	60	Pcfb	1,660	15.0 14.0	Feb. 10, 1967 Jan. 15, 1969	S, E, 3	Irr	Yield reported 130 gpm. Observation well.
*	203	J. H. Fry	--	1905?	36	6	--	Pcfc	1,664	24.0	June 19, 1967	J, E	D, S	--
*	204	Dr. J. C. Duff	Ed Chapman	1965	57	7	57	Pcfb	1,660	15	Feb. 10, 1967	T, E, 5	Irr	Water reported at 35 to 36 feet in "blue shale" (dolomite?). Yield reported 70 gpm.
	205	do	Jim Rea and Ed Chapman	1965	60	7	30	Pcfb	1,665	15	do	T, E, 2	Irr	Yield reported 50 gpm.
*	206	Olin Potts	--	1902?	25	--	--	Pcfv	1,656	11.9	Mar. 20, 1967	J, E	D, S	Dug well.
*	301	Tom O. Brown	Mr. Hart	1919?	20	--	--	Pcfv	1,638	15.2 9.7	July 10, 1953 Oct. 11, 1967	C, W	D, S	Well B-18 of Bulletin 5418[1], which showed erroneous location.
*	302	Mrs. C. S. Ratliff	--	--	20	6	--	Qal	1,612	6.8	Feb. 7, 1968	C, W	S	--
*	303	do	--	--	20	3-1/2	--	Qal	1,611	10	do	J, E	D, S	Water not used for human consumption.
	304	I. M. Treadwell	--	1922	50	6	--	Pcfv	1,605	14.6	do	N	N	Well B-15 of Bulletin 5418.[1]
*	305	A. R. McBay	--	--	61	6	--	Pcfb	1,652	23.2 8.8	July 10, 1953 Feb. 8, 1968	C, N	N	Well B-19 of Bulletin 5418.[1]

See footnotes at end of table.

Table 6. -- Records of Wells and Springs -- 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
30-09-401	Herman A. Propst	Ed Chapman	1966	60	16	60	Pcfb	1,680	4	Jan. 20, 1967	N	N	Unused irrigation well. Casing sealed at top with welded metal plate. Minor amount of water (cased off) reported at 20 to 21 feet in sand and gravel; main water reported from "blue shale" (dolomite?) at 51 to 53 feet. Yield reported 125 gpm.
402	J. M. Dubose	Mr. Wallace	1955	65	6	16	Pcfc	1,712	31.1	Apr. 4, 1967	C, N	N	--
* 403	Herman A. Propst	--	1957	90	5	--	Pcfc	1,716	73.6	Jan. 20, 1967	S, E	D, S	--
* 404	Chittenden estate	--	--	28	5	--	Pcfc	1,716	27.3	do	C, W	S	Water-level measurement is a pumping level.
* 405	J. B. Young estate	--	--	65	5	--	Pcfc	1,709	35.2	Jan. 25, 1967	J, E	D	--
406	do	--	--	27	5	--	Pcfc	1,705	12.3	do	C, W	N	--
407	do	--	--	27	--	--	Pcfc	1,706	18.3 12.3	July 10, 1953 Jan. 25, 1967	C, W	N	Dug well.
408	J. M. Dubose	Frank Hill	1931	45	6	16	Pcfc	1,698	27.9	Apr. 4, 1967	C, W	S	Water reported from gray streak in the redbeds at 45 feet. Yield reported 30 gpm.
409	J. B. Young estate	--	--	27	6	27	Pcfc	1,705	13	Jan. 25, 1967	C, W	S	--
410	do	--	1953	49	5	--	Pcfc	1,711	33.5	do	C, N	N	--
411	do	--	--	35	6	35	Pcfc	1,711	15.9	do	C, W	S	Small amount of water reported at 13 feet; main water reported at 23 to 25 feet.
* 412	do	--	--	47	5	--	Pcfc	1,710	23.6	July 10, 1953	C, W	N	Well F-9 of Bulletin 5418.[1]
413	do	--	--	52	6	52	Pcfc	1,709	16.8	Jan. 25, 1967	C, W	N	--
414	do	--	--	46	5	46	Pcfc	1,705	15.1	do	N	N	--
* 415	do	--	--	47	6	47	Pcfc	1,705	14.7	do	N	N	Yield reported 15 to 20 gpm.
416	do	--	--	48	5	48	Pcfc	1,706	14.6	do	N	N	--
* 417	Dr. J. C. Duff	Ed Chapman	1965	70	7	70	Pcfv	1,669	15.2	Feb. 10, 1967	N	N	Water reported from dolomite streak in the redbeds. Yield reported 10 to 15 gpm.
* 418	do	do	1965	60	5	60	Pcfv	1,668	12.5	do	N	N	Yield reported 10 to 15 gpm.
* 419	H. L. Ford	--	1945?	59	6	59	Pcfc	1,702	16.3	Feb. 8, 1967	J, E	D, S	--
* 420	Doyle Jacobs estate	--	--	35	6	35	Pcfc	1,689	33.6	Feb. 7, 1967	C, W	S	Water-level measurement is a pumping level.
* 421	do	--	--	36	5	36	Pcfc	1,688	16.8	do	C, W	S	--
* 422	do	--	1962	83	7	83	Pcfb	1,700	25.5	do	S, E, 5	Irr, S	Water reported from "blue shale" (dolomite?) at about 50 feet. Yield reported 70 gpm.
* 423	Maedgen Rainwater	Ed Chapman	1966	60	10-3/4	61	Pcfc	1,692	20.1	Feb. 23, 1967	S, E, 3/4	Irr	Water reported from "blue shale" (dolomite?) at 30 to 31 and 54 to 57 feet. Yield reported 30 gpm.
* 424	do	--	1924?	40	5	--	Pcfc	1,700	19.3	do	J, E	D	Yield reported greater than 20 gpm.
* 425	J. M. Dubose	Ed Chapman	1963	91	12	20	Pcfv	1,692	22.4	Apr. 4, 1967	J, E	S	Water reported from gray streak (dolomite?) in the redbeds at 65 feet. Yield reported 30 to 35 gpm.
* 426	M. T. McIlwain	--	--	24	5	24	Pcfc	1,698	22.7	do	C, W	S	Water-level measurement is a pumping level.
* 427	do	--	--	90	5-7/8	90	Pcfc	1,712	35.1	do	N	N	--

See footnotes at end of table.