GROUND-WATER RESOURCES OF CAMP, FRANKLIN, MORRIS AND TITUS COUNTIES, TEXAS

TEXAS WATER COMMISSION
BULLETIN 6517

JULY 1965

SECOND PRINTING APRIL 1975
BY
TEXAS WATER DEVELOPMENT BOARD

TEXAS WATER COMMISSION

Joe D. Carter, Chairman
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By

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Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Commission

July 1965

Second Printing April 1975
by
Texas Water Development Board

Published and distributed
by the
Texas Water Commission
Post Office Box 12311
Austin, Texas 78711

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GROUND-WATER RESOURCES OF CAMP, FRANKLIN, MORRIS, AND TITUS COUNTIES, TEXAS

SUMMARY

Camp, Franklin, Morris, and Titus Counties comprise an area of 1,161 square miles in the northeastern part of eastern Texas. Mount Pleasant, which is near the center of the four-county area, is about 120 miles east of Dallas and 65 miles west-southwest of Texarkana. The report area is in the Sulphur River and Cypress Creek Basins, and the rolling to hilly topography is typical of the inner border of the West Gulf Coastal Plain. The average annual precipitation is about 44 inches.

The economy of the four-county area is based chiefly on agriculture and industry. The raising of beef cattle is the most important part of the agricultural economy. About 40 percent of the four-county area is in forests. The principal industries are concerned with the production and refining of petroleum and the manufacture of steel products--mostly pipe for the oil and gas industry.

In 1963, approximately 19,000 acre-feet, or 17 mgd (million gallons per day) of water was used in Camp, Franklin, Morris, and Titus Counties. Approximately 15,000 acre-feet (13 mgd), almost 80 percent of the total amount used, was obtained from surface-water reservoirs; the remaining 4,300 acre-feet (3.8 mgd) was obtained from wells in the report area. About 13,000 acre-feet (12 mgd) of surface water was used by the industries in 1963, and approximately 2,000 acre-feet (1.8 mgd) was used for the public supplies of Daingerfield, Lone Star, Mount Pleasant, and Mount Vernon. Of the 4,300 acre-feet (3.8 mgd) of water obtained from wells in the report area in 1963, about 2,000 acre-feet (1.8 mgd) supplied domestic and livestock needs, about 1,200 acre-feet (1.1 mgd) was used by the industries, and about 1,100 acre-feet (0.98 mgd) was for the public supplies of Pittsburg, Winnsboro, Naples, and Omaha. Wells in Red River County supplied about 240 acre-feet (0.21 mgd) in 1963 for the public supply and industrial needs in the Talco area.

The geologic formations pertinent to the occurrence of ground water in the report area range in age from Cretaceous to Recent. They have a total thickness of about 2,600 feet and consist mainly of clay and marl in the lower half and sand and clay in the upper half. The formations crop out in belts that extend in a northeasterly direction across the report area and into adjacent counties. The rocks dip gently southeast toward the axis of the East Texas basin, a major structural feature in the region.

An important structural feature in the report area is the Talco fault zone which is about 3 miles wide extending across the northernmost parts of Franklin, Titus, and Morris Counties. The rocks near the land surface in the fault zone have been displaced downward (relative to the rocks on both sides) as much as 360 feet at the oil field near Talco. Water for public supply and industrial needs in the Talco area is obtained from wells tapping the Nacatoch Sand north of the Talco fault zone in Red River County. In and south of the fault zone, the water in the Nacatoch is too saline for most uses.

The Wilcox Group and the Carrizo Sand, Reklaw Formation, and Queen City Sand of the Claiborne Group have similar hydrologic properties and are the principal sources of fresh ground water in the four-county area. The units probably are inter-connected hydraulically and they function as a single aquifer; the aquifer is herein named the "Cypress aquifer" from Cypress Creek, which is the common boundary of the four counties. The outcrop of the Cypress aquifer includes about 900 square miles, which includes all the report area with the exception of about 260 square miles in the northwestern corner. The thickness of the Cypress aquifer ranges from zero in the northwestern part of the report area to about 1,200 feet in the southeastern part of Morris County. Sand comprises about half the volume of the aquifer, and the remainder is chiefly shale, clay, and silt, with numerous beds of lignite. The rocks generally contain some iron-bearing minerals. Many thin beds, lenses, and nodules of limonite (brown iron ore) are common on the surface and in the weathered zone beneath.

Almost all the water in the Cypress aquifer is contained in the sand. It is classified as fresh, with the exception of the saline water in a few thin sands at the base. The sands contain a large quantity of water, but much of it is not easily available to wells because of the low transmissibility of the aquifer.

The iron content of the water from wells tapping the upper part of the Cypress aquifer comes from two sources: (1) iron in solution in the ground water, and (2) iron derived from the corrosion of the well casings, pumps, and pipes by acid (low pH) ground water. Data from the laboratory analyses and field determinations of the iron content, pH, and hardness of water samples show a general relationship of these factors to the depths of wells, which can be classified as depth zones--"A", "B", and "C."

Zone A in the Cypress aquifer extends from the land surface to the altitude of the base of the alluvial deposits in the larger streams. Consequently, the thickness of Zone A varies according to the local relief of the land surface, which is a maximum of about 60 feet in most of the report area. In general, the water in Zone A contains little or no iron, the pH ranges from 4.5 to 6.5, and the hardness ranges from soft to very hard. Much of the water in Zone A is acid (low pH) and corrodes well casings, pumps, and pipes. Zone B extends from the base of Zone A to about 100 feet below the base of Zone A. In general, the water in Zone B contains iron in solution, the pH ranges from 5.0 to 7.0, and the hardness ranges from soft to moderately hard. Zone C extends from the base of Zone B to the base of the Cypress aquifer, and the thickness ranges from zero in the northwestern part of the report area to about 850 feet in the southeastern part of Morris County. In general, the water in Zone C contains less than 0.3 ppm (parts per million) of iron, the pH ranges from 7.0 to 8.0, and the water is soft.

The estimated minimum rate of recharge to the Cypress aquifer is about 12,000 acre-feet per year, and the transmission capacity of the aquifer under the present hydraulic gradient is about 1,100 acre-feet per year; the difference of about 11,000 acre-feet per year is the ground water discharged to streams from the shallow part of the aquifer, or rejected recharge.

Because of the abundance of surface water, the low transmissibility of the aquifer, and the iron and acid-water problems, not much development of the Cypress aquifer is anticipated in the near future. However, the present rate of ground-water withdrawal could be at least doubled (8,600 acre-feet per year) if the wells were properly constructed, adequately spaced, and discharge rates were regulated to prevent excessive drawdowns. Because of the low transmissibility of the aquifer, many low-yield wells will be required to properly develop the water resources. The cost of the wells will be the most important economic factor, and where iron-free water is required, the cost per well will be even greater because the wells should be completed in Zone C, the cemented surface casing should extend through Zones A and B, and the pumping levels should be regulated to minimize the downward movement of the iron-bearing water from Zone B.

INTRODUCTION

Camp, Franklin, Morris, and Titus Counties are in the northeastern part of eastern Texas (Figure 1). Mount Pleasant, which is near the center of the report area, is about 120 miles east of Dallas and 65 miles west-southwest of Texarkana. The report area includes 1,161 square miles--Camp County has an area of 190 square miles; Franklin County, 293 square miles; Morris County, 260 square miles; and Titus County, 418 square miles.

This investigation was a cooperative project of the Texas Water Commission and the U.S. Geological Survey. It was started September 1, 1962, and its purpose was to determine and describe the ground-water resources of Camp, Franklin, Morris, and Titus Counties. The results of the investigation are described in this report, which includes an analytical discussion of the occurrence and availability of ground water and tabulations of basic data obtained during the investigation. The purpose of the report is to present information and data that can be used as a guide to the development of the available ground-water supplies.

The investigation was made under the immediate supervision of A. G. Winslow, district geologist of the U.S. Geological Survey in charge of ground-water investigations in Texas.

The report is divided into two main parts--economic development and water use and a summary of the ground-water situation are discussed in the first part; the second part includes data supporting the summaries and conclusions discussed in the first part and related information. A glossary of hydrologic and geologic terms separates the two main parts of the report.

Figure 2 is a diagram of the hydrologic cycle. It shows the complex course of water from precipitation to surface and ground water and return to water vapor in the atmosphere. The ground-water part of the cycle is discussed in detail in the second part of the report.

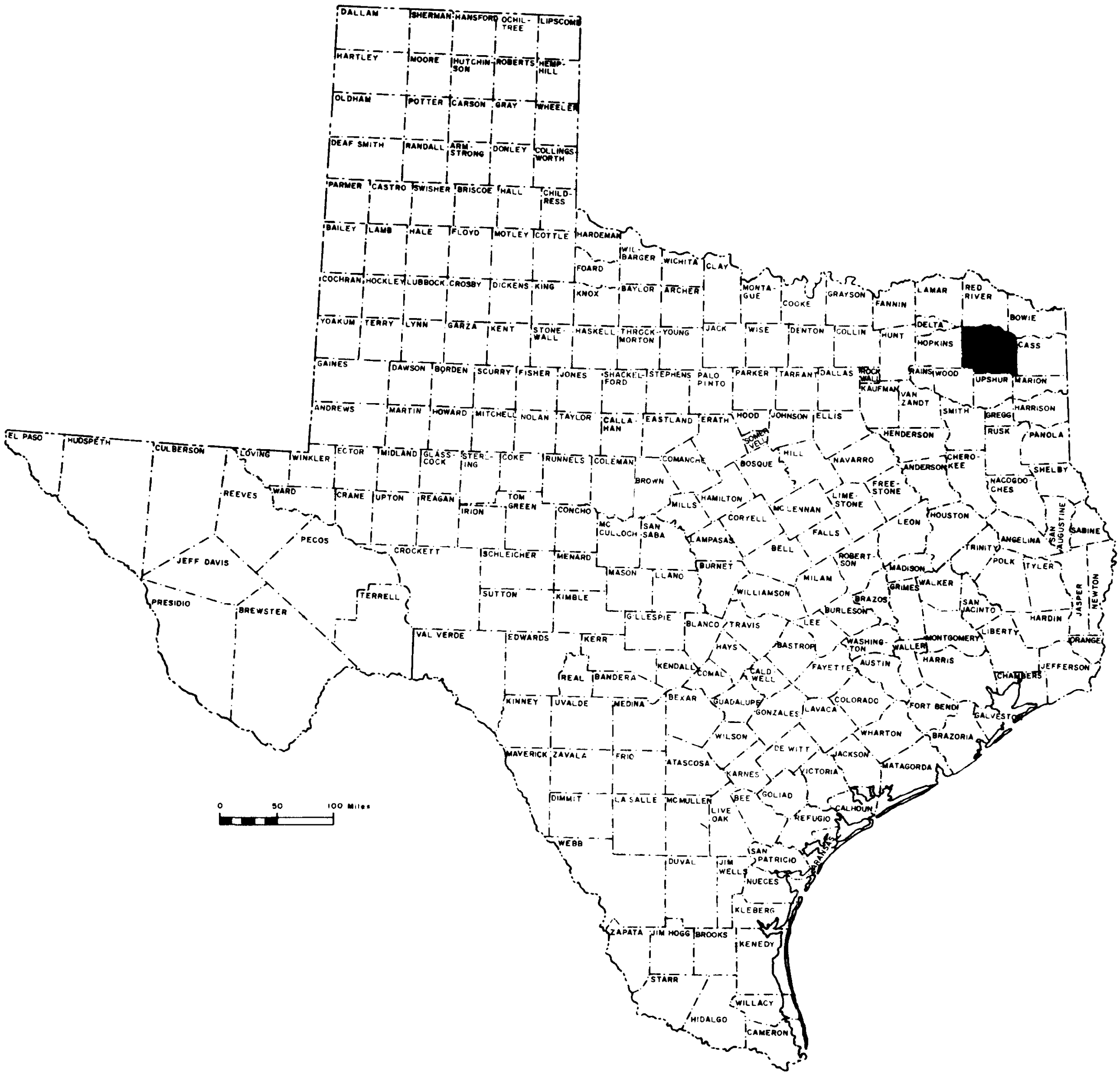

Figure 1

Map of Texas Showing Locations of Camp, Franklin, Morris, and Titus Counties

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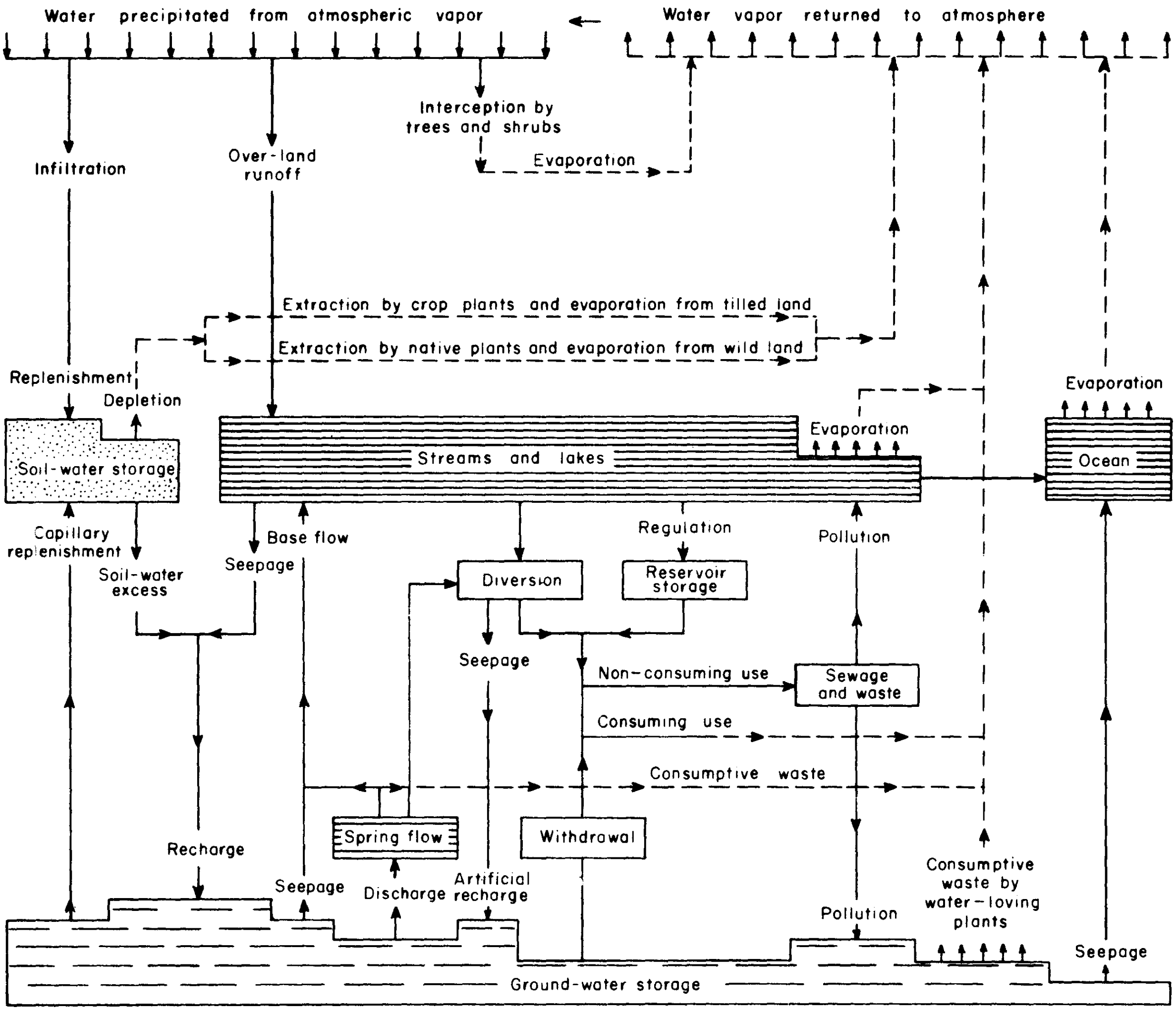

Modified from Piper (1953, p. 9)

Figure 2

The Hydrologic Cycle

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Economic Development and Water Use

The economy of Camp, Franklin, Morris, and Titus Counties is based chiefly on agriculture and industry. The raising of beef cattle has increased during the past several years until it is the most important part of the agricultural economy. This has resulted in increases in the production of feed crops such as corn, grain sorghum, and hay, and the conversion of cropland to pasture. Dairying is of importance, and poultry production is being developed. In addition to stock feed, the principal crops are peanuts, sweet potatoes, watermelons, peaches, and vegetables. About 40 percent of the four-county area is in forests, and the production of pulpwood and timber is of local importance. The large areas in forest and the numerous small reservoirs constructed primarily for livestock water supplies have been developed as hunting and fishing facilities.

The principal industries in the four-county area are concerned with the production and refining of petroleum and the manufacture of steel products, mostly pipe for the oil and gas industry. The production of oil in the four-county area during 1962 was 7,408,240 barrels, and the cumulative production to January 1, 1963 was 238,804,278 barrels (The Railroad Commission of Texas, 1963). The American Petrofina Co. operates an oil refinery at Mount Pleasant. The Lone Star Steel Co.'s smelter and mill are located in southern Morris County about 8 miles south of Daingerfield. The iron ore is obtained from Morris County and from nearby Cass, Marion, and Upshur Counties. The oil refinery and steel mill obtain water from both surface reservoirs and wells.

The populations of the counties, cities, and towns in 1960 (U.S. Census data) were as follows: Camp County, 7,849; Pittsburg, 3,796; Franklin County, 5,101; Mount Vernon, 1,338; Winnsboro (in Franklin and Wood Counties), 2,675; Morris County, 12,576; Daingerfield, 3,133; Lone Star, 1,513; Naples, 1,692; Omaha, 854; Titus County, 16,785; Mount Pleasant, 8,027; Talco, 1,024. The public water supplies for Pittsburg, Winnsboro, Naples, Omaha, and Talco are obtained from wells; Mount Vernon, Daingerfield, Lone Star, and Mount Pleasant are supplied with surface water from storage reservoirs. Most of the domestic supplies of water are obtained from wells, but some are supplied from rainwater collected in cisterns, and a few are supplied from small reservoirs. Almost all the ground water used for irrigation is applied to lawns and small gardens. Small reservoirs, springs, and streamflow supply much of the water for livestock; the remainder is obtained from wells.

In 1963, approximately 19,000 acre-feet, or 17 mgd (million gallons per day) of water was used in Camp, Franklin, Morris, and Titus Counties (Table 1). Approximately 15,000 acre-feet (13 mgd), almost 80 percent of the total amount used, was obtained from surface-water reservoirs (Table 7); the remaining 4,300 acre-feet (3.8 mgd) was ground water from the Cypress aquifer (Tables 1 and 4), the principal ground-water source in the four-county area. An additional 240 acre-feet (0.21 mgd) of ground water was used in 1963 in the Talco area, but it was obtained from wells tapping the Nacatoch Sand in Red River County.

The normal annual precipitation of about 44 inches and the rolling to hilly topography are factors favorable for the construction of dams and the development of surface-water resources. Several cities and towns have changed to surface-water supplies because of the generally low yields of the wells and high pumping costs and the presence of large amounts of iron in the ground water.

Table 1.--Water use in Camp, Franklin, Morris, and Titus Counties, 1963

Source	Public supply		Industrial		Domestic		Livestock		Total	
	Mgd	Acre-feet	Mgd	Acre-feet	Mgd	Acre-feet	Mgd	Acre-feet	Mgd	Acre-feet
Ground water from the Cypress aquifer	0.98	1,100	1.07	1,200	1.52	1,700	0.26	290	3.8	4,300
Surface water	1.78	2,000	11.60	13,000	--	--	--	--	13	15,000
Totals*	2.8	3,100	13	14,000	1.5	1,700	0.26	290	17	19,000

*Figures are approximate because some of the pumpage is estimated. Totals are rounded to two significant figures.

The Ground-Water Situation

The potential of ground-water development in the four-county area is limited chiefly by two factors: the low rate at which the aquifer transmits water and the high iron content of much of the water. The first factor is beyond the limit of man's control. However, the high iron content of the water can be controlled by proper construction and operation of the wells or treatment of the water.

The Cypress aquifer, which supplies the four-county area, contains a large quantity of fresh water in storage; the upper 400 feet of the aquifer contains an estimated 7,500,000 acre-feet of water. Much of this water, however, is not available to wells because of the low coefficient of transmissibility of the aquifer. (See definitions of terms.)

The aquifer receives its recharge from the rather heavy precipitation in the four-county area. A minimum estimate of the amount of recharge is about 12,000 acre-feet per year; however, about 11,000 acre-feet is lost by the discharge of springs and seeps in the outcrop area where the streams have intersected the water table. The spring and seep flow maintains the low flow of the major streams. Only about 1,100 acre-feet of the recharge reaches the deeper part of the aquifer at the present hydraulic gradient. A large part of the recharge, which is lost to the streams in the outcrop area, could be salvaged through wells; however, in order to salvage a sizeable percentage of this water, the wells would have to be rather closely spaced, and because of the low transmissibility, they would be rather low-yield wells. Because of the large number of wells required, it is probably not economically feasible to attempt to salvage a large percentage of the discharge.

The water in the aquifer that contains the high concentration of iron occurs generally between depths of about 60 to 160 feet. The water above approximately 60 feet contains little or no iron; however, the water is acidic and corrodes the metal pipes, pump, and casing with which it comes in contact. Thus, it may dissolve objectionable quantities of iron before it is used. The water below approximately 160 feet contains little or no iron in solution and is slightly alkaline. Thus, if iron-free water is required, the wells should be drilled completely through the two upper zones--that is, reaching a depth greater than 160 feet. The wells should be cased through the upper two zones and the casing should be cemented so as to minimize the possible downward movement along the casing of the high iron-bearing water or acid water. The wells should be pumped at low rates so that the drawdown is held to a minimum and the possibility of vertical movement of the overlying objectionable water downward through the aquifer into the iron-free water zone is minimized.

Because of the availability of surface water and the low coefficient of transmissibility and quality-of-water problems of the aquifer, no extensive development of the Cypress aquifer is anticipated. However, the present rate of ground-water withdrawal could be at least doubled (8,600 acre-feet per year) if the wells were properly constructed, adequately spaced, and discharge rates were regulated to prevent excessive drawdowns.

DEFINITIONS OF TERMS

Many of the definitions given below have been taken from the following reports: Meinzer (1923b), American Geological Institute (1960), Langbein and Iseri (1960), and Ferris and others (1962).

Acre-foot.--The volume of water required to cover 1 acre to a depth of 1 foot (43,560 cubic feet), or 325,851 gallons. The term is commonly used in measuring volume of water in storage in an aquifer, in a surface reservoir, or volume used.

Ac-ft.--Acre-foot or acre-feet.

Ac-ft/yr.--Acre-feet per year. One ac-ft/yr equals 892.07 gallons per day.

Alluvial deposits.--See alluvium.

Alluvium.--Sediments deposited by streams; includes flood-plain deposits and stream-terrace deposits. Also called alluvial deposits.

Aquifer.--A formation, group of formations, or part of a formation that is water bearing.

Aquifer, Cypress.--Name given collectively to several water-bearing geologic units in the report area: Wilcox Group, Carrizo Sand, Reklaw Formation, and Queen City Sand.

Aquifer test, pumping test.--The test consists of the measurement at specific intervals of the discharge and water level of the well being pumped and the water levels in nearby observation wells. Formulas have been developed to show the relationship among the yield of a well, the shape and extent of the cone of depression, and the properties of the aquifer such as the specific yield, porosity, and coefficients of permeability, transmissibility, and storage.

Aquifer test, recovery test.--The test consists of the measurement at specific intervals of the water level in the previously pumped well and the observation wells. (See Aquifer test, pumping test.) Measurements are begun shortly after the pump is stopped and are continued until the water levels rise (or recover) to their positions previous to the start of the test.

Artesian aquifer, confined aquifer.--Artesian (confined) water occurs where an aquifer is overlain by rock of lower permeability (e.g., clay) that confines the water under pressure greater than atmospheric. The water level in an artesian well will rise above the top of the aquifer. The well may or may not flow.

Artesian well.--One in which the water level rises above the top of the aquifer, whether or not the water flows at the land surface.

Base flow of a stream.--Fair weather flow in a stream supplied by groundwater discharge.

Basin, geologic.--A depressed area where the rock layers dip inward toward the center or axis, may or may not coincide with a topographic basin.

Cone of depression.--Depression of the water table or piezometric surface surrounding a discharging well, more or less the shape of an inverted cone.

Confining bed.--One which because of its position and its impermeability or low permeability relative to that of the aquifer keeps the water in the aquifer under artesian pressure.

Contact.--The place or surface where two different kinds of rock or geologic units come together, shown on both maps and cross sections (e.g., the Wilcox Group-Midway Group contact on Figure 3 and Plates 2 and 3, and the Kemp Clay-Corsicana Marl contact on Plates 2 and 3).

Dip of rocks.--The angle or amount of slope at which a bed is inclined from the horizontal; direction is also expressed (e.g., 1 degree, southeast; or 90 feet per mile, southeast).

Drawdown.--The lowering of the water table or piezometric surface caused by pumping (or artesian flow). In most instances, it is the difference, in feet, between the static level and the pumping level.

Electrical log.--A graph log showing the relation of the electrical properties of the rocks and their fluid contents penetrated in a well. The electrical properties are natural potentials and resistivities to induced electrical currents, some of which are modified by the presence of the drilling mud.

Equivalents per million (epm).--An expression of the concentration of chemical substances in terms of the reacting values of electrically charged particles, or ions, in solution. One epm of a positively charged ion (e.g., Na^+) will react with 1 epm of a negatively charged ion (e.g., Cl^-).

Evapotranspiration.--Water withdrawn by evaporation from a land area, a water surface, moist soil, or the water table, and the water consumed by transpiration of plants.

Facies.--The "aspect" belonging to a geological unit of sedimentation, including mineral composition, type of bedding, fossil content, etc. (e.g., sand facies). Sedimentary facies are areally segregated parts of differing nature belonging to any genetically related body of sedimentary deposits.

Fault.--A fracture or fracture zone along which there has been displacement of the two sides relative to one another parallel to the fracture.

Flood plain.--The lowland that borders a stream, usually dry but subject to flooding.

Formation.--A body of rock that is sufficiently homogeneous or distinctive to be regarded as a mappable unit, usually named from a locality where the formation is typical (e.g., Corsicana Marl, Kemp Clay, and Queen City Sand).

Fresh water.--Water containing less than 1,000 ppm (parts per million) of dissolved solids (Winslow and Kister, 1956, p. 5). For dissolved solids, see Table 8.

Gallons per day (gpd).

Gallons per hour (gph).

Gallons per minute (gpm).

Greensand.--A mixture of granular (sand size) iron silicate mineral of the glauconite group with varying proportions of quartz sand and clay (Eckel, 1938, p. 1).

Ground water.--Water in the ground that is in the zone of saturation from which wells, springs, and seeps are supplied.

Head.--Artesian pressure measured at the land surface reported in pounds per square inch or feet of water.

Hydraulic gradient.--The slope of the water table or piezometric surface, usually given in feet per mile.

Hydrologic cycle.--See Figure 2. The complete cycle of phenomena through which water passes, commencing as atmospheric water vapor, passing into liquid or solid form as precipitation, thence along or into the ground, and finally again returning to the form of atmospheric water vapor by means of evaporation and transpiration.

Irrigation, supplemental.--The use of ground or surface water for irrigation in humid regions as a supplement to rainfall during periods of drought. Not a primary source of moisture as in arid and semiarid regions.

Lignite.--A brownish-black coal in which the alteration of vegetal material has proceeded further than in peat but not so far as sub-bituminous coal.

Limonite.--Brown iron ore. A generic term for brown hydrous iron oxide, not specifically identified.

Lithology.--The description of rocks, usually from observation of hand specimen or outcrop.

Marl.--A calcareous clay.

Million(s) gallons per day (mgd).--One mgd equals 3.068883 acre-feet per day or 1,120.91 acre-feet per year.

Mineral.--Any chemical element or compound occurring naturally as a product of inorganic processes.

Outcrop.--That part of a rock layer which appears at the land surface. On an areal geologic map a formation or other stratigraphic unit is shown as an area of outcrop where exposed and where covered by alluvial deposits (contacts below the alluvial deposits are shown on map by dotted lines).

Permeability of an aquifer.--The capacity of an aquifer for transmitting water under pressure.

Piezometric surface.--An imaginary surface that everywhere coincides with the static level of the water in the aquifer. The surface to which the water from a given aquifer will rise under its full head.

Porosity.--The ratio of the aggregate volume of interstices (openings) in a rock or soil to its total volume, usually stated as a percentage.

Parts per million (ppm - weight).--One part per million represents 1 milligram of solute in 1 kilogram of solution. As commonly measured and used, parts per million is numerically equivalent to milligrams of a substance per liter of water.

Pyrite.--Iron pyrites. Fool's gold. A common mineral of a pale brass-yellow color and metallic luster, chemically iron disulfide (FeS_2).

Recharge of ground water.--The process by which water is absorbed and is added to the zone of saturation. Also used to designate the quantity of water that is added to the zone of saturation, usually given in acre-feet per year or in million gallons per day.

Recharge, rejected.--The natural discharge of ground water in the recharge area of an aquifer by springs, seeps, and evapotranspiration, occurs when the rate of recharge exceeds the rate of transmission in the aquifer.

Resistivity (electrical log).--The resistance of the rocks and their fluid contents penetrated in a well to induced electrical currents. Permeable rocks containing fresh water have high resistivities.

Salinity of water.--From a general classification of water based on dissolved-solids content by Winslow and Kister (1956, p. 5): slightly saline water, 1,000 to 3,000 ppm; moderately saline water, 3,000 to 10,000 ppm; very saline water, 10,000 to 35,000 ppm; and brine, more than 35,000 ppm. For dissolved solids, see Table 8.

Siderite.--A mineral of brown color, chemically ferrous carbonate ($FeCO_3$).

Specific capacity.--The rate of yield of a well per unit of drawdown, usually expressed as gallons per minute per foot of drawdown. If the yield is 250 gpm and the drawdown is 10 feet, the specific capacity is 25 gpm/ft.

Specific yield.--The quantity of water that an aquifer will yield by gravity if it is first saturated and then allowed to drain; the ratio expressed in percentage of the volume of water drained to volume of the aquifer that is drained.

Storage.--The volume of water in an aquifer, usually given in acre-feet.

Storage, coefficient of.--The volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Storage coefficients of artesian aquifers may range from about 0.00001 to 0.001; those of water-table aquifers may range from about 0.05 to 0.30.

Stream-gaging station.--A gaging station where a record of discharge (flow) of a stream is obtained.

Stream terrace.--A level and rather narrow plain in a valley at some height above the flood plain composed of alluvial deposits that represent a former flood plain of the stream.

Structural feature, geologic.--The result of the deformation or dislocation (e.g., faulting) of the rocks in the earth's crust. In a structural basin, the rock layers dip toward the center or axis of the basin. The structural basin may or may not coincide with a topographic basin.

Surface water.--Water on the surface of the earth.

Transmissibility, coefficient of.--The rate of flow of water in gallons per day through a vertical strip of the aquifer 1 foot wide extending through the vertical thickness of the aquifer at a hydraulic gradient of 1 foot per foot and at the prevailing temperature of the water. The coefficient of transmissibility from a pumping test is reported for the part of the aquifer tapped by the well.

Transmission capacity of an aquifer.--The quantity of water that can be transmitted through a given width of an aquifer at a given hydraulic gradient, usually expressed in acre-feet per year or million gallons per day.

Transpiration.--The process by which water vapor escapes from a living plant, principally the leaves, and enters the atmosphere.

Water level.--Depth to water, in feet below the land surface, where the water occurs under water-table conditions (or depth to the top of the zone of saturation). Under artesian conditions the water level is a measure of the pressure on the aquifer, and the water level may be at, below, or above the land surface.

Water level, pumping.--The water level during pumping measured in feet below the land surface.

Water level, static.--The water level in an unpumped or non-flowing well measured in feet above or below the land surface or sea-level datum.

Water table.--The upper surface of a zone of saturation except where that surface is formed by an impermeable body of rock.

Water-table aquifer (unconfined aquifer).--An aquifer in which the water is unconfined; the upper surface of the zone of saturation is under atmospheric pressure only and the water is free to rise or fall in response to the changes in the volume of water in storage. A well penetrating an aquifer under water-table conditions becomes filled with water to the level of the water table.

Yield of a well.--The rate of discharge, commonly expressed as gallons per minute, gallons per day, or gallons per hour. In this report, yields are classified as small, less than 50 gpm (gallons per minute); moderate, 50-500 gpm; and large, more than 500 gpm.

Present Investigation

The general scope of the investigation in Camp, Franklin, Morris, and Titus Counties included the collection, compilation, and analysis of data related to ground water in the project area. Included in the investigation were determinations of the location and extent of the water-bearing formations, the chemical quality of the water they contain, the quantity of water being withdrawn and the effects of these withdrawals on the water levels, the hydraulic characteristics of the important water-bearing formations, and estimates of the quantities of ground water available for development.

Methods of Investigation

The following items of work were included in the investigation of the ground-water resources of Camp, Franklin, Morris, and Titus Counties:

1. An inventory (Table 9) was made of 769 water wells and 13 springs, including all public supply and industrial wells and many of the domestic and stock wells. The locations of the wells inventoried are shown on Plate 1. Almost all of the ground water used for irrigation in the report area is applied to lawns and small gardens.

2. The electric logs of 137 oil or gas tests (Table 9) were used for correlation purposes and for a study of the water-bearing properties of the geologic formations. The locations of these tests are shown on Plate 1.

3. An inventory (Table 1) was made of the quantities of water used for public supply and industry, and an estimate was made of the quantity of water used for domestic and livestock purposes.

4. Aquifer tests (Table 3) were run in 11 wells to determine the hydraulic characteristics of the water-bearing sands.

5. Measurements of water levels were made in wells and available records of past fluctuations of water levels were compiled (Table 9).

6. Climatological and streamflow records (Table 6) were collected and compiled.

7. Analyses of samples of water collected during this and previous investigations (Tables 11 and 12) were used to determine the chemical quality of the water.

8. A map showing the extent and thickness of the sands containing fresh water in the principal aquifer was made from electrical-log data and from the chemical analyses of water samples (Figure 13).

9. Two geologic cross sections were made from electric logs (Plates 2 and 3).

10. The hydrologic data were analyzed to determine the quantity and quality of ground water available for development.

11. Problems related to the development of ground-water supplies in the four-county area were studied.

Well-Numbering System

The well-numbering system used in this report is one adopted by the Texas Water Commission for use throughout the State and is based on latitude and longitude. Under this system, each 1-degree quadrangle in the State is given a number consisting of two digits. These are the first two digits appearing in the well number. Each 1-degree quadrangle is divided into 7½-minute quadrangles which are also given 2-digit numbers from 01 to 64. These are the third and fourth digits of the well number. Each 7½-minute quadrangle is subdivided into 2½-minute quadrangles and given a single digit number from 1 to 9. This is the fifth digit of the well number. Finally, each well within a 2½-minute quadrangle is given a 2-digit number in the order in which it is inventoried, starting with 01. These are the last two digits of the well number. In addition to the 7-digit well number, a 2-letter prefix is used to identify the county. The prefixes for Camp, Franklin, Morris, Red River, Titus, and Wood Counties are as follows:

County	Prefix	County	Prefix
Camp	BZ	Red River	WB
Franklin	JZ	Titus	YA
Morris	TU	Wood	ZS

Thus, well YA-16-49-402 (the standby water well for the city of Mount Pleasant) is in Titus County (YA), in the 1-degree quadrangle number (16), in the 7½-minute quadrangle (49), in the 2½-minute quadrangle (4), and was the second well (02) inventoried in that 2½-minute quadrangle.

On the well-location map of this report (Plate 1), the 7½-minute quadrangles are numbered in the northwest corner of each quadrangle. The 3-digit number shown with the well symbol is the number of the 2½-minute quadrangle in which the well is located and the number of the well within that quadrangle. For example, the city of Mount Pleasant well is numbered 402 in the quadrangle numbered 1649 in the upper left corner.

Previous Investigations

Previous investigations of the ground-water resources of the four-county area include well inventories of Morris County by Follett (1942) and of Camp, Franklin, and Titus Counties by Broadhurst (1943). These inventories included records of wells, drillers' logs, water analyses, and maps showing locations of wells and springs. Sundstrom (1941) described the ground-water resources in the vicinity of Daingerfield and the adjacent part of Cass County. The public water supplies of Pittsburg, Mount Vernon, Daingerfield, Naples, Omaha, Mount Pleasant, and Talco were included in an inventory of the public water supplies in eastern Texas by Sundstrom, Hastings, and Broadhurst (1948, p. 40-41, 92-93, 223-225, 263-264). A reconnaissance report on the ground-water resources of the Red River, Sulphur River, and Cypress Creek Basins (Baker, Long, Reeves, and Wood, 1963) included information on Camp, Franklin, Morris, and Titus

Counties. Two reports on regional geology (Sellards and others, 1932; Eckel, 1938) include descriptions of the geologic formations in the report area.

Acknowledgments

The authors are indebted to the landowners in Camp, Franklin, Morris, and Titus Counties for supplying information about their water wells and for permitting access to their properties, to the well drillers for logs and other information on water wells, and to the officials of the cities and towns. Considerable help was received from Max Hightower and John B. Stephens, Jr., of Mount Pleasant, the Layne-Texas Co., and J. D. Hem, U.S. Geological Survey.

PHYSIOGRAPHY AND CLIMATE

Camp, Franklin, Morris, and Titus Counties are in the West Gulf Coastal Plain of Texas (Fenneman, 1938, p. 100). The principal physiographic features in the area are the wide lowland along Sulphur River and White Oak Creek extending across the northern part of the report area, the gently rolling topography across the central part, and the gently rolling to hilly topography across the southern part. Most of the northern one-half of the report area is drained by White Oak Creek and its tributaries, and most of the southern half is drained by Cypress Creek and its tributaries. The only relatively flat areas are the alluvial lands along the major streams.

Altitudes range from about 250 to about 600 feet. Altitudes along the Sulphur River range from about 250 feet in northeastern Morris County to about 350 feet in northwestern Franklin County. On the divide between White Oak Creek and Cypress Creek, the altitudes range from about 400 feet at Naples to about 500 feet near Mount Vernon; the altitude at Mount Pleasant is about 413 feet. In the southern part of the report area, altitudes range from about 250 feet along Cypress Creek in southeastern Morris County to about 600 feet on isolated hills. In the central and northern parts of the report area, the local relief is about 60 feet; in the southern part, it ranges from 250 to 350 feet.

Hundreds of small reservoirs have been constructed on the rolling to hilly topography, primarily for livestock water supplies; approximately 1,500 reservoirs from one-half acre to 30 acres in size are in Titus County. Three large-capacity reservoirs have been constructed in and near the report area for public supply and industrial uses--Lake O' the Pines on Cypress Creek, Lake Texarkana on the Sulphur River, and Ellison Creek Reservoir.

The records of the U.S. Weather Bureau at Mount Pleasant date from 1933 and provide the most complete climatological data for the four-county area. The normal annual precipitation at Mount Pleasant is 43.87 inches, and the normal monthly precipitation, in inches, is as follows:

Jan.	4.10	May	4.65	Sept.	2.25
Feb.	3.17	June	3.32	Oct.	3.58
Mar.	4.28	July	3.24	Nov.	3.55
Apr.	4.69	Aug.	2.70	Dec.	4.34

The normal January temperature is 45.0°F, and the normal July temperature is 82.9°F. The average date of the first killing frost is November 8 and the last is March 25. The mean annual growing season is 228 days.

In Thornthwaite's (1952, p. 25-35, and Fig. 30) classification of the climate, the boundary between the moist subhumid and humid belts extends across Camp and Titus Counties; east of the boundary the climate is humid. Because of the generally high precipitation in the report area, the surface-water resources have been extensively developed for public supply, industrial, livestock, and recreational uses.

GEOLOGY AS RELATED TO THE OCCURRENCE OF GROUND WATER

General Geology

The geologic formations pertinent to the occurrence of ground water in the report area range in age from Cretaceous to Recent. Their thickness, lithology, age, and water-bearing characteristics are summarized in Table 2. The general geology, including the areas where the formations crop out, is shown by the geologic map (Figure 3). The geologic sections (Plates 2 and 3) show the stratigraphic relationship between the geologic units. Figure 4 is a map showing by contours the altitude of the top of the Midway Group; this horizon is the base of the principal aquifer and is the approximate base of the fresh to slightly saline water. In the area east of Talco, the contours are not shown because of complicated faulting.

The rocks comprising the geologic formations in the report area have a total thickness of about 2,860 feet and consist mainly of clay and marl in the lower half and sand and clay in the upper half. The geologic formations crop out in belts that extend in a northeasterly direction across the report area and into adjacent counties (Figure 3).

The rocks dip southeast toward the axis of the East Texas basin which extends northeasterly and lies just south of the report area.

An important structural feature is the Talco fault zone which is about 3 miles wide extending across the northernmost parts of Franklin, Titus, and Morris Counties (Figure 3). The rocks near the land surface in the area between the north and south faults have been displaced downward (relative to the rocks on both sides) as much as 360 feet at the oil field near Talco (Wendlandt and Shelby, 1948, p. 443).

Physical Characteristics and Water-Bearing Properties of the Geologic Formations

Navarro Group

The Nacatoch Sand of the Navarro Group crops out north of the report area. The formation has a maximum observed thickness of about 500 feet and consists of fossiliferous fine sand and marl. The sand is thickest near the top and marl predominates near the base. South of the Talco fault zone, the Nacatoch is capable of yielding large quantities (more than 500 gpm) of very saline water

Table 2.--Geologic units and their water-bearing properties, Camp, Franklin, Morris, and Titus Counties

System	Series	Group	Unit	Approximate thickness (feet)	Character of rocks	Water-bearing properties
Quaternary	Recent and Pleistocene		Alluvium	50	Clay and fine sand.	Yields small quantities of fresh water to a few wells.
Tertiary	Eocene	Claiborne	Sparta Sand	50	Sand, sandy shale, and clay.	Yields small quantities of fresh water to domestic and livestock wells.
			Weches Greensand	30	Greensand, sand, and clay. Iron ore on outcrop.	Do.
			Queen City Sand	210	Fine to medium sand, shale, silt, and impure lignite.	Yields moderate to large quantities of fresh water to wells. Principal source of ground water in Camp, Franklin, Morris, and Titus Counties --Units are interconnected hydraulically and function as a single aquifer which is herein named the "Cypress Aquifer."
			Recklaw Formation	110	Sand and shale.	
			Carrizo Sand	80	Fine to coarse sand, silt, and clay.	
		Wilcox		770	Fine to medium sand, shale, clay, and lignite.	
	Paleocene	Midway		760	Calcareous clay and some thin beds of fine sand or silt in upper part.	Yields only small quantities of fresh water to a few wells in area of outcrop. Mostly non-water-bearing.
Cretaceous	Gulf	Navarro	Kemp Clay	220	Clay.	Not known to yield water to wells.
			Corsicana Marl	30	Hard marl.	Do.
			Nacatoch Sand	500	Fine sand and marl. Sand beds thickest near top; marl predominates near base.	Yields large quantities of very saline water to wells south of the Talco fault zone, and moderate quantities of fresh water to wells north of the fault zone.

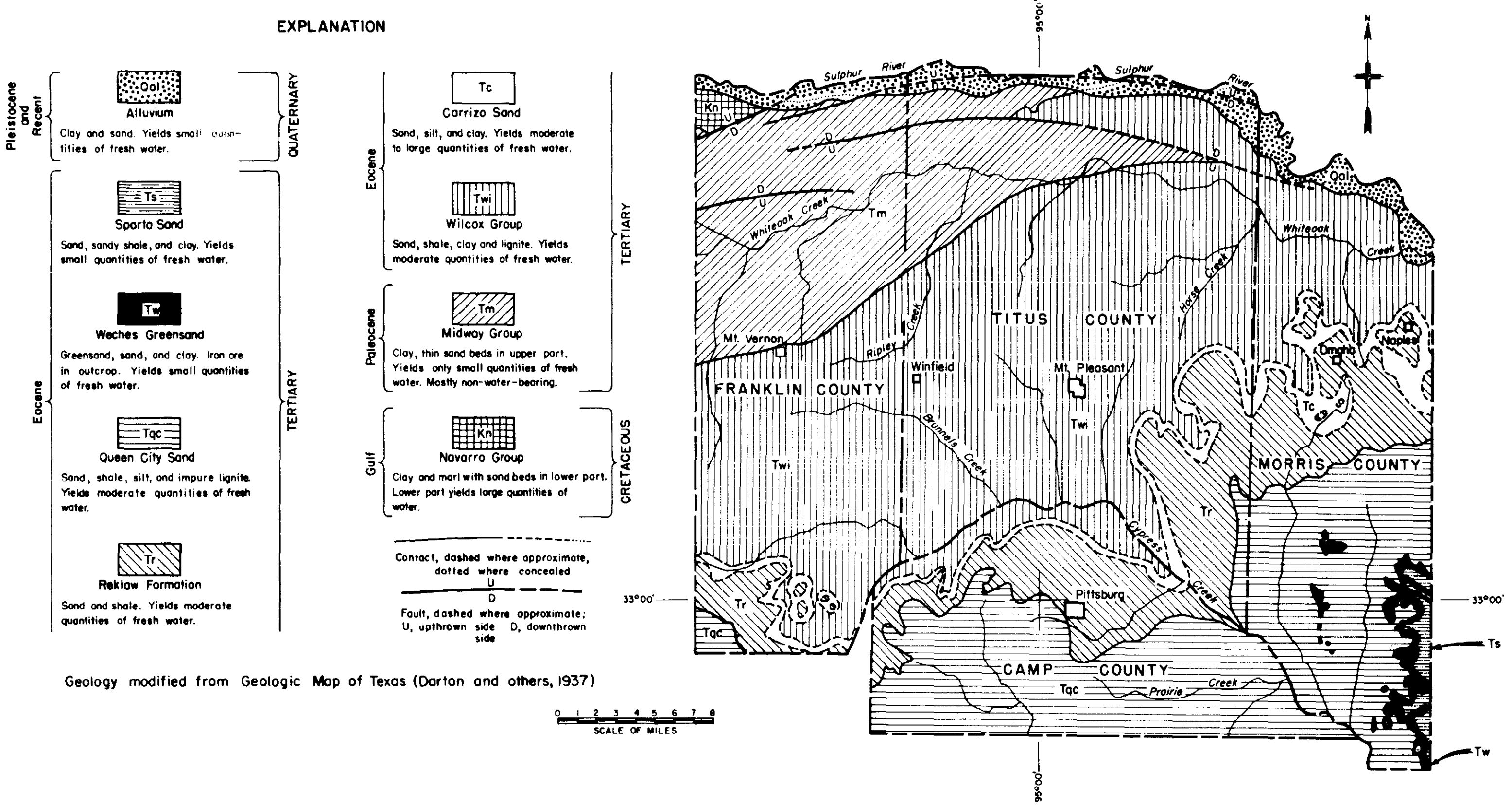

Figure 3

Geologic Map of Camp, Franklin, Morris, and Titus Counties

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(10,000-35,000 ppm dissolved solids); north of the fault zone in Red River County, it yields moderate quantities (50-500 gpm) of fresh water (less than 1,000 ppm dissolved solids) to wells that supply the city of Talco and industrial needs in the Talco oil field.

The Corsicana Marl crops out north of the report area. It has a maximum thickness of about 30 feet and consists chiefly of hard marl that makes an excellent correlation bed on electrical logs (Plates 2 and 3). The formation is not known to yield water to wells. The Corsicana overlies the Nacatoch Sand and forms the confining layer for it.

The Kemp Clay, the uppermost member of the Navarro Group, has a maximum thickness of about 220 feet and consists of fossiliferous clay. Most of the outcrop of the Kemp is north of the report area, but the formation also crops out in a small area in the northwest corner of Franklin County (Figure 3). The formation is not known to yield water to wells.

Midway Group

The Midway Group crops out in the northern part of Franklin County and in the northwestern part of Titus County (Figure 3). The group has a maximum thickness of about 760 feet and consists of calcareous clay and some thin beds of fine sand or silt in the upper part. The dip of the top of the Midway is to the southeast at the rate of about 66 feet per mile in the northwestern part of the report area and from 30 to 15 feet per mile in the southeastern part (Figure 4). The Midway yields only small quantities (less than 50 gpm) of fresh water to a few shallow wells in the area of outcrop; in most places it yields no water. It is hydrologically significant in that it forms the bottom confining layer for the overlying Wilcox Group.

Wilcox Group

The Wilcox Group crops out in the southern part of Franklin County, the southwestern and northeastern parts of Titus County, and in the northern part of Morris County (Figure 3). The group is about 770 feet thick and consists mostly of fine to medium crossbedded sand, shale, clay, and lignite. Some beds contain minor amounts of greensand, siderite, and pyrite. Thick sand beds are present locally in the Wilcox Group; however, the individual sand beds are not continuous but lens out in short distances. Thin beds of limonite are common on the surface. The Wilcox yields moderate quantities of fresh water to wells. For practical purposes, the base of the Wilcox is approximately the base of fresh water (Plates 2 and 3), although slightly saline water (1,000-3,000 ppm dissolved solids) probably occurs in the extreme lower part of the group in many places.

Claiborne Group

The Claiborne Group in the report area includes the Carrizo Sand, Reklaw Formation, Queen City Sand, Weches Greensand, and Sparta Sand. The Carrizo, Reklaw, and Queen City crop out in the southwest corner of Franklin County, most of Camp County, the southeastern part of Titus County, and the southern part of Morris County; the Weches and the overlying Sparta Sand cap the ridges in the southeastern part of Morris County (Figure 3).

The Carrizo Sand has a maximum thickness of about 80 feet and consists chiefly of fine to coarse sand, silt, and clay; it contains thin lignite beds in a few places. In central and south Texas, the Carrizo Sand is a distinct unit and is an important aquifer. In Camp, Franklin, Morris, and Titus Counties, the Carrizo is indistinguishable in most places from the underlying Wilcox Group and the overlying Reklaw Formation. In some places it is even doubtful whether the Carrizo is actually present. Where the Carrizo is present, it yields moderate to large quantities of fresh water to wells.

The Reklaw consists of sand and shale and some greensand; thin lenses of limonite are found in weathered outcrop zones. The Reklaw has a maximum thickness of about 110 feet and yields moderate amounts of fresh water to wells. In south and central Texas, the Reklaw consists chiefly of shale, and the unit forms the confining layer for the underlying massive Carrizo Sand. In the report area, apparently a different facies is present, and the Reklaw is chiefly sand. The unit is not easily determined on electric logs of wells.

The Queen City Sand has a maximum thickness of about 210 feet in the report area. It consists chiefly of fine to medium sand interbedded with carbonaceous shale, silt, and impure lignite, and contains some greensand. Limonite forms on the weathered outcrops of the formation. The sand is typically lenticular and crossbedded. The Queen City yields moderate quantities of fresh water to wells. Because of the sandy nature of the underlying Reklaw Formation, the Queen City Sand has not been separated from it on the geologic sections.

The Weches Greensand consists mainly of greensand, quartz sand, siderite, pyrite, and clay. The iron-bearing minerals, greensand, siderite, and pyrite weather to limonite or brown ore, which is distributed irregularly through the weathered zone in the upper part of the formation. The average thickness of the Weches is about 30 feet, and the formation supplies small quantities of fresh water to domestic and livestock wells. The Weches caps the ridges and isolated hills in the southern and southeastern parts of Morris County. This area supplies part of the iron ore used by the steel mill near Daingerfield.

The Sparta Sand consists of sand with interbedded layers or lenses of clay and sandy shale, and some greensand. There is some limonite in the weathered zone. The Sparta has a maximum thickness of about 50 feet in the report area. It overlies the Weches Greensand on the ridges and hills in the southeastern part of Morris County where it supplies small quantities of fresh water to domestic and livestock wells.

Alluvium

The alluvial deposits reach a maximum thickness of about 50 feet and they consist mainly of clay and sand. They comprise the flood plains of the larger streams and include the terrace deposits along the Sulphur River. Only the alluvial deposits along the Sulphur River are shown on the geologic map (Figure 3). The alluvium yields only small quantities of fresh water to a few wells.

Cypress Aquifer

The Wilcox Group and the Carrizo Sand, Reklaw Formation, and Queen City Sand of the Claiborne Group have similar hydrologic properties and are the principal source of fresh ground water in the four-county area. The units probably are interconnected hydraulically and they function as a single aquifer; the aquifer is herein named the "Cypress aquifer" from Cypress Creek, which is the common boundary of the four counties.

The outcrop of the Cypress aquifer includes about 900 square miles, representing all of the report area southeast of the contact of the Wilcox Group with the underlying Midway Group (Figure 3), with the exception of a small area in southern Morris County where the aquifer is overlain by the Weches Greensand. As described previously, the rocks comprising the geologic units of the aquifer have many characteristics in common. Sand comprises about half the volume of the aquifer, and the remainder is chiefly shale, clay, and silt, and numerous beds of lignite. The rocks generally contain some iron-bearing minerals. Many thin beds, lenses, and nodules of limonite are common on the surface and in the weathered zone underneath, and many of the exposed sand beds are cemented with limonite. The limonite deposits were derived from the weathering of the iron-bearing minerals in the rocks. The thickness of the Cypress aquifer ranges from zero at the contact of the Wilcox Group with the underlying Midway Group to about 1,200 feet in the southeastern part of the four-county area.

The numerous sand beds in the Cypress aquifer are deviously connected to each other through or around the intervening lenses and beds of shale, clay, and silt. The range in thickness of the individual sand beds and the discontinuity of the beds are shown on the geologic sections (Plates 2 and 3), which were constructed from electric logs. The sand beds are represented by high resistivities on the logs and the shale and clay beds by low resistivities. The difficulty in correlating the beds from well to well is obvious.

The sand beds in the Cypress aquifer constitute the principal source of fresh ground water in the four-county area. Because of the discontinuities of the individual sand beds and the associated shales and clays, the occurrence of ground water is complex. In and near the outcrop area of the sand beds, the contained water is under water-table conditions. Water-table conditions prevail to depths of more than 100 feet in some areas; in others, artesian conditions occur at depths considerably less than 100 feet. Below about 100 feet, all of the water is under artesian pressure.

GROUND-WATER HYDROLOGY

The following discussion concerns the general principles of ground-water hydrology as they apply to the four-county area. For a more comprehensive discussion of these and other hydrologic principles, the reader is referred to Meinzer (1923a, 1923b), Meinzer and others (1942), Todd (1959), Tolman (1937), and Wisler and Brater (1959); for nontechnical discussions, Leopold and Langbein (1960), and Baldwin and McGuinness (1963).

Source and Occurrence of Ground Water

The source of ground water in the Cypress aquifer is precipitation on the outcrop of the aquifer in the four-county area. Much of the water from precipitation is evaporated at the land surface, transpired by plants, or retained by capillary forces in the soil; a small part migrates downward by gravity through the zone of areation or essentially dry rocks until it reaches the zone of saturation where the rocks are saturated with water. In the zone of saturation, water is contained in the interstices or pore spaces between the rock particles, such as sand grains.

Water-bearing rock units, or aquifers, are classified into two types--water-table, or unconfined aquifers, and artesian, or confined aquifers. Unconfined water occurs where the upper surface of the zone of saturation is under atmospheric pressure only and the water is free to rise or fall in response to the changes in the volume of water in storage. The upper surface of the zone of saturation is the water table, and a well penetrating an aquifer under water-table conditions becomes filled with water to the level of the water table. Water-table conditions occur in the upper part of the Cypress aquifer.

Confined water occurs where an aquifer is overlain by rock of lower permeability such as clay that confines the water under a pressure greater than atmospheric. Such artesian conditions occur downdip from the outcrops of sands in the Cypress aquifer. A well penetrating sands under artesian pressure becomes filled with water to a level above the base of the confining layer of rock, and, if the pressure head is large enough to cause the water in the well to rise to an altitude greater than that of the land surface, the well will flow. Flowing wells are more common at lower altitudes especially in valleys of the larger streams. The level or surface to which water will rise in artesian wells is called the piezometric surface. Although the terms water table and piezometric surface are synonomous in the outcrop areas of the aquifers, the term piezometric surface, as used in this report, is applicable only in artesian areas.

Recharge, Movement, and Discharge of Ground Water

Aquifers may be recharged by either natural or artificial processes. Natural recharge results from the infiltration of precipitation, either where it falls or from runoff en route to a water course, and from the infiltration of water from streams and lakes. Artificial recharge processes include infiltration of irrigation water, industrial waste water, and sewage. Improperly treated waste water and sewage may contaminate the supply of fresh ground water, especially at shallow depths.

Many factors govern the rate of natural recharge--the type of soil, the duration and intensity of rainfall, the slope of the land surface, the presence or absence of a cover of vegetation, and the position of the water table are among the most important. The sandy soil on the outcrop of the Cypress aquifer is favorable to recharge. In general, the greater the precipitation on the outcrop area of an aquifer, the greater the recharge, but the duration and intensity of rainfall are also factors of considerable importance. A given amount of rainfall during a short period usually results in less recharge than the same amount of rainfall during a longer period. Also, the rate of recharge can be greater during the winter months when plant growth is at a minimum and the evaporation rate is lower.

Ground water moves through the sand beds in the Cypress aquifer from areas of recharge to areas of discharge at a slow rate, perhaps a few hundred feet per year. The force of gravity is responsible for the initial infiltration and the downward movement of the water to the zone of saturation. After reaching the zone of saturation, the movement of the water generally has a large and almost horizontal component in the direction of decreasing pressure or head--generally toward the southeast in the direction of the dip of the rocks.

However, the movement is rarely uniform in direction or velocity. The flow is greatest along routes of least resistance, such as unconsolidated sand, and least in masses of sediment having relatively low permeability, such as cemented sand or clay.

The quantity of recharge to the Cypress aquifer has not been measured; however, an estimate of the minimum figure for recharge can be made. The water table in the outcrop or recharge area of the aquifer lies at an altitude above the base of the streams in most areas and the water table is intersected by the major streams. As a result of the position of the water table, much of the water which enters the aquifer in the outcrop area moves to the stream valleys and is discharged as seep and spring flow in the outcrop area. This is actually a form of discharge from the aquifer, but for purposes of this report, it is referred to as rejected recharge in that the water did not reach the deeper part of the aquifer below the level of the streams. Part of the discharge in the outcrop area is consumed by evapotranspiration in the stream valleys; the remainder maintains the low flow of the streams in the area. On the basis of the low flow of Cypress Creek as measured at the stream-gaging station Cypress Creek near Pittsburg, the quantity of flow contributed to the stream by rejected recharge is estimated at about 11,000 acre-feet per year, or 10 mgd. The part of the recharge which escapes rejection in the outcrop area moves down the dip of the formations and leaves the four-county area as underflow moving toward the southeast. This quantity can be estimated knowing the transmissibility of the aquifer and the approximate hydraulic gradient. Based on estimates of these values, the quantity moving through the aquifer under the present gradient is approximately 1,100 acre-feet per year, or about 1 mgd. Thus, the total minimum recharge to the aquifer is the sum of these two values, or a total figure of about 12,000 acre-feet per year, or 11 mgd. This figure is a minimum because it neglects the water which has been consumed by evapotranspiration in the outcrop area.

The water in the Cypress aquifer is discharged both naturally and artificially. The natural discharge is the flow of springs and seeps, evaporation from the water table, and the transpiration by trees and plants whose roots reach the water table. The discharge from springs and seeps (rejected recharge) was estimated previously at a minimum of 11,000 acre-feet per year, or 10 mgd. The discharge by evaporation and transpiration is not known, but the quantity is large because of the shallow depth to the water table and the great density of vegetation. The artificial discharge of ground water is from flowing or pumped wells. This quantity was about 4,300 acre-feet (3.8 mgd) in 1963.

Hydraulic Characteristics of the Cypress Aquifer

When water is discharged from an aquifer through a well, a hydraulic gradient in the water table or piezometric surface is established toward the well. When a well is pumped or allowed to flow, the level of the water table or piezometric surface is lowered; the difference between the discharging level and the static level (water level before pumping or before start of flow) is the drawdown. The water table or piezometric surface surrounding a discharging well assumes more or less the shape of an inverted cone which is called the cone of depression.

The rate at which water is transmitted by an aquifer depends on the ability of the aquifer to transmit water and the hydraulic gradient. The amount of water released from storage depends chiefly on the elasticity and compressibility of the sands and the associated rocks and the expansion of the water as the artesian pressure is lowered.

Formulas have been developed to show the relationship among the yield of a well, the shape and extent of the cone of depression, and the properties of the aquifer--the specific yield, porosity, permeability or transmissibility, and storage. (See Definitions of Terms.) The coefficient of transmissibility of an aquifer is the rate of flow in gallons per day through a vertical strip of the aquifer 1 foot wide and extending the full saturated thickness of the aquifer under a hydraulic gradient of 100 percent. The coefficient of transmissibility determined from an aquifer test is reported for the part of the aquifer tapped by the well (the screened interval in Table 3).

The coefficient of storage is the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface (Table 3). When artesian conditions prevail, the coefficient of storage is a measure of the ability of the aquifer to yield water from storage by the compression of the aquifer and the expansion of the water as the artesian pressure is lowered. The coefficient of storage in an artesian aquifer is small compared to that in a water-table aquifer; consequently, when an artesian well starts discharging, a cone of depression is developed through a wide area in a short time. Where water-table conditions prevail, the coefficient of storage is a measure of the ability of the aquifer to yield water from storage by gravity drainage of the aquifer; consequently, the cone of depression extends through a relatively small area. Under water-table conditions, the volume of water attributable to expansion is usually such a negligible part of the total volume of water released from the aquifer that the coefficient of storage is considered the same as the specific yield.

The yield or discharge rate of a well usually is measured in gallons per minute, gallons per hour, or gallons per day (Table 3). Yield depends on the ability of the aquifer to transmit water, the thickness of the water-bearing material, the construction of the well, the size and efficiency of the pump, and the allowable drawdown.

Formulas based on the hydraulic characteristics of an aquifer indicate that within limits the discharge from a well varies directly with the drawdown--that is, doubling the drawdown will double or nearly double the amount of discharge. The discharge per unit of drawdown (gpm per foot), or specific capacity (Table 3), is of value in estimating the probable yield of a well.

Aquifer tests were made in 11 wells tapping the Cypress aquifer to determine the ability of the aquifer to transmit and store water. The results of the tests are given in Table 3. The data from the tests were analyzed using the Theis nonequilibrium method as modified by Cooper and Jacob (1946, p. 526-534) and the Theis recovery method (Wenzel, 1942, p. 94-97). With the exception of well JZ-34-06-302 (city of Winnsboro well no. 4) in the southwest corner of the four-county area, the coefficients of transmissibility ranged from 170 to 7,300 gpd per foot, discharge rates ranged from 25 to 140 gpm, and specific capacities ranged from 0.4 to 2.0 gpm per foot of drawdown. A coefficient of storage of 0.00015 was obtained from the test of well YA-16-49-709. The test at well JZ-34-06-302 is not considered representative of conditions in the report area.

The coefficients of transmissibility and storage may be used to predict future drawdown of water levels caused by pumping. Figure 5 shows the relation

Table 3.--Results of aquifer tests in Camp, Franklin, Morris, and Titus Counties

Well	Screened Interval (feet)	Average Discharge During Test (gpm)	Coefficient of Transmissibility gpd/ft	Specific Capacity gpm/ft	Coefficient of Storage	Remarks
BZ-35-01-104	515-546 550-556 605-613 617-631 641-660	140	340	0.5	--	Recovery of pumped well. (Specific Capacity determined from a test by the Layne-Texas Company.)
JZ-17-55-404	43-90	25	5,400 7,300	2.0 --	-- --	Drawdown of pumped well. Recovery of pumped well.
JZ-17-55-403	38-72	42	6,200	--	--	Recovery of pumped well.
JZ-34-06-302	165-229	517	81,000	19.1	--	Recovery of pumped well.
TU-16-51-402	395-460 470-498	80	360 960	.9 --	-- --	Drawdown of pumped well. Recovery of pumped well.
TU-16-59-702	? -554	58	970	.6	--	Recovery of pumped well.
TU-35-03-403	289-394	70	2,000	--	--	Recovery of pumped well.
YA-16-49-402	172-208 310-350	108	2,200 2,200	1.3 --	-- --	Drawdown of pumped well. Recovery of pumped well.
YA-16-49-708	325-460	28	2,100 2,000	1.0 --	-- --	Drawdown of pumped well. Recovery of pumped well.
YA-16-49-709	321-458	28	2,500 2,500	-- --	0.00015 .00015	Drawdown in observation well. Recovery in observation well.
YA-17-56-707	125-130 135-140 150-160 165-170 185-200 210-220 235-250	28	170 250	.4 --	-- --	Drawdown of pumped well--test by Layne-Texas Company. Recovery of pumped well--test by Layne-Texas Company.

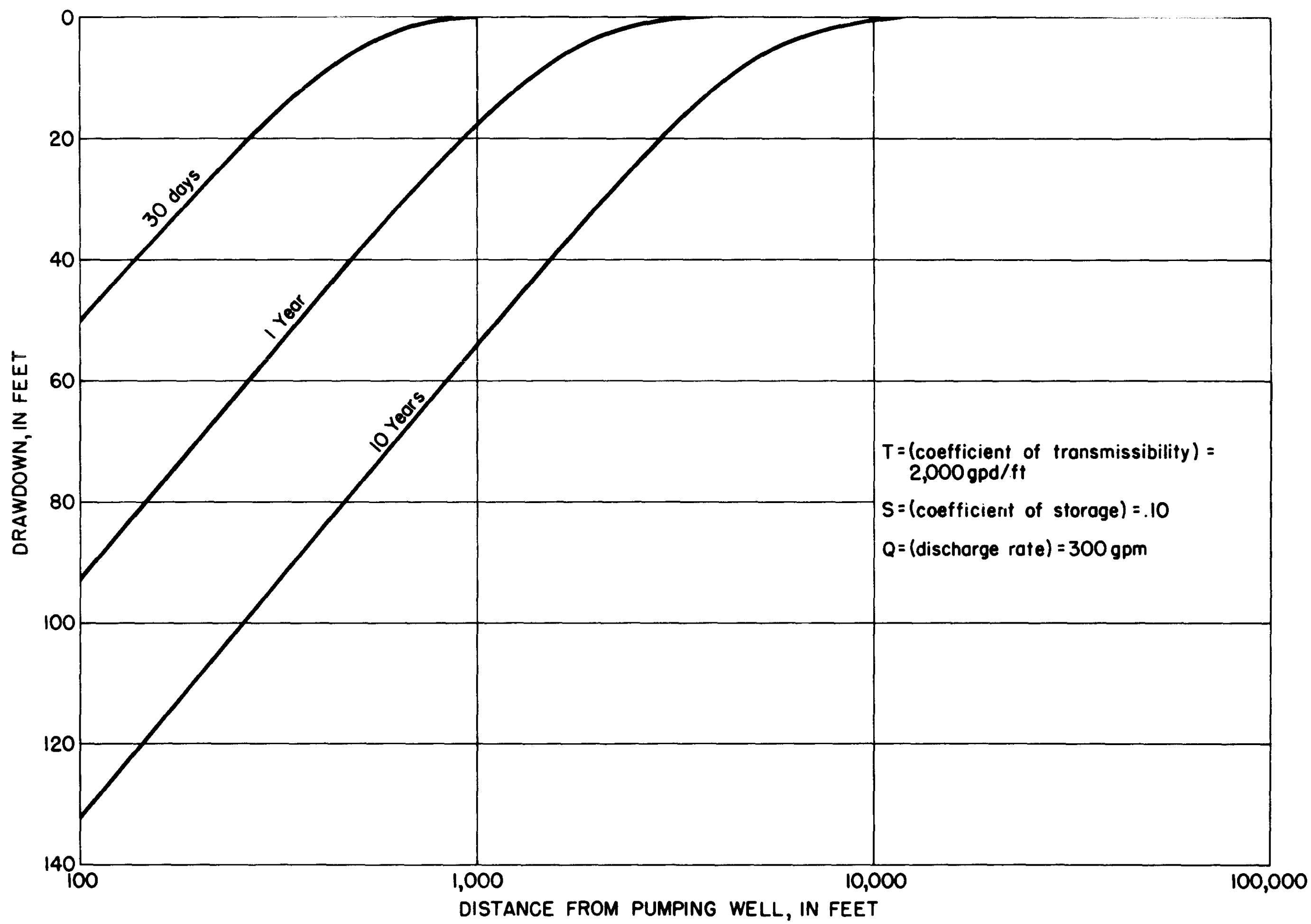

Figure 5

Graph Showing Relation Between Drawdown, Distance, and Time as a Result of Pumping Under Water-Table Conditions

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between drawdown, distance, and time as a result of pumping from a water-table aquifer of infinite areal extent. Pumping is assumed to be at a constant rate of 300 gpm, the storage coefficient is 0.10, and the coefficient of transmissibility is 2,000 gpd per foot. The figure shows that the amount of drawdown increases with time. For example, at a point 1,000 feet from the pumped well there will be no drawdown after 30 days of pumping, about 18 feet after 1 year, and about 54 feet after 10 years.

The storage coefficient of 0.10 used in the preparation of Figure 5 is a water-table storage coefficient. This graph should be used in predicting the long-term effects of pumping from wells in the four-county area or for predicting the effects of short-term pumping in shallow wells where it is clear that water-table conditions prevail. Although artesian conditions prevail in the deep wells on a short-term basis, it is believed that with long continuous pumping the aquifer will ultimately perform as a water-table aquifer. Therefore, in the long-range predictions, the values shown on Figure 5 should be used. For predicting the effect of short-term pumping from deep wells, Figure 6 has been prepared showing the relation between drawdown, distance, and time as a result of pumping from an artesian aquifer of infinite areal extent. This graph shows, for example, that at a point 1,000 feet from the pumped well there will be a drawdown of approximately 82 feet after 30 days of pumping, about 125 feet after 1 year, and about 165 feet after 10 years of pumping.

Pumping from wells drilled close together may create cones of depression that intersect, thereby causing additional lowering of the piezometric surface or water table. The intersection of cones of depression, or interference between wells, will result in lower pumping levels (and increased pumping costs) and may cause serious declines in yields of the wells. If the pumping level is lowered below the top of the well screen, that part of the aquifer will become dewatered, and the yield of the well will decrease with the decrease in the thickness of the saturated part of the aquifer. The proper spacing of wells to minimize interference can be determined from the aquifer-test data.

Development of Ground Water

Cypress Aquifer

The use of ground water from the Cypress aquifer in the four-county area in 1963 was 3.8 mgd, or 4,300 acre-feet (Table 4). Domestic use was 1.5 mgd, or about 40 percent of the total; industrial use was 1.1 mgd, or about 27 percent; public supply was 0.98 mgd, or about 25 percent; and livestock use was 0.26 mgd, or about 8 percent. Water for domestic and stock uses was obtained from about 4,000 wells; about 3,000 of these wells are less than 50 feet deep. Water for industrial use was obtained from 11 wells ranging in depth from 404 to 640 feet, and water for public supply was obtained from 12 wells ranging in depth from 220 to 670 feet. The locations of wells, springs, and stream-gaging stations in the four-county area are shown on Plate 1.

The city of Pittsburg in Camp County used 0.37 mgd (418 acre-feet) in 1963--more than one-half of the ground water used in the county. The city is supplied from 4 wells, BZ-35-01-103, BZ-35-01-104, BZ-35-01-105, and BZ-35-01-108. The depths of the wells range from 220 to 670 feet, and the yields range from 100 to 310 gpm.

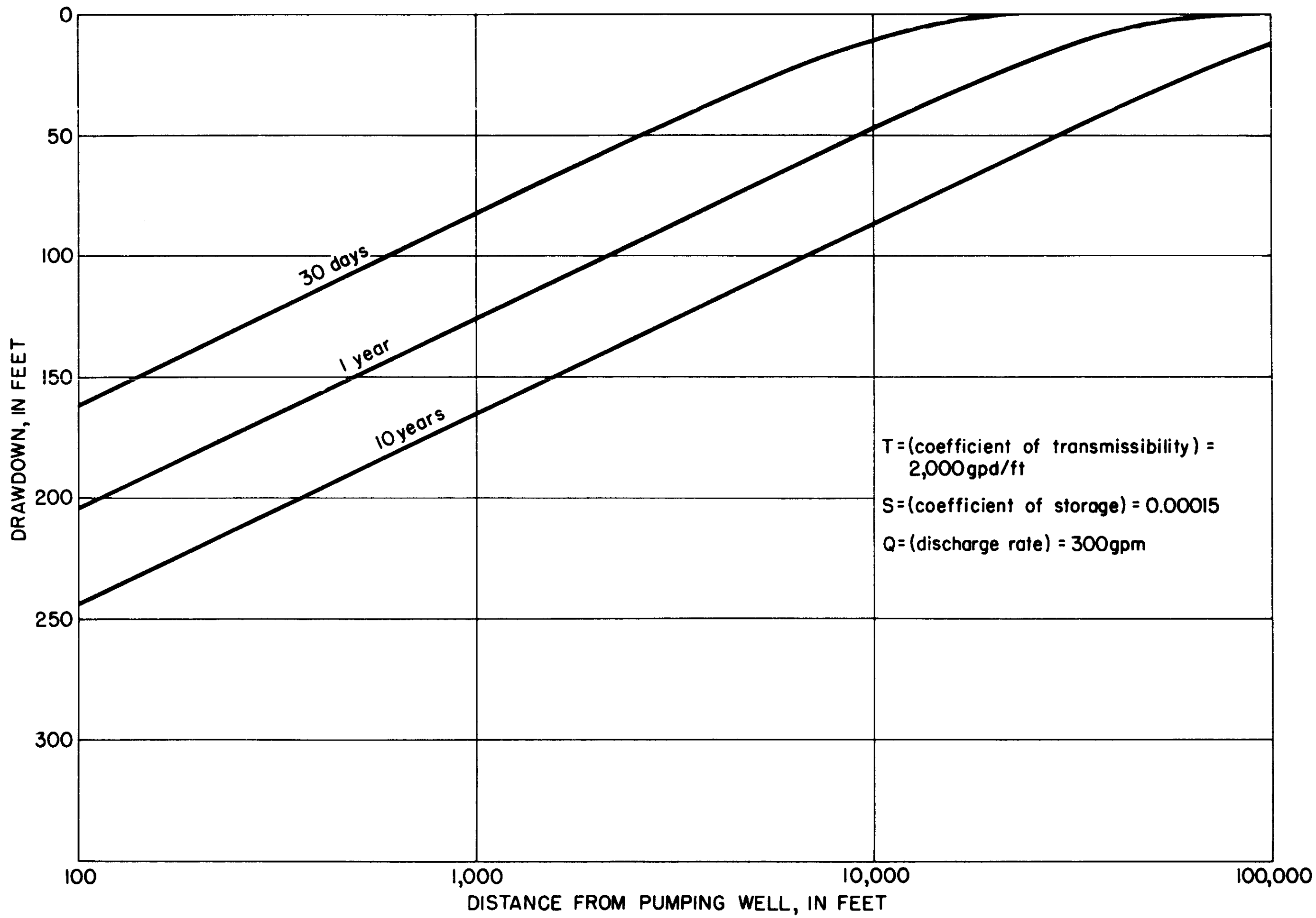

Figure 6

Graph Showing Relation Between Drawdown, Distance, and Time as a Result of Pumping Under Artesian Conditions

U.S. Geological Survey in cooperation with the Texas Water Commission

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Table 4.--Use of ground water from the Cypress aquifer in Camp, Franklin, Morris, and Titus Counties, 1963

County	Public supply		Industrial		Domestic		Livestock		Total	
	Mgd	Acre-feet	Mgd	Acre-feet	Mgd	Acre-feet	Mgd	Acre-feet	Mgd	Acre-feet
Camp	0.37	418	--	--	0.25	276	0.07	77	0.69	770
Franklin	.32	356	0.48	536	.33	368	.04	46	1.2	1,300
Morris	.27	307	.22	251	.14	153	.01	15	.65	730
Titus	--	--	.34	379	.82	921	.14	153	1.3	1,500
Totals*	0.98	1,100	1.1	1,200	1.5	1,700	0.26	290	3.8	4,300

*Figures are approximate because some of the pumpage is estimated. Totals are rounded to two significant figures.

In Franklin County in 1963, about two-thirds of the pumpage was by the city of Winnsboro and by industry. Winnsboro is actually in Franklin and Wood Counties, and in 1963, the public supply of 0.32 mgd (356 acre-feet) was obtained from two wells in Franklin County, JZ-34-06-302, depth 277 feet, yield 517 gpm, and JZ-34-06-304, depth 255 feet, yield 415 gpm. The industrial use of ground water in the county in 1963 was 0.48 mgd (536 acre-feet), which was obtained from 7 wells in the New Hope oil field. Most of the water was used to repressure the oil reservoir. The depths of the wells range from 440 to 640 feet, and the yields range from 60 to 150 gpm.

In Morris County in 1963, more than three-fourths of the pumpage was for public supply and industrial uses. The city of Omaha obtained about 0.18 mgd (200 acre-feet) from two wells, TU-16-51-401, depth 260 feet, yield 100 gpm, and TU-16-51-402, depth 508 feet, yield 80 gpm. The city of Naples obtained about 0.09 mgd (107 acre-feet) from four wells, TU-16-51-501, TU-16-51-503, TU-16-51-504, and TU-16-51-505. The depths of the wells range from 436 to 605 feet, and the yields range from 45 to 75 gpm. Part of the industrial water supply for the Lone Star Steel Co., 0.22 mgd (251 acre-feet), was pumped from two wells 404 and 618 feet deep, respectively.

In Titus County in 1963, about three-fourths of the pumpage was for domestic and livestock uses, and one-fourth for industrial use. Part of the industrial water supply for the Amercian Petrófina oil refinery, 0.34 mgd (379 acre-feet) was pumped from two wells, YA-16-49-701, depth 437 feet, yield 125 gpm, and YA-16-49-702, depth 597 feet, yield 125 gpm.

Other Aquifers

As previously discussed, wells tapping the Nacatoch Sand in adjacent Red River County supply water for the city of Talco and the industrial needs in the Talco oil field. In 1963, the pumpage for the city of Talco was 0.06 mgd (70 acre-feet) and the pumpage for industrial use was 0.15 mgd (170 acre-feet).

The other aquifers in the four-county area produce insignificant amounts of water. Small quantities of water for domestic and livestock uses are obtained from wells tapping the Sparta Sand and Weches Greensand in the southeastern part of Morris County. The alluvial deposits supply small quantities of water to a few wells in the larger valleys.

Changes in Water Levels

Records of measurements of water levels in wells in the four-county area are given in Table 9. A comparison of the 1963 measurements with those of Follett (1942) and Broadhurst (1943) shows no general decline of water levels in the shallow wells (less than 60 feet in depth). However, owners of these wells report that the water levels fluctuate from 5 to 10 feet each year in response to rainfall.

Water levels in the heavily-pumped deeper wells (Table 5) show average declines of 3.5 to 15.7 feet per year for various periods of record. The rather large declines are in accord with the low coefficient of transmissibility of the Cypress aquifer and the low specific capacities of the wells.

Table 5.--Decline of water levels in heavily-pumped wells in Franklin, Morris, and Titus Counties

Well	Depth (ft)	Yield (gpm)	Water level (feet below land-surface datum)								Decline (ft)	Period of record (yrs)	Decline per yr (ft)
			1937	1941	1942	1943	1955	1959	1960	1963			
JZ-17-63-801	440	150	--	--	--	--	--	--	134.1	181.1	47.0	3	15.7
TU-16-51-402	508	80	--	--	--	--	110	--	--	194.5	84.5	8	10.6
TU-35-03-403	404	70	--	--	87	--	--	--	--	160.0	73	21	3.5
TU-35-03-501	618	--	--	--	--	188	--	--	--	275.8	87.8	20	4.4
YA-16-49-701	437	125	--	185	--	--	--	250	--	--	65	18	3.6
YA-16-49-702	597	125	88	--	--	--	--	275.5	--	--	169.5	22	7.7

Construction of Wells

About 75 percent of the estimated 4,000 water wells in the report area are less than 50 feet deep. These shallow wells tap the Cypress aquifer and supply most of the ground water used for domestic and livestock needs. The older wells were dug and lined with brick and range from 3 to 8 feet in diameter. Most of the newer wells are excavated by bucket-type power augers to depths ranging from 20 to 50 feet and are cased with 3-foot lengths of 30-inch diameter cement pipe. However, some of the shallow wells are cased with 6-inch diameter tile pipe. The shallow wells are equipped with water-jet, cylinder, or centrifugal pumps which are operated by electric motors of $\frac{1}{4}$ to $\frac{1}{2}$ horsepower. The lift seldom exceeds 30 feet, and generally the yields of the wells are sufficient for domestic and livestock needs.

Prior to the drought of the early 1950's, almost all of the ground water for domestic and livestock needs was obtained from the shallow bored or dug wells. An appreciable number of these wells went dry during the drought and were replaced with wells drilled by hydraulic rotary rigs to depths from about 100 to more than 250 feet. By 1960, about 1,000 wells had been drilled by the rotary method in the four-county area. A typical drilled well is cased with 4-inch diameter steel pipe with a casing shoe on the bottom of the pipe, which is seated in clay at depths ranging from 100 to 250 feet. Then the well is drilled deeper and generally the lower part of the well is not cased. However, in a few wells smaller-diameter perforated pipe or screens are set below the casing shoe. The wells are equipped with water-jet, cylinder, or submersible pumps which are operated by electric motors of $\frac{1}{2}$ to 1 horsepower. The pump setting or the depth of the surface casing seldom exceeds 200 feet. The pumps have capacities ranging from 5 to 10 gpm.

In recent years, many of the wells that were drilled for domestic and livestock uses have been either abandoned or used very little. The present trend in well construction is toward a considerable increase in the number of shallow wells excavated by power augers and the resultant decrease in the number of deeper wells drilled by hydraulic rotary rigs. The abandonment of the drilled wells generally is attributed to the filling of the uncased part of the well with sand, the change from clear to muddy water, and the change from iron-free water to water having objectionable amounts of iron.

Water for industrial use in the four-county area is obtained from 11 wells ranging in depth from 404 to 640 feet, and water for public supply is obtained from 12 wells ranging in depth from 220 to 670 feet. These wells all tap the Cypress aquifer and the yields range from 45 to 517 gpm. The wells are equipped with turbine pumps operated by electric motors--motor ratings range from $7\frac{1}{2}$ to 50 horsepower.

Well BZ-35-01-104 (city of Pittsburg well no. 4) is typical of the construction of wells for public supply and industrial uses in the four-county area. The well site was selected from data from bit cuttings, the drillers' logs, and electrical logs of several test holes. The water well was drilled to 670 feet--the test hole had been drilled to 1,000 feet, but the driller's log (Table 10) and the electrical log indicated that the better water sands are between 519 and 657 feet. Briefly, the construction details of the well are as follows: (1) the well was drilled to 515 feet and cased with 16-inch surface casing; (2) the 16-inch casing was cemented to the wall of the well; (3) the well was drilled to 670 feet and then underreamed to a hole 30 inches in diameter that extended from the bottom of the surface casing to the bottom of the well; (4) a total length of 256 feet of 10-3/4-inch blank pipe and screen, with a back-pressure valve on the bottom, was lowered to the bottom of the well--the screens were placed in positions that would be opposite the water sands when the liner reached the bottom of the well. A total of 75 feet of screen was placed in this well--one 50-foot section opposite a thick sand between the depths of 519 and 569 feet and two 5-foot sections and one 15-foot section opposite sands below 569 feet; (5) the space between the 10-3/4-inch pipe and screens and the wall of the well was filled with small-size gravel--gravel was also inserted in the space between the overlap of the 10-3/4-inch pipe inside the 16-inch surface casing, a distance of about 100 feet; and (6) the drilling mud was washed from the well. The static water level in the well was 175 feet below the land surface before the start of the production test on July 24, 1957. After pumping at the rate of 200 gpm for 12 hours, the pumping level was 568 feet below the land surface, or 393 feet below the static level--a specific capacity of 0.5 gpm per foot of drawdown.

USE OF SURFACE WATER

The character of the precipitation and runoff and the favorable topography make feasible the construction of dams and the development of surface-water resources in the four-county area. The average discharge at each of the four stream-gaging stations maintained by the U.S. Geological Survey (1962, p. 49, 50, 52, and 54) in the report area is given in Table 6, and the locations of the stations are shown Plate 1.

The use of surface water in Camp, Franklin, Morris, and Titus Counties in 1963 is given in Table 7. Most of the water used by industries and the public supplies for four of the eight towns and cities in the report area are obtained from surface reservoirs.

Table 6.--Average discharge at stream-gaging stations in Camp, Franklin, Morris, and Titus Counties

Stream-gaging station	Drainage area (sq mi)	Average discharge		
		Years of record	Cubic feet per second	Acre-feet per year
Sulphur River near Talco	1,365	1957-62	1,499	1,085,000
White Oak Creek near Talco	494	1950-62	411	297,600
Cypress Creek near Pittsburg	366	1943-62	354	256,300
Boggy Creek near Daingerfield	72	1943-62	92.3	66,820

QUALITY OF GROUND WATER

The chemical constituents of ground water originate principally from the soil and rocks through which the water has moved. Generally, the chemical

Table 7.--Use of surface water in Camp, Franklin, Morris, and Titus Counties, 1963

County and water user	Public supply		Industrial		Total	
	Mgd	Acre-feet	Mgd	Acre-feet	Mgd	Acre-feet
Camp County	--	--	--	--	--	--
Franklin County						
Mount Vernon	0.17	193	--	--	0.17	190
Morris County						
Daingerfield	0.18	200	--	--		
Lone Star	.57	634	--	--		
Lone Star Steel Co.	--	--	11.20	12,554		
Subtotal	.75	834	11.20	12,554	12	13,000
Titus County						
Mount Pleasant	0.87	977	--	--		
American Petrofina Co.	--	--	0.64	712		
Subtotal	.87	977	.64	712	1.5	1,700
Totals*	1.8	2,000	12	13,000	13	15,000

*Totals are rounded to two significant figures.

content of ground water increases with depth. The temperature of ground water near the land surface is generally about the same as the mean air temperature of the region and increases with depth. The laboratory analyses of water from 189 wells and 6 springs tapping the Cypress aquifer in the report area, 1 well tapping the Cypress aquifer in Wood County, and 2 wells tapping the Nacatoch Sand in Red River County are given in Table 11. Field determinations of iron, pH, and hardness of 360 samples from the Cypress aquifer are given in Table 12. Temperatures of the water samples are given in Table 9.

The major factors that determine the suitability of a water supply are the limitations imposed by the contemplated use of the water. Various criteria of water-quality requirements have been developed that include bacterial content, physical characteristics such as temperature, odor, color, and turbidity, and chemical constituents. Usually the bacterial content and the undesirable physical properties can be alleviated economically, but the removal of undesirable chemical constituents can be difficult and expensive. For many purposes, the dissolved-solids content is a major limitation on the use of the water. A general classification of water according to the dissolved-solids content in given in Table 8. The source and significance of dissolved mineral constituents and properties of water summarized in Table 8 was adapted from Doll and others (1963, Table 7) with additions.

The U.S. Public Health Service (1962, p. 7-8) has established and periodically revises standards of drinking water to be used on common carriers engaged in interstate commerce. The standards are designed to protect the traveling public and may be used to evaluate domestic and public water supplies. According to the standards, chemical constituents should not be present in a public water supply in excess of the listed concentrations shown in Table 8, except where other more suitable supplies are not available. When fluoride is naturally present in drinking water, the concentration should not average more than the appropriate upper limit shown in the following table (U.S. Public Health Service, 1962, Table 1):

Annual average of maximum daily air temperatures (obtained for a minimum of 5 years) (°F)	Recommended control limits of fluoride concentrations (parts per million)		
	Lower	Optimum	Upper
50.0 - 53.7	0.9	1.2	1.7
53.8 - 58.3	.8	1.1	1.5
58.4 - 63.8	.8	1.0	1.3
63.9 - 70.6	.7	.9	1.2
70.7 - 79.2	.7	.8	1.0
79.3 - 90.5	.6	.7	.8

For the 5-year period, 1958-62, the annual average of the maximum daily air temperatures at Mount Pleasant ranged from 74.3° to 75.7°F and averaged 74.8°F (records of U.S. Weather Bureau). Consequently, the recommended control limits of fluoride concentrations in the report area range from 0.7 to 1.0 ppm (parts per million). Water from 123 wells tapping the Cypress aquifer was analyzed for fluoride--120 wells contained less than 0.8 ppm, and 3 contained 0.9, 0.9,

Table 8.--Source and significance of dissolved mineral constituents and properties of water

Constituent or property	Source or cause	Significance
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 ppm. High concentrations, as much as 100 ppm, 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 ppm stain laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. USPHS (1962) drinking water standards state that iron should not exceed 0.3 ppm. 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 (see 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 usefulness 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. USPHS (1962) drinking water standards recommend that the sulfate content should not exceed 250 ppm.
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. USPHS (1962) drinking water standards recommend that the chloride content should not exceed 250 ppm.
Flouride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by flouridation of municipal supplies.	Flouride 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 flouride, the age of the child, amount of drinking water consumed, and susceptibility of the individual (Maier, F. J., 1950).
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. USPHS (1962) drinking water standards suggest a limit of 45 ppm. 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. Nitrate has been shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Boron (B)	A minor constituent of rocks and of natural waters.	An excessive boron content will make water unsuitable for irrigation. Wilcox (1955, p. 11) indicated that a boron concentration of as much as 1.0 ppm is permissible for irrigating sensitive crops; as much as 2.0 ppm for semitolerant crops; and as much as 3.0 for tolerant crops. Crops sensitive to boron include most deciduous fruit and nut trees and navy beans; semitolerant crops include most small grains, potatoes and some other vegetables, and cotton; and tolerant crops include alfalfa, most root vegetables, and the date palm.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils.	USPHS (1962) drinking water standards recommend that waters containing more than 500 ppm dissolved solids not be used if other less mineralized supplies are available. For many purposes the dissolved-solids content is a major limitation on the use of water. A general classification of water based on dissolved-solids content, in ppm, is as follows (Winslow and Kister, 1956, p. 5): Waters containing less than 1,000 ppm of dissolved solids are considered fresh; 1,000 to 3,000 ppm, slightly saline; 3,000 to 10,000 ppm, moderately saline; 10,000 to 35,000 ppm, very saline; and more than 35,000 ppm, brine.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All of the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness up to 60 ppm are considered soft; 61 to 120 ppm, moderately hard; 121 to 180 ppm, hard; more than 180 ppm, very hard.
Sodium-adsorption ratio (SAR)	Sodium in water.	A ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange reactions with soil (U.S. Salinity Laboratory Staff, 1954, p. 72, 156). Defined by the following equation: $SAR = Na/\sqrt{(Ca + Mg)/2}$ where Na, Ca, and Mg represent the concentrations in equivalents per million (epm) of the respective ions.
Residual sodium carbonate (RSC)	Sodium and carbonate or bicarbonate in water.	As calcium and magnesium precipitate as carbonates in the soil, the relative proportion of sodium in the water is increased (Eaton, 1950, p. 123-133). Defined by the following equation: $RSC = (CO_3 + HCO_3) - (Ca + Mg)$ where CO_3, HCO_3, Ca, and Mg represent the concentrations in equivalents per million (epm) of the respective ions.
Specific conductance (micromhos at 25°C)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.
Hydrogen ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.

and 1.4 ppm. Two wells, WB-17-39-602 and WB-17-39-901, tapping the Nacatoch Sand in Red River County contained 0.2 and 0.3 ppm of fluoride, respectively.

Water from 180 wells tapping the Cypress aquifer was analyzed for nitrate. Twenty-one wells, including 15 which were less than 30 feet deep, contained more than 45 ppm nitrate.

Water having a chloride content exceeding 250 ppm may have a salty taste. The chloride content of 195 wells tapping the Cypress aquifer ranged from 1 to 238 ppm in 181 samples, and from 252 to 890 ppm in 14 samples. The 14 samples containing more than 250 ppm were collected from wells that ranged in depth from 17 to 700 feet.

Sulfate in water in excess of 250 ppm may produce a laxative effect. The sulfate content of 189 samples from wells tapping the Cypress aquifer ranged from 0 to 211 ppm in 182 samples, and from 274 to 1,420 ppm in 7 samples. The 7 wells having high sulfate content were 60 feet or less in depth.

Most of the wells tapping the Cypress aquifer yield water that is soft or moderately hard (Table 8). The relation of hardness of water to depths of the wells is shown by Figure 7. Water from wells less than 60 feet deep ranges from soft to very hard, but most of the water is soft or moderately hard. The water from most of the wells more than 60 feet deep is soft.

Water used for industry may be classified into three categories--process water, cooling water, and boiler water. Process water is the term used for the water incorporated into or in contact with the manufactured products. The quality requirements for this use may include physical and biological factors in addition to chemical factors. Water for cooling and boiler uses should be noncorrosive and relatively free of scale-forming constituents. The presence of silica in boiler water is undesirable because it forms a hard scale or encrustation, the scale-forming tendency increasing with the pressure in the boiler. The following table shows the maximum suggested concentrations of silica for water used in boilers (Moore, 1940, p. 263):

Concentration of silica (ppm)	Boiler pressure (pounds per square inch)
40	Less than 150
20	150 - 250
5	251 - 400
1	More than 400

The silica content in the water from 69 wells supplied from the Cypress aquifer ranged as follows: from 6.6 to 20 ppm in 54 wells; from 21 to 40 ppm in 8 wells; and from 41 to 87 ppm in 7 wells.

The iron content and hydrogen ion concentration (pH) are important factors in the report area in determining the suitability of water from the Cypress aquifer for public supply and domestic uses and for many industrial uses. Iron in water pumped from wells comes from two sources: (1) iron in solution in the ground water, and (2) iron derived from the corrosion of the well casing, pump, and pipes by acid (low pH) ground water. For discussions of the occurrence of

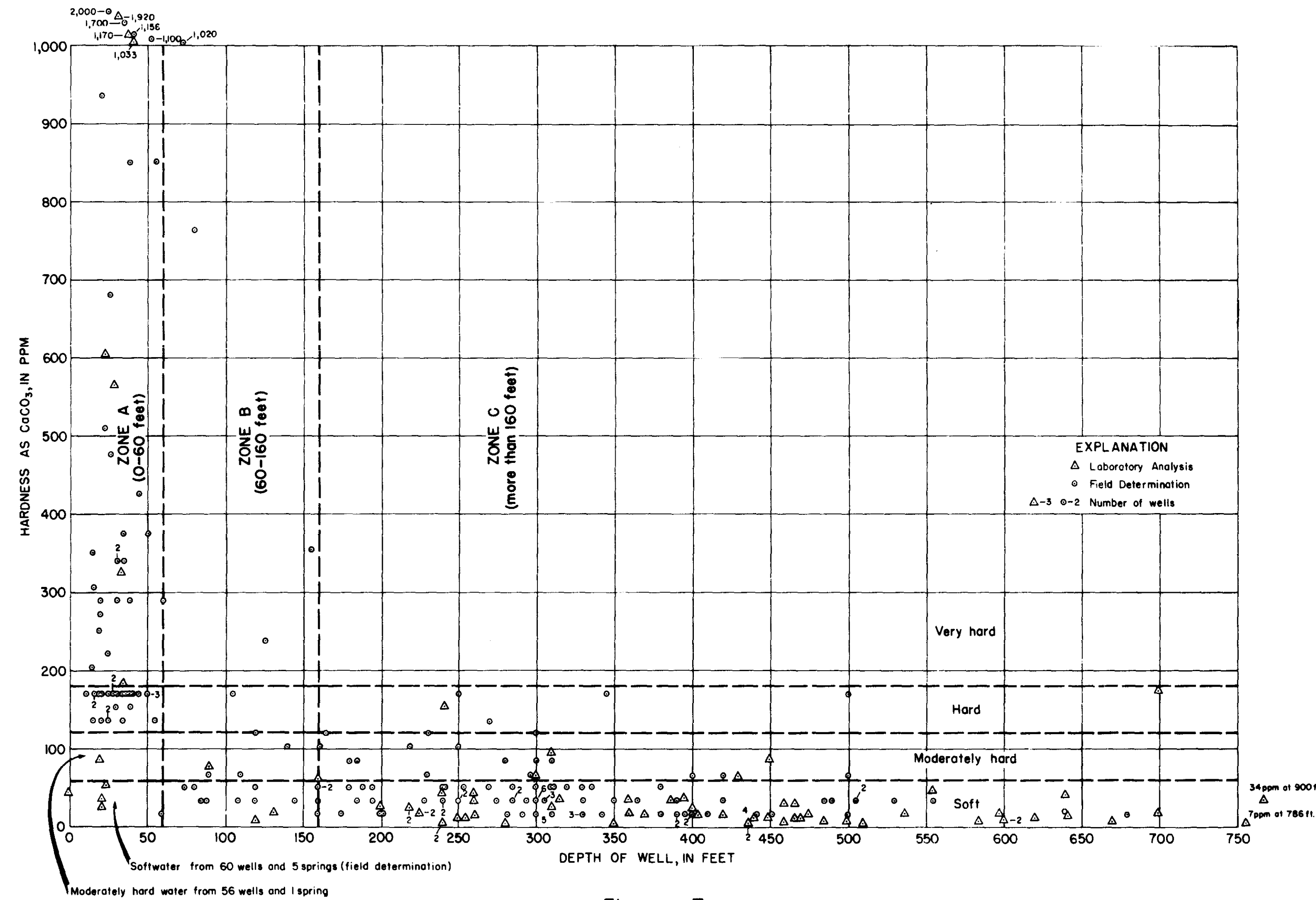

Figure 7

Graph Showing Relation of Hardness of Water to Depths of Wells Tapping the Cypress Aquifer in Camp, Franklin, Morris, and Titus Counties

U. S. Geological Survey in cooperation with the Texas Water Commission

iron in ground water and research on the subject see Hem (1959, 1960a, and 1960b) and Hem and Cropper (1959).

Many wells tapping the Cypress aquifer produce water having a high iron content. The relation of the iron content of water to the depths of the wells is shown by Figure 8. Most of the wells in zone A contain little or no iron in solution, and most of the wells in zone B contain from 0.3 to more than 10 ppm of iron. Almost all wells in zone C contain less than 0.3 ppm of iron.

The relation of the pH of the water to the depths of the wells is shown by Figure 9. The general ranges of the pH values are as follows: wells less than 60 feet deep, from 4.5 to 6.5; wells ranging from 60 to 160 feet in depth, 5.0 to 7.0; and wells more than 160 feet deep, 7.0 to 8.0. Because the corrosiveness of water generally increases with decreasing pH values, water from wells less than 60 feet deep is more likely to be corrosive than water from deeper wells.

Several factors other than the chemical quality are involved in determining the suitability of water for irrigation purposes. The type of soil, adequacy of drainage, crops grown, climatic conditions, and quantity of water used all have important bearing on the continued productivity of irrigated land.

A classification commonly used for judging the quality of a water for irrigation was proposed in 1954 by the U.S. Salinity Laboratory Staff (1954, p. 69-82). The classification is based on the salinity hazard as measured by the electrical conductivity (Table 8) of the water and the sodium hazard as measured by the SAR (sodium-adsorption ratio, Table 8). The relative importance of the dissolved constituents in irrigation water is dependent upon the degree to which they accumulate in the soil--more of the mineral content of the water will accumulate in tight soils than in more permeable soils under similar conditions. Sodium can be a significant factor in evaluating quality of irrigation water because water with a high SAR will cause the soil structure to break down by deflocculating the colloidal soil particles. Consequently, the soil can become plastic, thereby causing poor aeration and low water availability. This is especially true in fine-textured soils. Wilcox (1955, p. 15) stated that the system of classification of irrigation water proposed by the laboratory staff "...is not directly applicable to supplemental waters used in areas of relatively high rainfall." Wilcox (1955, p. 16) indicated that generally water may be used safely for supplemental irrigation if its conductivity is less than 2,250 micromhos per centimeter at 25°C and its SAR is less than 14. The SAR values of water from 57 wells tapping the Cypress aquifer ranged from 0.6 to 46, and the conductivities ranged from 47 to 1,890 micromhos. In 33 of these samples, the SAR values were 14 or less. With the exception of wells less than 200 feet deep, there is no definite relation between the depth of the well and the SAR value of the water (Figure 10). Water from 24 wells each more than 200 feet deep had SAR values of more than 14; however, samples having SAR values of 14 or less were collected from 29 wells ranging in depth from 200 to 700 feet. The SAR value and the conductivity of water from 48 wells tapping the Cypress aquifer are shown in Figure 11.

Another factor used in assessing the quality of water for irrigation is the RSC (residual sodium carbonate, Table 8) in the water. Excessive RSC will cause the water to be alkaline, and the organic content of the soil will tend to dissolve. The soil may become a grayish black and the land areas affected are referred to as "black alkali." Wilcox (1955, p. 11) states that laboratory and field studies have resulted in the conclusion that water containing more than

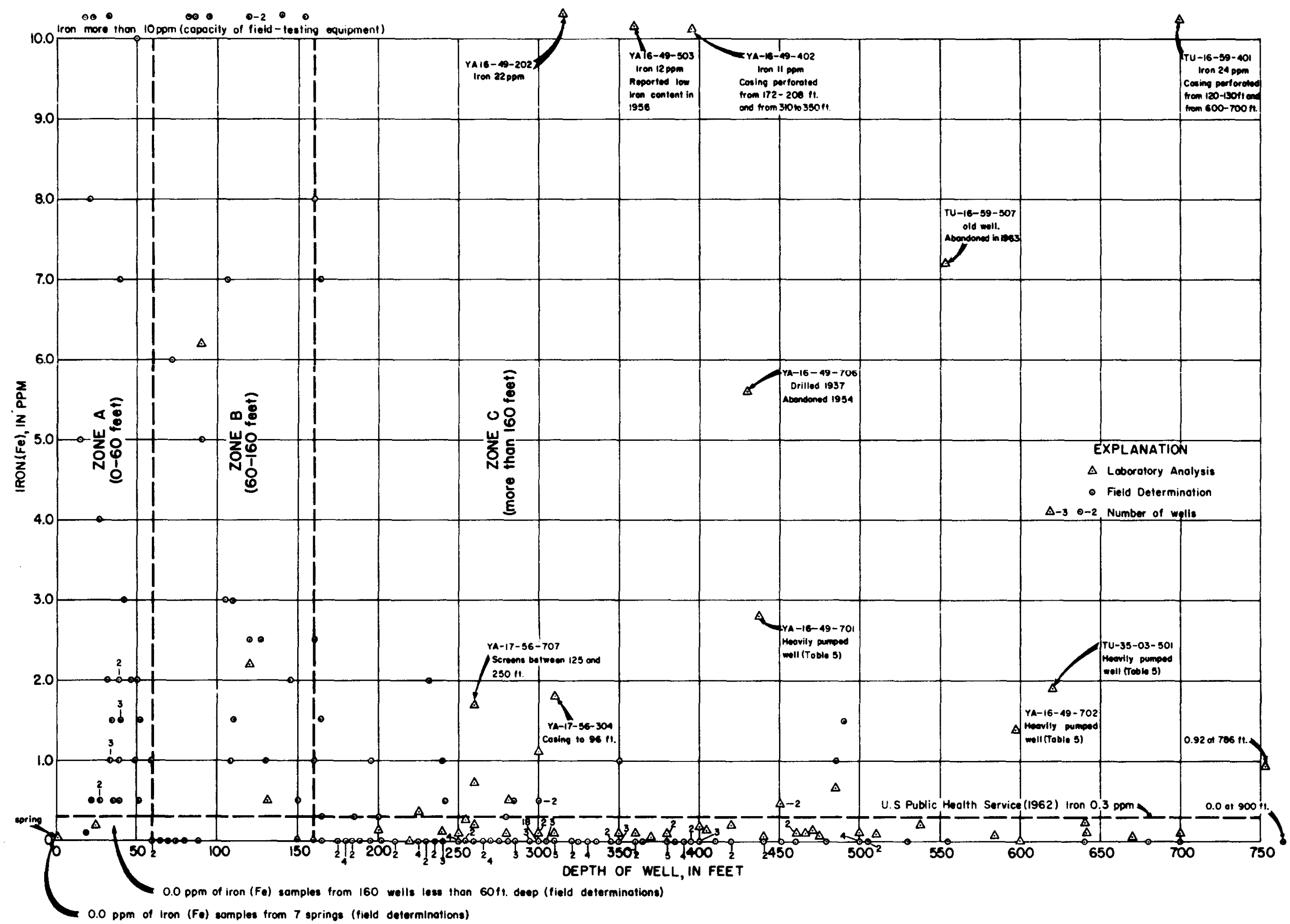

Figure 8

Graph Showing Relation of the Iron Content of Water to Depths of Wells Tapping the Cypress Aquifer in Camp, Franklin, Morris, and Titus Counties

U. S. Geological Survey in cooperation with the Texas Water Commission

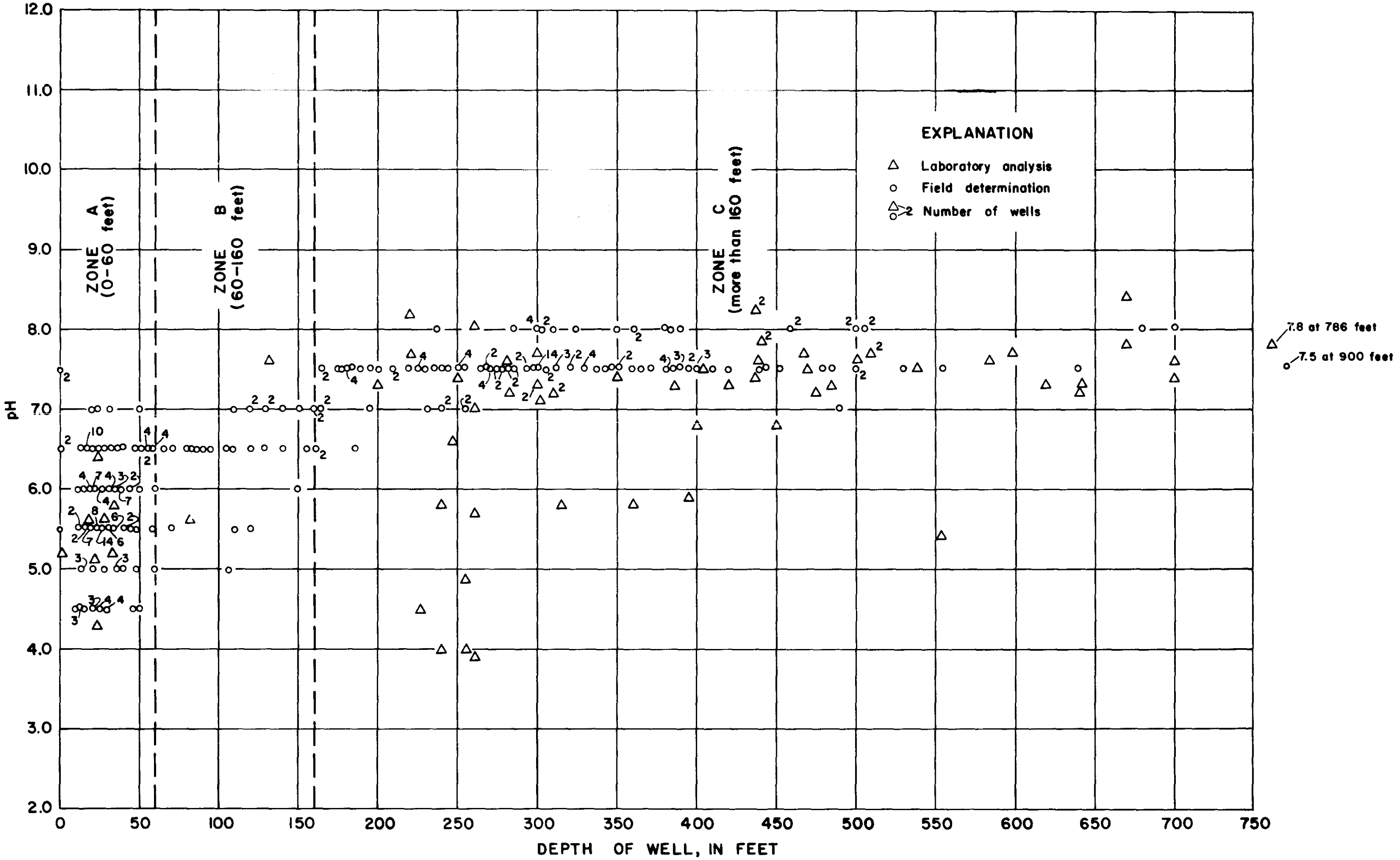

Figure 9

Graph Showing Relation of the pH of Water to the Depths of Wells Tapping the Cypress Aquifer in Camp, Franklin, Morris, and Titus Counties

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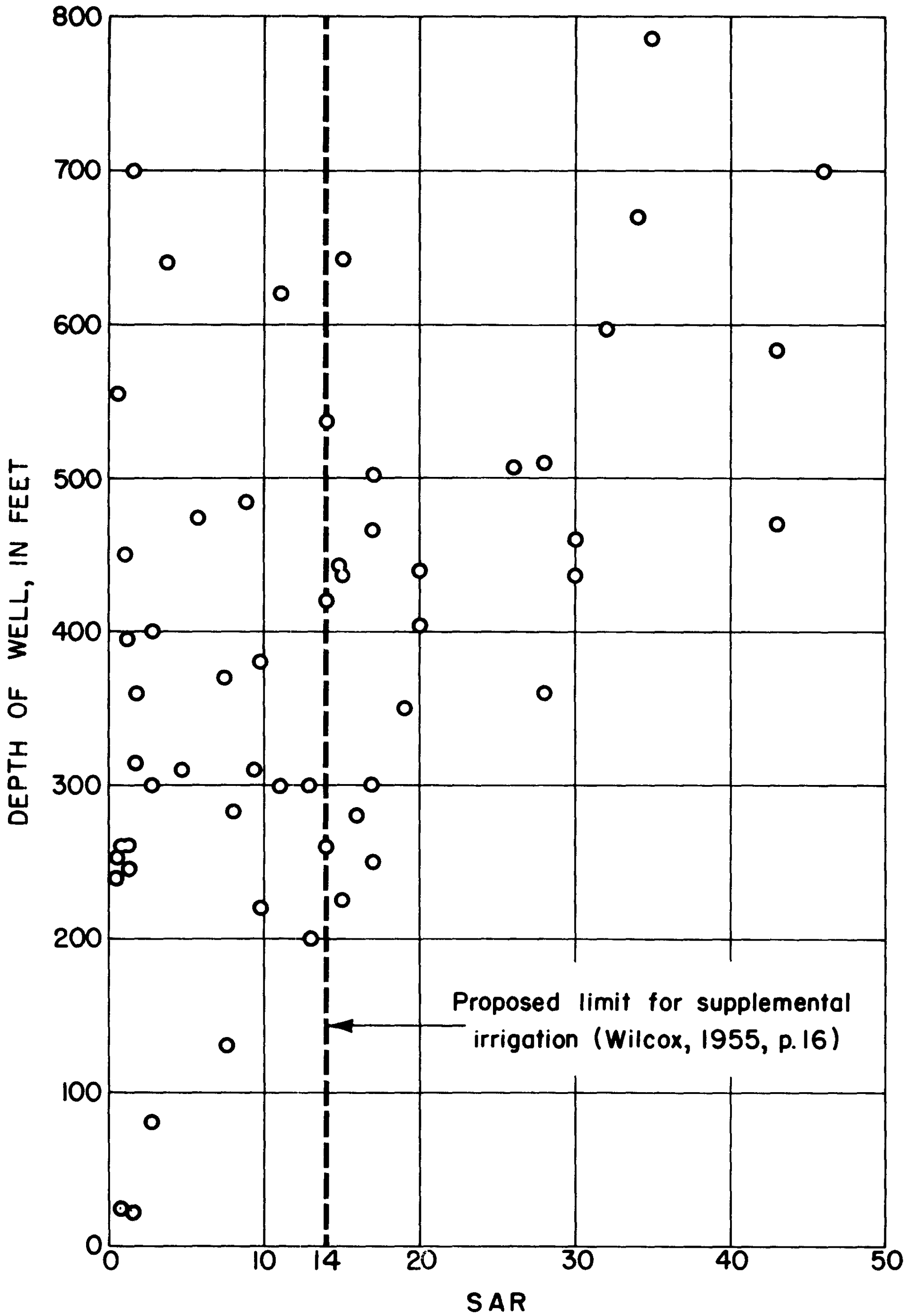

Figure 10

Graph Showing Relation of the Sodium-Adsorption Ratio (SAR) of Water to the Depths of Wells Tapping the Cypress Aquifer in Camp, Franklin, Morris, and Titus Counties

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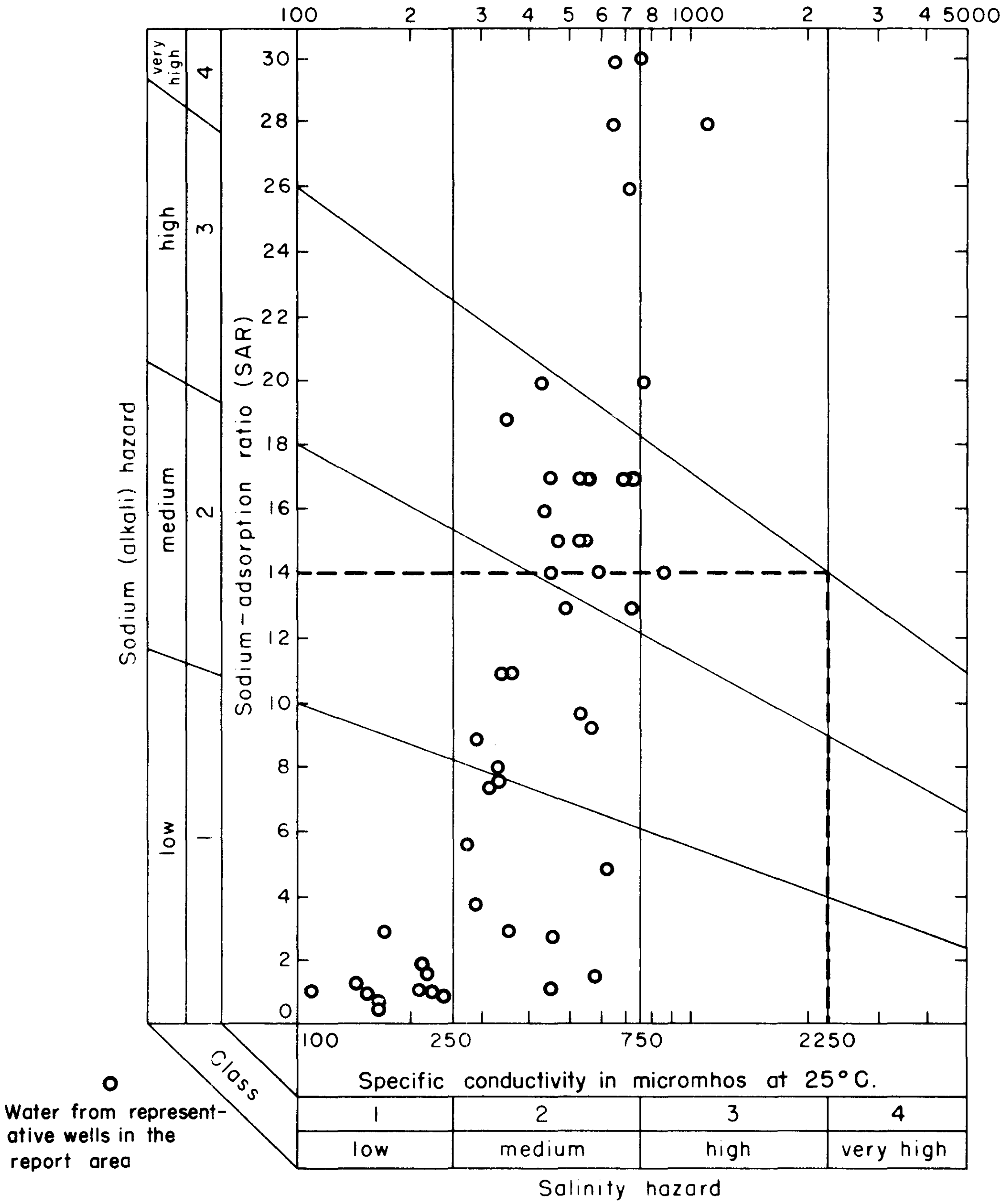

Figure 11

Diagram for the Classification of Irrigation Waters

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

U.S. Geological Survey in cooperation with the Texas Water Commission

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2.5 epm (equivalents per million) RSC is not suitable for irrigation. Water containing from 1.25 to 2.5 epm is marginal, and water containing less than 1.25 epm RSC probably is safe. However, it is believed that good irrigation practices and proper use of soil amendments might make it possible to use the marginal water successfully for irrigation. Furthermore, the degree of leaching will modify the permissible limit to some extent (Wilcox, Blair, and Bower, 1954, p. 265). The RSC values of 62 samples from wells tapping the Cypress aquifer ranged as follows: from 0 to 1.25 epm, 21 samples; from 1.25 to 2.50 epm, 5 samples; more than 2.50 epm, 36 samples. Samples having RSC values of more than 2.50 epm were collected from wells more than 200 feet deep.

Boron (Table 8) does not seem to be a significant problem in water from the Cypress aquifer. The boron content of water from 28 wells ranged from 0.00 to 0.79 ppm.

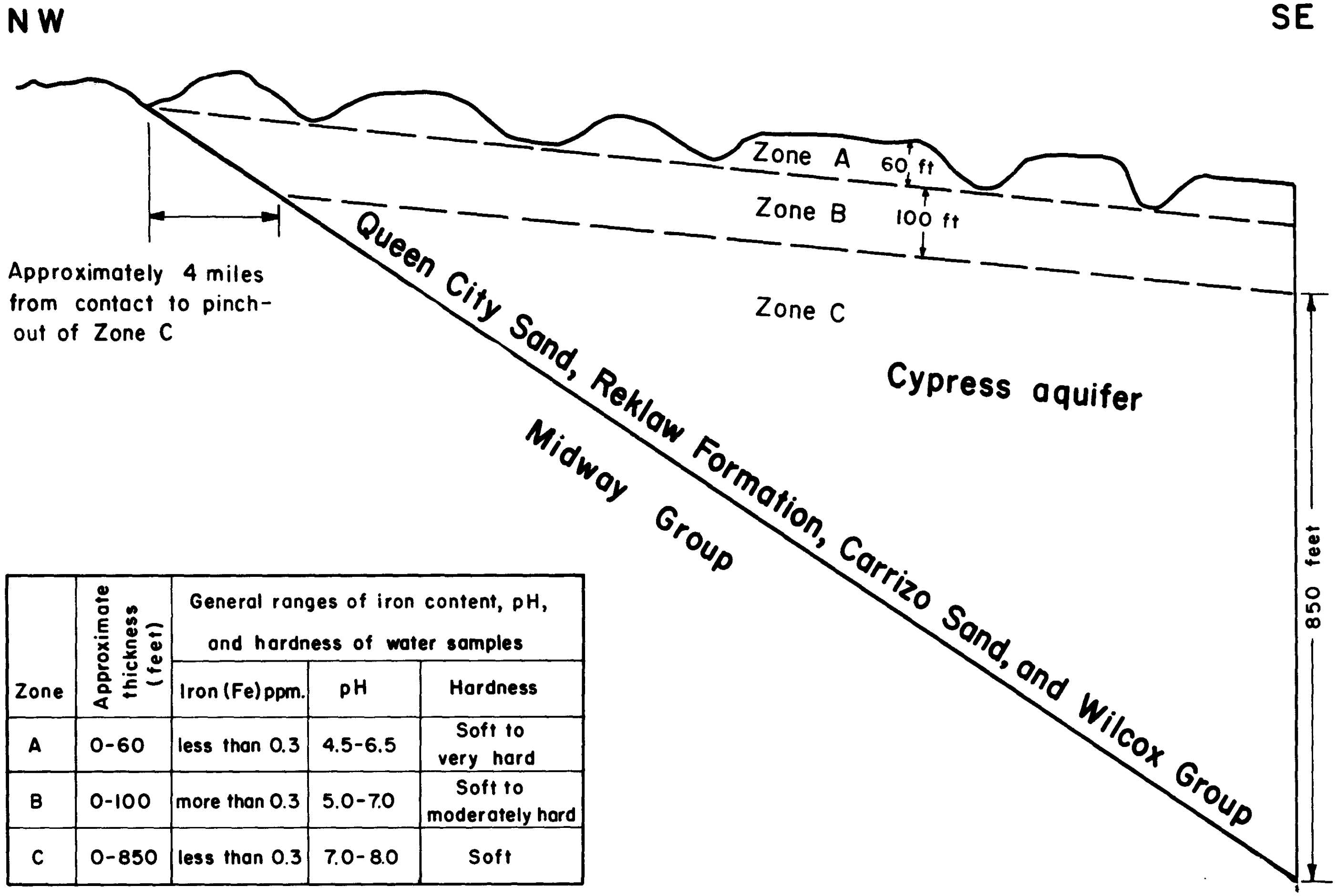
Wells tapping the Nacatoch Sand in the report area are capable of yielding large quantities of very saline water. Wendlandt and Shelby (1948, p. 450) reported that a typical water from the Nacatoch Sand in the Talco oil field contained 15,100 ppm of chloride and 24,769 ppm dissolved solids. North of the Talco fault zone in Red River County, the Nacatoch yields moderate quantities of fresh water to wells that supply the city of Talco and the industrial needs in the Talco oil field.

In addition to the similarities of the hydrologic properties of the several geologic units comprising the Cypress aquifer, there are similarities in the chemical quality of the water. The aquifer yields moderate to large quantities of fresh water to wells, and the principal mineral content in most of the water samples is sodium and bicarbonate--only a few samples contain objectionable amounts of chloride and sulfate. The principal differences in the chemical quality and properties of the water in the Cypress aquifer are in the iron content, hardness, and pH. Each is an important factor in determining the suitability of water for public supply and domestic uses. Data from the 197 laboratory analyses and 360 field determinations show that these factors are related generally to the depths of wells, which can be classified into three zones--"A," "B," and "C" shown on Figure 12.

Zone A extends from the land surface to the altitude of the base of the alluvial deposits of the larger streams. Consequently, the thickness of Zone A varies according to the local relief of the land surface, which is a maximum of about 60 feet in most of the report area. In general, the water in Zone A contains little or no iron (Figure 8), the pH values range from 4.5 to 6.5 (Figure 9), and the hardness ranges from soft to very hard (Figure 7); however, most of the samples are soft or moderately hard.

Zone B extends from the base of Zone A to about 100 feet below the base of Zone A. The depth to the base of Zone B ranges from about 100 feet in wells near the larger streams to about 160 feet in wells on the higher hills. In general, the iron content of the water in Zone B ranges from 0.3 to more than 10 ppm (Figure 8), the pH values range from 5.0 to 7.0 (Figure 9), and most of the samples are soft or moderately hard (Figure 7).

Zone C extends from the base of Zone B to the base of the Cypress aquifer. The thickness of Zone C ranges from 0 feet, where Zones A and B comprise the entire thickness of the aquifer, to about 850 feet in the southeastern part of the four-county area. The up-dip limit, or "pinch out" of Zone C is along a line about 4 miles southeast of the contact of the rocks of the Cypress aquifer



Zone	Approximate thickness (feet)	General ranges of iron content, pH, and hardness of water samples		
		Iron (Fe) ppm.	pH	Hardness
A	0-60	less than 0.3	4.5-6.5	Soft to very hard
B	0-100	more than 0.3	5.0-7.0	Soft to moderately hard
C	0-850	less than 0.3	7.0-8.0	Soft

Figure 12

Diagrammatic Section Showing Zones A, B, and C in the Cypress Aquifer

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with the underlying Midway Group (Figures 3 and 12). Generally, the water in Zone C is iron-free or nearly so--almost all of the samples from wells more than 160 feet deep contained less than 0.3 ppm of iron (Figure 8). The pH values of water from Zone C range from 7.0 to 8.0 (Figure 9), and most of the samples are classified as soft water (Figure 7). Zone C offers the best prospects for obtaining soft, non-corrosive water having a low iron content. However, several wells were reported to be pumping high iron water from Zone C after several years of pumping iron-free water. The increase in iron content probably resulted from the downward movement of water from Zone B--either along the outside of the casing, or through the aquifer where the wells are completed in the uppermost part of Zone C. In old wells, holes in the casing caused by corrosion also would permit the inflow of water from Zone B.

On the basis of the chemical activity of the water, the three zones may be classified as follows: Zone A, the zone of oxidation and acid waters; Zone B, the intermediate zone; and Zone C, the zone of reduction and neutral or alkaline waters. In Zone A, much of the ground water moves freely from sandy recharge areas to the springs and seeps along the large streams, and to a lesser extent the water moves downward into Zone B. The water in Zone A contains both dissolved oxygen and carbon dioxide. The iron-bearing minerals in the rocks are converted by the oxygen to insoluble oxides and the ground water generally has little or no iron in solution. Generally, the carbon dioxide content is sufficiently high to result in low pH values and corrosion of iron casings, pumps, and pipes. Many wells produced iron-free water, while samples of this water from seldom-used taps contained as much as 5 ppm of iron. Reddish-brown iron deposits on plumbing fixtures also result from the corrosion of iron casings, pumps, and pipes--bluish-green deposits result from the corrosion of copper pipes and brass plumbing fixtures.

Apparently, most of the oxygen is removed from the ground water as it passes through Zone A; but, when it moves into Zone B it still contains enough carbon dioxide to result in low pH values but the absence of oxygen permits this acidity to be present along with reducing conditions. Consequently, iron is removed from the iron-bearing minerals in the rocks and held in solution in the ground water. The high pH values of water samples from Zone C indicate that conditions generally are not favorable for the solution of iron, and consequently, most of the water samples contain very little iron. A more complete investigation of the geochemistry of the occurrence of iron water in the Cypress aquifer is beyond the scope of this report. The problem of iron in ground water is not restricted to the report area and nearby counties, but includes much of the inner border of the Coastal Plain from southern to northeastern Texas.

A potential source of contamination of the water in the Cypress aquifer is by the movement of brines from the underlying salt-water-bearing formations through improperly cased oil wells or from improperly plugged oil tests. In recent years, the Texas Water Commission has made recommendations to the oil operators as to the depths to which water-bearing formations are to be protected, and the Oil and Gas Division of the Railroad Commission of Texas is responsible for the protection of the water-bearing formations. The surface-casing requirements in all the oil fields mentioned in the field rules of the Railroad Commission as of April 1964 are deep enough to protect the fresh water in the Cypress aquifer. No instances of contamination from inadequate casing or plugging have been observed in the four-county area.

Another potential source of contamination of the water in the Cypress aquifer is the infiltration of oil-field brine from disposal pits on the outcrop of the aquifer. The Texas Water Commission and the Texas Water Pollution Control Board (1963, p. 27-28, 49-52, and 239-247) published a statistical analysis of data on oil-field brine production and disposal in Texas for the year 1961 from an inventory conducted by the Texas Railroad Commission. A tabulation of these data show that 58,772,363 barrels (7,575.87 acre-feet, or 2,468.44 million gallons) of brine was produced in 1961 from the 24 oil reservoirs in the report area. Of this amount, 56,963,793 barrels (7,342.75 acre-feet, or 2,392.48 million gallons) or 97.0 percent of the total was disposed through injection wells, 1,603,270 barrels (206.66 acre-feet, or 67.34 million gallons) or 2.7 percent of the total was disposed in pits, and 205,300 barrels (26.46 acre-feet, or 8.62 million gallons) or 0.3 percent was disposed by unknown methods. Of the brine disposed in pits, 607,689 barrels (78.33 acre-feet, or 25.52 million gallons) or 1.0 percent of the total quantity of brine produced in 1961 was disposed on the outcrop of the Cypress aquifer. The remainder was disposed on the outcrop of either the Midway or the Navarro Group. No contamination of ground water through the use of pits has been reported in the four-county area.

AVAILABILITY OF GROUND WATER FOR FUTURE DEVELOPMENT

The availability of water for future development from the Cypress aquifer in Camp, Franklin, Morris, and Titus Counties is dependent on several hydrologic, chemical-quality, and economic factors. Among the hydrologic factors, the most important are the ability of the aquifer to transmit water, the amount of water in storage, and the rate of recharge to the aquifer. The most important of the chemical-quality factors are the corrosiveness of the water from shallow wells in Zone A, the high iron content of the water in Zone B, and the sodium content of the water at various depths. The principal economic factor is the cost of the number of wells that would be required to obtain the desired quantities of water at reasonable pumping costs.

The most important hydrologic factor is the low coefficient of transmissibility of the aquifer. The transmission capacity of the Cypress aquifer at the present regional gradient is about 1,100 acre-feet per year (1 mgd), which was about 27 percent of the 4,300 acre-feet (3.8 mgd) of water pumped in 1963 in the four-county area (Table 4). The estimate of the transmission capacity of the Cypress aquifer in the four-county area was computed for the section along an assumed line that extends from the southwestern corner of Franklin County to the eastern boundary of Morris County; the line is 42 miles in length and is approximately parallel with the contact between the Cypress aquifer and the underlying Midway Group. The average coefficient of transmissibility of the aquifer is about 4,600 gpd per foot, and the average regional slope of the piezometric surface is about 5 feet per mile, southeasterly and normal to the assumed line. The excessive lowering of the water levels in the heavily-pumped industrial wells previously mentioned results from the low transmissibility of the aquifer, and most of the water pumped from these wells is removed from storage in the aquifer.

The total thickness of the water-bearing sands (nearly all contain fresh water) in the Cypress aquifer in the four-county area is shown by Figure 13. The sands contain a large quantity of fresh water in storage; the sands in the upper 400 feet of the aquifer contain an estimated 7,500,000 acre-feet. Because of the low transmissibility, much of the water in storage is not available to wells.

As indicated earlier in this report, the estimated minimum rate of recharge to the aquifer is about 12,000 acre-feet per year. However, only about 1,100 acre-feet of this water reaches the deeper part of the aquifer at the present gradient. Approximately 11,000 acre-feet per year is discharged to streams from the shallow part of the aquifer. A considerable part of this 11,000 acre-feet possibly could be salvaged by the installation of shallow wells throughout the recharge area; however, because of the extremely low coefficient of transmissibility, the wells would necessarily be closely spaced in order to capture a significant part of the water before it reaches the streams. On a practical basis, it probably would not be feasible to attempt to salvage a large percentage of this rejected recharge because of the large number of wells which would be required. However, the present rate of ground-water withdrawal could be at least doubled (8,600 acre-feet per year) if the wells are properly constructed, adequately spaced, and discharge rates are regulated to prevent excessive drawdowns.

In general, the total thickness of the water sands shown on Figure 13 ranges from zero feet at the contact of the rocks of the Cypress aquifer with the underlying Midway Group to about 500 feet in the southeastern corner of Morris County. Other factors being equal, the quantity of water available to a well will increase with the increase of the thickness of the water sands. In this respect, the data shown on Figure 13 are misleading to some extent; in the southeastern corner of the four-county area where the total thickness is greatest, the sand beds are composed of finer-textured sand than elsewhere and have lower transmissibilities. The more permeable sands in the aquifer are in certain parts of a belt about 10 miles wide that extends from western Camp and southern Franklin Counties to northeastern Morris County--in the parts where the greater thicknesses of sand extend as fingers to the northwest. The greater sand thicknesses are in the areas of lower altitude shown on the map of the top of the Midway Group (Figure 4), and the lesser sand thicknesses are in the areas of higher altitude, especially in the western part of Camp County and the southeastern part of Franklin County. In other words, the areas of lower altitude of the top of the Midway Group in this belt are probably the better places in the report area to prospect for large-yield wells.

Almost half of the ground water used from the Cypress aquifer in 1963 supplied domestic and livestock needs (Table 4) and was obtained from wells less than 60 feet deep in Zone A. Although there are about 4,000 of these shallow wells in the 900 square mile outcrop area of the Cypress aquifer, their number could be increased many times. Many of the wells are pumped at rates of only a few hundred gallons per day, and the withdrawals are readily replaced. In general, the water levels in the shallow wells fluctuate from 5 to 10 feet each year in response to rainfall. The principal problem in obtaining water from these wells is the decline of water level during droughts; many of them were bored or dug during times of normal rainfall and are not deep enough. An adequate supply of generally soft water is available to these shallow wells and to many additional wells, but much of the shallow water will corrode the casings, pumps, and plumbing fixtures. As previously mentioned, most of the water samples from the shallow wells in Zone A contained no dissolved iron. In many instances where the sample from the well was iron free, a sample from a seldom used water tap contained as much as 5 ppm of iron.

Because of the generally high rainfall, there is seldom need of water for irrigation. However, water for a limited amount of irrigation is available from the Cypress aquifer and probably could be used on a supplemental basis during periods of low rainfall. Continuous irrigation should be done with caution as much of the water has a high sodium percentage and high RSC.

Because of the low coefficient of transmissibility, many low-yield wells would be required to develop fully the water resources of the Cypress aquifer. The cost of the wells would be the most important economic factor, and where iron-free water is required, the cost per well would be even greater because the wells should be completed in Zone C, the cemented surface casing should extend through Zone B, and pumping levels should be regulated to minimize the downward movement of the iron-bearing water from Zone B.

REFERENCES CITED

American Geological Institute, 1960, Glossary of geology and related sciences with supplement: Washington, Am. Geol. Institute, 395 p.

Baker, E. T., Jr., Long, A. T., Jr., Reeves, R. D., and Wood, L. A., 1963, Reconnaissance investigation of the ground-water resources of the Red River, Sulphur River, and Cypress Creek Basins, Texas: Texas Water Commission Bull. 6306, 127 p., 18 figs., 22 pls.

Baldwin, H. L., and McGuinness, C. L., 1963, A primer on ground water: U.S. Gov't. Printing Office, Washington, 26 p., 15 figs.

Broadhurst, W. L., 1943, Records of wells and springs, drillers' logs, water analyses, and map showing locations of wells and springs in Camp, Franklin, and Titus Counties, Texas: Texas Board Water Engineers dupl. rept., 40 p., 1 fig.

Cooper, H. H., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., v. 27, no. IV, p. 526-534.

Darton, N. H., Stephenson, L. W., and Gardner, Julia, 1937, Geologic map of Texas: U.S. Geol. Survey map.

Doll, W. L., Meyer, G., and Archer, R. J., 1963, Water resources of West Virginia: West Virginia Dept. of Natural Resources, Div. of Water Resources, 134 p., 58 figs.

Eaton, F. M., 1950, Significance of carbonates in irrigation waters: Soil Sci., v. 69, p. 123-133.

Eckel, Edwin B., 1938, The brown iron ores of eastern Texas: U.S. Geol. Survey Bull. 902, 157 p., 20 pls., 6 figs.

Fenneman, N. M., 1938, Physiography of Eastern United States: New York, McGraw-Hill Book Co., Inc., 714 p.

Ferris, J. G., and others, 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536-E, p. 69-174, 29 figs.

Follett, C. R., 1942, Records of wells and springs, drillers' logs, water analyses, and map showing locations of wells and springs in Morris County, Texas: Texas Board Water Engineers dupl. rept., 19 p., 1 fig.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p., 40 figs., 2 pls.

_______1960a, Restraints on dissolved ferrous iron imposed by bicarbonate, redox potential, and pH, in Chemistry of iron in natural water: U.S. Geol. Survey Water-Supply Paper 1459-B, p. 33-55, 3 figs.

Hem, J. D., 1960b, Some chemical relationships among sulfur species and dissolved ferrous iron, in Chemistry or iron in natural water: U.S. Geol. Survey Water-Supply Paper 1459-C, p. 57-73, 3 figs.

Hem, J. D., and Cropper, W. H., 1959, A survey of ferrous-ferric chemical equilibria and redox potentials, in Chemistry of iron in natural water: U.S. Geol. Survey Water-Supply Paper 1459-A, 31 p., 2 figs.

Langbein, W. B., and Iseri, K. T., 1960, General introduction and hydrologic definitions: U.S. Geol. Survey Water-Supply Paper 1541-A, 29 p.

Leopold, L. B., and Langbein, W. B., 1960, A primer on water: U.S. Gov't. Printing Office, Washington, 50 p., 16 figs.

Maier, F. J., 1950, Fluoridation of public water supplies: Jour. Am. Water Works Assoc., v. 42, pt. 1, p. 1120-1132.

Meinzer, O. E., 1923a, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p., 31 pls.

_______1923b, Outline of ground-water hydrology, with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

Meinzer, O. E., and others, 1942, Physics of the earth, v. 9, Hydrology: New York, McGraw-Hill Book Co., Inc., 712 p.

Moore, E. W., 1940, Progress report of the committee on quality tolerances of water for industrial uses: New England Water Works Assoc. Journal, v. 54, p. 261-272.

Piper, A. M., 1953, The Nation-wide situation, in The Physical and Economic Foundation of Natural Resources, v. IV, Subsurface facilities of water management and patterns of supply-type area studies: U.S. Cong., House of Representatives, Committee on Interior and Insular Affairs, p. 1-120.

Railroad Commission of Texas, 1963, Annual report of the oil and gas division, 1962: The Railroad Commission of Texas, 579 p.

Sellards, E. H., Adkins, W. S., and Plummer, F. B., 1932, The geology of Texas, v. I, Stratigraphy: Texas Univ. Bull. 3232, 1007 p., 54 figs., 11 pls.

Sundstrom, R. W., 1941, Water supply in the vicinity of Hughes Springs, Cass County, Texas, and Daingerfield, Morris County, Texas: U.S. Geol. Survey open-file rept., 6 p.

Sundstrom, R. W., Hastings, W. W., and Broadhurst, W. L., 1948, Public water supplies in eastern Texas: U.S. Geol. Survey Water-Supply Paper 1047, 285 p., 1 fig.

Texas Water Commission and Texas Water Pollution Control Board, 1963, A statistical analysis of data on oil field brine production and disposal in Texas for the year 1961 from an inventory conducted by the Texas Railroad Commission, RRC District 6, v. 1, 291 p.

Thornthwaite, C. W., 1952, Evapotranspiration in the hydrologic cycle, in The Physical and Economic Foundation of Natural Resources, v. II, The physical basis of water supply and its principal uses: U.S. Cong., House of Representatives, Committee on Interior and Insular Affairs, p. 25-35.

Todd, D. K., 1959, Ground water hydrology: New York, John Wiley and Sons., Inc., 336 p.

Tolman, C. F., 1937, Ground water: New York, McGraw-Hill Book Co., Inc., 593 p.

U.S. Department of the Interior-Geological Survey, 1962, Surface water records of Texas, 1962: U.S. Dept. of the Interior, Geol. Survey, Water Res. Div. dupl. rept., 414 p.

U.S. Public Health Service, 1962, Public Health Service drinking-water standards: Public Health Service Pub. 956, 61 p., 1 fig.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agr., Agr. Handbook 60, 160 p., 32 figs.

Wendlandt, E. A., and Shelby, T. H., Jr., 1948, Talco oil field, Franklin and Titus Counties, Texas, in Structure of typical American oil fields, v. 3: Am. Assoc. Petroleum Geologists, p. 432-451.

Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials with special reference to discharging-well methods: U.S. Geol. Survey Water-Supply Paper 887, 192 p.

Wilcox, L. V., 1955, Classification and use of irrigation waters: U.S. Dept. Agr. Circ. 969, 19 p., 4 figs.

Wilcox, L. V., Blair, G. Y., and Bower, C. A., 1954, Effect of bicarbonate on suitability of water for irrigation: Soil Science, v. 77, no. 4, p. 259-266.

Winslow, A. G., and Kister, L. R., Jr., 1956, Saline-water resources of Texas: U.S. Geol. Survey Water-Supply Paper 1365, 105 p., 12 figs, 9 pls.

Wisler, C. O., and Brater, E. F., 1959, Hydrology: New York, John Wiley and Sons, 408 p.

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties

Camp County

Well BZ-35-01-104

Owner: City of Pittsburg, well 4 (test hole). Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, sandy ----------	6	6	Shale and lignite -----	30	346
Clay, sandy ----------	4	10	Sand and shale --------	15	361
Clay and rock streaks -	27	37	Shale ----------------	13	374
Sand and clay ---------	13	50	Rock -----------------	1	375
Sand -----------------	40	90	Shale and sandy shale -	51	426
Sand and rock streaks	6	96	Shale and sand --------	5	431
Sand, hard, gray, lignite and shale ---	34	130	Sand -----------------	9	440
Rock -----------------	1	131	Shale, brown ----------	25	465
Sand, shale, and lignite ------------	37	168	Shale, sandy shale and lignite ------------	31	496
Shale, sandy and lignite ------------	40	208	Lignite --------------	4	500
Rock -----------------	1	209	Shale, sandy shale, and lignite ------------	15	515
Sand -----------------	8	217	Sand, cut good --------	31	546
Shale ----------------	5	222	Shale and sand --------	4	550
Sand -----------------	18	240	Sand -----------------	6	556
Shale, sandy ----------	10	250	Shale, sandy, and shale	31	587
Rock, soft -----------	1	251	Shale, sandy, and sand	17	604
Shale ----------------	16	267	Rock -----------------	1	605
Sand and sandy shale --	10	277	Sand and sandy shale --	8	613
Shale ----------------	31	308	Shale ----------------	4	617
Sand and shale layers -	8	316	Sand and sandy shale --	14	631

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Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Camp County--Continued

Well BZ-35-01-104--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale	13	644	Rock	1	753
Sand	16	660	Shale, sandy, and shale	63	816
Shale	20	680	Shale, sandy	25	841
Shale, sandy, and sand	11	691	Sand and shale streaks	37	878
Shale	4	695	Sand and shale layers	37	915
Rock	1	696	Shale	21	936
Shale	19	715	Sand and shale	29	965
Rock, hard	1	716	Shale and rock streaks	35	1,000
Shale, sandy, and shale	36	752			

Well BZ-35-01-108

Owner: City of Pittsburg, well 5. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, sandy and sand	12	12	Sand, cut good, few shale streaks	30	190
Iron, ore, and clay	5	17	Sand and sandy shale	14	204
Sand and clay, gray	10	27	Sand and lignite	3	207
Rock	1	28	Shale, gray, and lignite	12	219
Shale and hard sand	21	49	Shale and sandy shale	23	242
Shale, gray, and lignite	40	89	Shale and lignite	9	251
Rock	2	91	Shale and sand streaks	46	297
Shale, gray, and lignite	44	135	Sand, fine	7	304
Sand and shale streaks	6	141	Shale and sandy shale	16	320
Sand, good	19	160			

(Continued on next page)

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Camp County--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well BZ-35-01-108--Continued					
Sand, fine, and layers of shale ------------	39	359	Sand and shale --------	43	513
Sand, fine, cut good --	25	384	Sand, cut good --------	20	533
Sand and sandy shale --	14	398	Rock -----------------	5	538
Shale, sandy, and lignite -------------	22	420	Sand, cut good --------	5	543
Sand, sandy shale and lignite -------------	19	439	Sand, fine, and hard shale layers --------	17	560
Shale, sandy, and lignite -------------	22	461	Sand, shale and rock streaks -------------	45	605
Sand and sandy shale	9	470	Shale, sandy ----------	8	613
			Shale -----------------	30	643

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Franklin County

Well JZ-17-55-403

Owner: City of Mount Vernon, well 4. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface soil	1	1	Sand, medium coarse	8	49
Clay, red	14	15	Clay, sandy	2	51
Sand, yellow	4	19	Sand, blue, medium coarse	17	68
Clay, sandy	4	23	Clay, blue, sandy	13	81
Sand, brown	6	29			
Clay, yellow	12	41			

Well JZ-17-55-404

Owner: City of Mount Vernon, well 3. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface soil	3	3	Lignite, hard or tight streaks	32	77
Clay, red	12	15	Lignite	2	79
Sand, fine, gray	3	18	Clay, sandy with gravel	11	90
Clay, yellow, sandy	5	23			
Sand, hard streaks, dirty brown	22	45			

Well JZ-17-63-801

Owner: Tidewater Oil Co. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand and gravel	20	20	Rock	1	85
Sand	8	28	Shale, sandy	19	104
Sand and lignite	5	33	Shale	16	120
Shale	51	84	Rock	2	122

(Continued on next page)

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Franklin County--Continued

Well JZ-17-63-801--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale	60	182	Shale	7	318
Shale, sandy	10	192	Shale, sandy	12	330
Shale	78	270	Rock	1	331
Shale, hard	5	275	Shale	18	349
Shale	15	290	Sand, hard layers	11	360
Shale, sandy	20	310	Sand, layers of shale	70	430
Rock	1	311	Shale, sandy	10	440

Well JZ-17-63-902

Owner: Tidewater Oil Co. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	3	3	Shale and boulders	47	164
Sand	10	13	Shale, hard	68	232
Shale	2	15	Shale, hard and boulders	82	314
Sand	17	32	Shale, tough and hard	40	354
Shale and lignite	19	51	Shale and boulders	81	435
Sand and lignite	15	66	Shale, hard	50	485
Rock	1	67	Sand, hard	10	495
Shale and boulders	6	73	Sand, good flow	66	561
Shale, boulders and rock	44	117			

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Franklin County--Continued

Well JZ-17-63-903

Owner: Tidewater Oil Co. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand, surface ---------	3	3	Rock ------------------	1	350
Clay, sandy -----------	29	32	Sand, hard ------------	7	357
Shale, sandy, and sand	149	181	Shale and boulders ----	126	483
Shale, hard and lignite	92	273	Lime, hard ------------	32	515
Sand, hard and boulders	61	334	Sand, hard, good ------	69	584
Shale, sandy ----------	15	349			

Well JZ-34-06-302

Owner: City of Winnsboro, well 4. Driller: B. F. Edington Drilling Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand ------------------	21	21	Shale -----------------	5	134
Clay, sandy -----------	39	60	Clay, sandy, yellow ---	29	163
Shale -----------------	15	75	Sand, fine, good ------	50	213
Shale, sandy ----------	12	87	Shale, soft, oily -----	6	219
Shale -----------------	6	93	Sand, good ------------	12	231
Sand, shale, and lignite	17	110	Shale, sandy ----------	46	277
Sand ------------------	19	129			

Well JZ-34-06-304

Owner: City of Winnsboro, well 3. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, sandy -----------	3	3	Clay, sandy -----------	4	100
Clay, yellow ----------	33	36	Sand and sandy clay ---	65	165
Sand ------------------	60	96	Clay, sandy -----------	6	171

(Continued on next page)

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Franklin County--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well JZ-34-06-304--Continued					
Sand ------------------	9	180	Sand ------------------	30	240
Clay, sandy -----------	6	186	Clay, sandy -----------	6	246
Sand ------------------	12	198	Clay, blue, stiff -----	9	255
Clay, sandy -----------	12	210			

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Morris County

Well TU-16-51-402

Owner: City of Omaha, well 2. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil ---------------	2	2	Sand, fine, gray ------	15	335
Clay and sand ---------	15	17	Shale and lignite -----	33	368
Shale -----------------	34	51	Sand, fine, gray ------	13	381
Sand and shale streaks	19	70	Shale and lignite -----	17	398
Sand, gray ------------	27	97	Sand, fine, white -----	35	433
Shale, sandy ----------	8	105	Sand, shale and lignite	20	453
Sand ------------------	8	113	Shale and lignite -----	21	474
Shale, sandy and lignite	39	152	Rock ------------------	1	475
Shale, sandy ----------	18	170	Sand and shale streaks	22	497
Shale -----------------	38	208	Shale, hard -----------	23	520
Sand, streaks of shale and lignite ---------	69	277	Rock ------------------	2	522
Lignite and shale -----	13	290	Shale and sandy shale -	78	600
Shale -----------------	30	320			

Well TU-16-51-501

Owner: City of Naples, well 2. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, sandy -----------	20	20	Shale -----------------	81	172
Shale and lignite -----	8	28	Shale, sandy ----------	18	190
Shale -----------------	23	51	Rock ------------------	1	191
Rock ------------------	1	52	Shale, hard -----------	17	208
Shale and lignite -----	39	91	Rock ------------------	2	210

(Continued on next page)

Morris County--Continued

Well TU-16-51-501--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale	18	228	Shale	11	355
Rock	1	229	Sand	7	362
Shale	51	280	Shale	30	392
Shale, sandy and thin layers of sand	35	315	Sand	34	426
Shale	13	328	Shale	8	434
Shale, sandy	16	344			

Well TU-16-51-503

Owner: City of Naples, well 3. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	2	2	Shale, hard, sandy	6	289
Clay and boulders	13	15	Rock, rough, not so hard	2	291
Rock	11	26	Shale	9	300
Lignite and shale	33	59	Sand, fine	20	320
Rock	1	60	Shale	12	332
Lignite and shale	9	69	Rock	1	333
Rock	2	71	Shale	19	352
Shale and boulders	13	84	Shale, sandy	8	360
Lignite and shale	14	98	Shale	55	415
Shale	88	186	Shale and streaks of sand	39	454
Shale, sandy	18	204	Sand, white	38	492
Shale	69	273	Shale, sandy	18	510
Rock, hard	10	283			

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Morris County--Continued

Well TU-16-51-504

Owner: City of Naples, well 4. Driller: B. F. Edington.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, white	20	20	Shale, sandy	25	260
Lignite and shale	20	40	Shale, gray	9	269
Shale and boulders, brown	20	60	Rock	21	290
Shale, gray	20	80	Sand with streaks of lignite	65	355
Shale, gray, sandy	24	104	Shale, gray	20	375
Rock, hard	1	105	Shale, sandy	65	440
Shale, gray	35	140	Sand	10	450
Shale, sandy	20	160	Rock	1	451
Shale and lignite	40	200	Shale	47	498
Shale, gray	20	220	Sand	22	520
Shale and lignite	15	235	Shale	73	593

Well TU-16-51-505

Owner: City of Naples, well 5. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	2	2	Sand and shale breaks	44	359
Clay, red	18	20	Shale and sandy shale	26	385
Clay, blue	105	125	Clay, white, sandy	20	405
Shale	94	219	Sand, white, fine	28	433
Shale, sandy and lignite	96	315	Shale, green, sandy	4	437

Morris County--Continued

Well TU-35-03-403

Owner: Lone Star Steel Co. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand and gravel	2	2	Shale, sandy	5	222
Clay and red sand	12	14	Rock	1	223
Clay, yellow	26	40	Sand	7	230
Shale, sandy	46	86	Rock	1	231
Rock	1	87	Shale	53	284
Shale, sandy, hard	55	142	Sand	19	303
Shale, hard	31	173	Rock	1	304
Shale, sandy	9	182	Sand	32	336
Sand, hard	21	203	Rock	2	338
Shale	12	215	Sand	55	393
Rock	2	217	Shale	11	404

Well TU-35-03-501

Owner: Lone Star Steel Co. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale, sandy and boulders	51	51	Shale, hard	86	294
Shale	22	73	Shale, sandy	31	325
Sand and shale	16	89	Shale	23	348
Sand	38	127	Sand and shale	16	364
Shale and boulders	29	156	Shale	27	391
Shale, sandy	30	186	Shale and boulders	37	428
Sand and shale	22	208	Shale, sandy	23	451

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Morris County--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well TU-35-03-501--Continued					
Sand, fine ------------	16	467	Sand ------------------	33	563
Shale -----------------	7	474	Shale, hard, and lignite ------------	11	574
Shale, hard -----------	15	489	Shale -----------------	46	620
Sand, good ------------	19	508			
Sand and sandy shale --	22	530			

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County

Well YA-16-49-402

Owner: City of Mount Pleasant. Driller: H. P. Narramore.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, red	5	5	Sand	20	125
Sand	35	40	Shale, blue	45	170
Shale, sandy	30	70	Rock	2	172
Sand	10	80	Sand	36	208
Shale, blue	7	87	Shale, blue	102	310
Lignite	3	90	Sand	40	350
Shale, blue	15	105	Shale, sandy	45	395

Well YA-16-49-701

Owner: American Petrofina Co., well 2. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, red, sandy	27	27	Shale, sandy and lignite	21	201
Shale, sandy	38	65	Rock	1	202
Sand, green	12	77	Shale and lignite	9	211
Sand, fine	8	85	Sand, hard	10	221
Shale, sandy	7	92	Lignite and shale	55	276
Rock	1	93	Rock	1	277
Shale and lignite	14	107	Shale and lignite	22	299
Sand, gray, fine	6	113	Sand, white, fine	25	324
Shale and lignite	13	126	Shale, sandy and lignite	19	343
Sand, gray, fine	10	136	Shale and lignite	7	350
Shale, sandy shale, and lignite	44	180			

(Continued on next page)

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well YA-16-49-701--Continued					
Rock	1	351	Rock	1	383
Sand	2	353	Sand, gray, fine	11	394
Rock	1	354	Rock	1	395
Sand	6	360	Sand, shale layers	28	423
Rock	2	362	Shale and lignite	14	437
Sand, gray, fine	20	382			

Well YA-16-49-702

Owner: American Petrofina Co., well 1. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, red	25	25	Rock	1	307
Sand, dark gray, fine	45	70	Sand, gray, hard, fine	5	312
Shale, soft and lignite	10	80	Shale, soft	8	320
Sand, gray, fine and lignite	25	105	Rock	1	321
Shale, gray, soft	10	115	Sand, gray, fine, silty	12	333
Lignite, sand, and shale	21	136	Shale, dark-brown, hard	19	352
Shale, gray, soft	25	161	Rock, hard	2	354
Rock, soft	2	163	Sand, water	58	412
Shale, soft	36	199	Shale, gray, soft	38	450
Rock, hard	1	200	Rock	1	451
Lignite	26	226	Shale, gray, soft and sand, hard layers	66	517
Shale, soft, gray and lignite	80	306	Shale, blue, hard	80	597

Table 10.--Drillers' logs of wells in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well Well YA-17-56-707

Owner: Winfield Water Supply Cooperation. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay and sand ---------	4	4	Sand and sandy shale --	10	151
Clay and lignite ------	33	37	Clay ------------------	3	154
Clay, sandy, and clay -	21	58	Sand, sandy shale and lignite -------------	25	179
Shale -----------------	12	70	Clay and lignite ------	6	185
Shale and lignite -----	30	100	Sand and clay layers --	16	201
Sand ------------------	8	108	Clay and sand layers --	59	260
Shale, fine sandy shale and lignite ---------	33	141	Shale and hard streaks	31	291

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties

(Analyses given are in parts per million except specific conductance, pH, percent sodium, sodium adsorption ratio, and residual sodium carbonate)

Camp County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
BZ-16-57-903	20	May 7, 1942	--	--	--	8.0	4.4	*7.1		12	15	18	0.3	2.0	--	--	61	38	--	--	--	--	--
904	36	May 13, 1942	--	--	--	7.6	1.7	*16		0	15	20	.3	45	--	--	106	26	--	--	--	--	--
17-64-601	15	May 15, 1942	--	--	--	4.8	8.0	*3.0		6	7	10	.3	30	--	--	66	45	--	--	--	--	--
802	24	May 8, 1942	--	--	--	2.0	4.4	*3.7		6	3	5.0	--	20	--	--	41	23	--	--	--	--	--
902	18	May 9, 1942	--	--	--	.4	3.9	*6.9		18	3	9.0	--	2.0	--	--	34	17	--	--	--	--	--
34-07-301	260	Aug. 12, 1963	44	0.18	--	1.0	1.8	7.4	0.8	a/ 0	14	11	.2	7.8	--	--	88	10	44	1.0	0.00	111	3.9
304	18	May 8, 1942	--	--	--	.8	8.0	*43		85	20	21	.2	9.0	--	--	144	35	--	--	--	--	--
08-101	30	do	--	--	--	2.8	8.0	*33		0	52	39	.5	1.5	--	--	137	40	--	--	--	--	--
103	280	Aug. 12, 1963	13	.09	--	2.5	.4	*106		248	19	11	.2	1.0	--	--	273	8	97	16	3.91	433	7.6
401	14	May 8, 1942	--	--	--	12	6.8	*1.8		0	63	1.0	.4	0	--	--	85	59	--	--	--	--	--
501	300	Aug. 22, 1963	14	.07	--	3.2	.5	*83		176	35	5.9	.2	.0	--	--	229	10	95	11	2.68	369	7.4
502	131	do	6.6	.49	--	4.8	1.2	*72		150	42	4.5	.4	.0	--	--	206	17	90	7.6	2.12	338	7.6
602	21	May 8, 1942	--	--	--	8.4	6.8	*12		6	37	16	.4	9.0	--	--	93	49	--	--	--	--	--
901	500	Aug. 9, 1963	14	.11	--	2.5	.4	*111		250	20	16	.2	.0	--	--	287	8	97	17	3.94	456	7.6
35-01-101	17	May 12, 1942	--	--	--	30	56	*225		0	100	460	.4	100	--	--	972	305	--	--	--	--	--
102	225	May 6, 1942	--	--	--	2.0	2.9	*120		183	104	13	.1	2.0	--	--	334	17	--	--	--	--	--
103	641	July 16, 1963	13	.06	0.01	3.5	.9	121	2.0	248	48	18	.3	.0	0.51	0.11	329	12	95	15	3.82	534	7.3
† 104	670	July 25, 1957	14	.01	--	1.3	.3	182		346	0	68.0	--	--	--	--	--	4.5	--	--	--	740	8.4
104	670	July 16, 1963	13	.05	.01	1.5	.4	176	1.8	344	.0	74	.3	.2	1.0	.20	437	5	98	34	5.54	740	7.8
105	466	Oct. 14, 1941	12	.40	--	8.7	2.1	*92		180	65	9.0	--	2.0	--	--	289	30	--	--	--	--	--
105	466	July 16, 1963	14	.07	.02	3.0	.6	126	1.1	284	10	32	.3	2.2	.84	.17	330	10	96	17	4.45	546	7.7
107	275	May 6, 1942	--	--	--	2.4	4.1	*106		232	37	16	.2	1.0	--	--	281	23	--	--	--	--	--
† 108	220	Oct. 23, 1957	14.0	.1	--	6.5	1.7	120	--	250	53.4	17	--	--	--	--	--	23	--	--	--	510	8.15
108	643	July 16, 1963	13	.02	.03	6.8	1.5	107	3.2	208	73	10	.3	2.1	.48	.08	320	23	90	9.7	2.95	517	7.7
301	15	May 14, 1942	--	--	--	12	5.6	*18		12	11	21	.2	50	--	--	124	53	--	--	--	--	--
302	21	May 7, 1942	--	--	--	.8	.7	*11		6	7	10	.2	3.0	--	--	36	5	--	--	--	--	--

See footnotes at end of table.

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Camp County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
BZ-35-01-402	13	May 13, 1942	--	--	--	11	0.7	*17		55	12	5.5	0.2	2.0	--	--	76	30	--	--	--	--	--
702	26	May 6, 1942	--	--	--	2.0	5.6	*6.0		31	4	8.0	.1	0	--	--	41	28	--	--	--	--	--
803	440	Jan. 5, 1961	12	--	--	3.0	.9	113	2.0	275	12	12	.3	2.8	--	--	293	11	--	15	4.29	485	7.8
02-101	25	May 7, 1942	--	--	--	8.8	8.0	*19		0	3	50	--	41	--	--	130	55	--	--	--	--	--
401	17	do	--	--	--	1.2	1.9	--		0	2	3.5	.2	3.0	--	--	12	11	--	--	--	--	--
501	23	do	--	--	--	54	36	*88		6	370	58	.6	0	--	--	610	282	--	--	--	--	--
501	23	July 27, 1961	62	0.18	--	6.0	4.9	*11		[b] 0	55	22	.2	.8	--	--	163	35	27	.8	.00	213	4.3

* Sodium and potassium calculated as sodium (Na).
† Analyses by Curtis Laboratories.
[a] Contains 0.19 ppm acidity (H^+).
[b] Contains 0.61 ppm acidity (H^+).

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Franklin County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
JZ-17-39-902	23	Aug. 20, 1963	--	--	--	--	--	--		720	--	76	--	--	--	--	--	602	--	--	0.00	1,500	6.4
46-801	26	June 17, 1942	--	--	--	27	11	*189		31	129	252	--	10	--	--	633	112	--	--	--	--	--
47-101	22	do	--	--	--	107	21	*75		220	170	73	--	70	--	--	624	353	--	--	--	--	--
102	30	Aug. 21, 1963	--	--	--	--	--	--		550	--	225	--	--	--	--	--	565	--	--	.00	2,100	6.3
301	24	June 17, 1942	--	--	--	8.8	3.6	*72		12	70	42	--	64	--	--	266	37	--	--	--	--	--
401	21	do	--	--	--	44	15	*26		18	17	75	--	108	--	--	294	169	--	--	--	--	--
501	15	do	--	--	--	33	2.4	*84		18	63	64	--	128	--	--	384	92	---	--	--	--	--
55-301	21	do	--	--	--	15	3.6	*47		79	63	11	--	10	--	--	189	52	--	--	--	--	--
401	120	June 19, 1942	87	2.2	--	1.7	1.1	22	--	48	2.6	5.0	0.4	7.5	--	--	198	9	--	--	--	--	7.0
403	81	Mar. 11, 1963	52	6.2	--	20	6.8	54	1.9	60	6.6	70	.2	48	--	--	290	78	59	2.7	.00	466	5.6
501	17	June 18, 1942	--	--	--	59	12	*246		55	554	63	.3	24	--	--	985	198	--	--	--	--	--
601	8	June 17, 1942	--	--	--	6.4	1.2	*9.0		18	5	14	--	1.0	--	--	46	21	--	--	--	--	--
701	18	June 11, 1942	--	--	--	58	58	*102		18	33	280	.3	200	--	--	742	386	--	--	--	--	--
706	250	Aug. 19, 1963	11	.1	--	3.5	.9	*134		254	52	28	.4	.0	--	--	355	12	96	17	3.92	569	7.4
802	11	June 12, 1942	--	--	--	6.8	2.2	*59		67	30	48	--	0	--	--	179	26	--	--	--	--	--
901	14	June 8, 1942	--	--	--	9.6	6.1	*53		61	3	55	--	41	--	--	198	49	--	--	--	--	--
902	36	June 18, 1942	--	--	--	8.8	2.4	*24		24	30	21	--	4.5	--	--	103	32	--	--	--	--	--
62-301	34	June 11, 1942	--	--	--	29	4.9	*70		98	7	110	---	4.5	--	--	273	93	--	--	--	--	---
302	282	Aug. 19, 1963	12	.5	--	5.0	1.1	*76		181	9.6	16	.2	.0	--	--	209	17	91	8.0	2.63	335	7.2
602	Spring	June 11, 1942	--	--	--	13	2.4	*.5		31	2	5.0	--	11	--	--	49	42	--	--	--	--	--
603	38	do	--	--	--	4.8	2.4	*20		37	26	5.0	.2	1.5	--	--	83	22	--	--	--	--	--
63-302	14	June 18, 1942	--	--	--	17	12	*95		49	63	136	--	3.0	--	--	350	93	--	--	--	--	--
701	16	June 11, 1942	--	--	--	4.8	2.4	*7.1		12	2	16	.1	3.0	--	--	41	22	--	--	--	--	--
801	440	June 1, 1960	13	.05	--	1.5	.4	101	1.1	240	.2	18	.2	.2	--	0.28	254	5	97	20	3.83	417	7.9
803	640	Aug. 19, 1963	21	.22	--	12	2.4	*55		173	5.4	8.7	.2	.0	--	--	190	40	75	3.8	2.04	296	7.2
805	370	do	13	.06	--	4.5	1.2	69	1.9	195	3.6	5.2	.2	.2	--	.08	195	16	89	7.5	2.87	314	7.5
807	15	June 18, 1942	--	--	--	15	14	*12		0	100	20	--	10	--	--	171	93	--	--	--	--	--

See footnotes at end of table.

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Franklin County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
JZ-17-63-903	584	Aug. 19, 1963	12	0.08	--	2.5	0.0	*244		386	0.0	156	0.3	0.0	--	--	605	6	99	43	6.21	1,030	7.6
34-06-301	30	June 15, 1942	--	--	--	17	11	*68		43	52	51	.4	90	--	--	310	87	--	--	--	--	--
‡ 302	240	June 7, 1956	13.2	.37	--	8.0	.0	--		--	--	--	--	--	--	--	--	8.0	--	--	--	48	5.8
302	240	July 17, 1963	16	.11	0.02	2.2	.6	3.8	1.1	a/ 0	8.4	6.0	.1	4.1	0.00	0.00	43	8	14	.6	.16	71	4.0
303	Spring	Feb. 14, 1942	--	--	--	8.8	3.6	*12		18	7	10	.1	32	--	--	82	37	--	--	--	--	--
303	Spring	Aug. 22, 1963	14	.03	--	12	2.9	8.3	5.2	10	13	12	.1	36	--	.06	109	42	27	.6	.00	164	5.2
† 304	255	Aug. 19, 1951	12.0	.1	--	3.7	.3	4.5	--	7.3	4.3	7.0	--	--	--	--	55.4	10	--	--	--	--	4.85
304	255	July 17, 1963	19	.82	.03	3.0	.9	4.4	1.2	b/ 0	15	7.0	.1	.3	.00	.00	52	11	17	.6	.22	90	4.0
310	400	Aug. 19, 1963	18	.18	--	5.0	2.0	*31		87	9.2	5.2	.3	1.2	--	--	115	22	76	2.9	.99	173	6.8
07-102	25	June 11, 1942	--	--	--	7.2	4.9	*2.3		18	10	4.0	.1	14	--	--	52	38	--	--	--	--	--
201	25	do	--	--	--	11	4.9	*34		31	55	26	.1	2.0	--	--	148	48	--	--	--	--	--
202	160	do	--	--	--	14	6.1	*64		140	63	11	.1	2.0	--	--	229	59	--	--	--	--	--
203	224	do	--	--	--	9.2	4.9	*33		85	30	8.0	.1	1.0	--	--	129	43	--	--	--	--	--
204	240	do	--	--	--	9.2	4.9	*35		98	26	8.0	.2	1.0		--	133	43	--	--	--	--	--

* Sodium and potassium calculated as Sodium (Na).
† Analyses by Curtis Laboratories.
‡ Water Treatment Engineering Co.
a/ Contains 0.8 ppm acidity (H^+).
b/ Contains 0.7 ppm acidity (H^+).

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Morris County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
TU-16-42-601	65	Mar. 17, 1942	--	--	--	251	51	*251		6	112	302	0.9	1,031	--	--	2,002	836	--	--	--	--	--
901	43	do	--	--	--	102	45	*59		311	15	204	--	9.0	--	--	587	437	--	--	--	--	--
43-401	360	May 27, 1963	11	0.07	0.00	4.5	1.2	259	1.8	352	15	198	.4	3.3	0.37	0.64	668	16	97	28	5.45	1,160	7.5
50-206	25	Mar. 17, 1942	--	--	--	7.2	3.4	*20		79	2	5.0	--	1.0	--	--	78	32	--	--	--	--	--
301	27	do	--	--	--	10	6.8	*26		43	7	25	--	40	--	--	136	54	--	--	--	--	--
808	17	Mar. 19, 1942	--	--	--	7.2	3.4	*1.4		24	5	6.5	.0	1.0	--	--	37	32	--	--	--	--	--
901	22	Mar. 16, 1942	--	--	--	2.8	2.2	*2.8		0	2	6.0	--	14	--	--	30	16	--	--	--	--	--
902	20	do	--	--	--	5.6	4.6	*19		6	12	26	--	24	--	--	94	33	--	--	--	--	--
51-401	260	Mar. 11, 1942	--	--	--	8.8	2.2	*21		6	17	22	.0	30	--	--	104	31	--	--	--	--	--
51-401	260	Jan. 8, 1963	30	.73	--	7.5	5.4	18	3.1	7	16	28	.2	27	--	.15	138	41	47	1.2	.00	202	5.7
402	508	do	12	.02	--	2.2	.5	166	1.2	375	.0	45	.3	2.8	--	.28	414	8	98	26	6.00	702	7.7
501	436	Dec. 1, 1943	20	.47	--	3.0	.8	225	3.6	a/411	1.4	114	1.4	.2	--	--	578	11	--	--	--	--	8.3
502	450	Mar. 11, 1942	--	--	--	4.8	1.0	*183		317	20	94	.2	.0	--	--	459	16	--	--	--	--	--
503	510	Aug. 7, 1963	11	.08	--	2.0	.2	159	1.0	352	.0	48	.3	.0	--	.28	395	6	98	28	5.65	665	7.7
504	538	June 3, 1963	15	.20	.03	5.0	1.1	136	2.5	320	27	22	.2	.2	.17	.11	366	17	94	14	4.90	598	7.5
505	437	Aug. 7, 1963	14	.08	--	2.8	.7	109	1.4	258	21	13	.2	1.8	--	.05	291	10	95	15	4.03	476	7.6
801	26	Mar. 11, 1942	--	--	--	8.0	4.4	*17		6	60	5.0	.1	.5	--	--	98	38	--	--	--	--	--
803	25	Mar. 11, 1942	--	--	--	11	27	*32		.0	15	98	--	104	--	--	287	137	--	--	--	--	--
58-204	22	Mar. 19, 1942	--	--	--	6.0	5.8	*2.1		6	26	7.5	--	1.0	--	--	51	39	--	--	--	--	--
302	380	Mar. 16, 1942	--	--	--	11	3.4	*93		232	34	14	.1	.0	--	--	270	42	--	--	--	--	--
508	16	Mar. 19, 1942	--	--	--	12	7.1	*36		12	8	41	--	75	--	--	185	59	--	--	--	--	--
601	20	Mar. 23, 1942	--	--	--	.8	1.0	*14		12	3	9.0	.1	12	--	--	46	6	--	--	--	--	--
806	786	June 6, 1963	13	.92	.01	2.0	.5	215	2.3	356	.4	138	.4	.2	.78	.34	548	7	98	35	5.69	947	7.8
809	25	Mar. 24, 1942	--	--	--	6.0	5.8	*6.4		6	10	23	--	6.0	--	--	60	39	--	--	--	--	--
901	28	do	--	--	--	3.2	3.4	*48		18	5	34	--	72	--	--	175	22	--	--	--	--	--
905	27	Mar. 13, 1942	--	--	--	1.6	3.2	*10		6	3	14	.0	14	--	--	49	17	--	--	--	--	--

See footnotes at end of table.

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Morris County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
TU-16-58-906	Spring	Mar. 13, 1942	--	--	--	4.0	5.8	*15		6	2	28	0.1	24	--	--	82	34	--	--	--	--	--
59-103	27	Mar. 16, 1942	--	--	--	4.0	5.8	*32		6	11	44	--	30	--	--	130	34	--	--	--	--	--
104	26	do	--	--	--	<3	1.0	*15		31	3	5.5	.1	.0	--	--	40	4	--	--	--	--	--
401	700	June 1, 1960	18	24	--	42	17	50	7.6	102	162	31	--	.0	--	0.05	378	175	37	1.6	0.00	585	7.4
601	19	Mar. 13, 1942	--	--	--	.8	1.0	*5.3		6	3	4.0	--	5.0	--	--	22	6	--	--	--	--	--
602	30	do	--	--	--	2.8	2.2	*20		.0	7	30	--	12	--	--	74	16	--	--	--	--	--
† 701	386	1941	--	2.3	0.06	8.8	5.0	--		34	30	16	.4	.4	--	--	142	43	--	--	--	--	6.0
‡ 701	386	Nov. 2, 1943	29	.08	--	8.0	3.2	6.3	6.0	23	24	7.0	.2	.2	--	--	99	33	--	--	--	--	7.3
702	554	Jan. 10, 1963	31	7.2	--	10	4.5	9.5	6.2	22	37	11	.1	.2	--	.03	121	43	29	.6	.00	164	5.4
707	Spring	Mar. 13, 1942	--	--	--	4.4	<3	*3.9		12	3	4.5	.0	.0	--	--	22	11	--	--	--	--	--
801	493	Mar. 22, 1942	--	--	--	10	<3	*70		177	26	3.5	.0	.0	--	--	197	26	--	--	--	--	--
802	450	Aug. 7, 1963	13	.47	--	24	6.8	22	7.4	123	25	14	.2	.8	--	.00	173	88	33	1.0	.26	288	6.8
807	21	Mar. 24, 1942	--	--	--	2.8	2.2	*2.8		12	5	2.5	.1	3.5	--	--	25	16	--	--	--	--	--
35-02-201	22	Mar. 12, 1942	--	--	--	1.2	3.4	*4.1		.0	7	7.5	.1	9.0	--	--	32	17	--	--	--	--	--
301	16	do	--	--	--	2.8	2.4	*37		18	30	34	--	3.0	--	--	118	17	--	--	--	--	--
302	37	do	--	--	--	.4	1.2	*51		18	13	34	--	49	--	--	158	6	--	--	--	--	--
03-105	28	Mar. 23, 1942	--	--	--	.4	<3	*16		6	8	12	.1	5.0	--	--	45	1	--	--	--	--	--
401	333	do	--	--	--	6.8	1.0	*106		250	4	28	.3	2.0	--	--	271	21	--	--	--	--	--
402	336	do	--	--	--	11	3.4	*89		244	12	16	.3	.0	--	--	252	42	--	--	--	--	--
403	404	Aug. 7, 1963	10	.17	--	4.5	1.2	184	2.4	456	.2	34	.7	.0	--	.20	461	16	95	20	7.15	762	7.5
501	620	do	10	1.9	--	2.5	.9	80	1.9	170	40	5.5	.2	.5	--	.12	226	10	93	11	2.59	367	7.3
801	45	Mar. 12, 1942	--	--	--	2.8	1.0	*9.4		18	2	10	.1	.0	--	--	34	11	--	--	--	--	--

* Sodium and potassium calculated as sodium (Na).
† Untreated water.
‡ Treated water.
a/ Includes the equivalent of 29 ppm as carbonate (CO_3).

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
YA-16-41-101	22	Aug. 20, 1963	--	--	--	--	--	*17		7	0.0	18	--	40	--	--	--	27	57	1.4	0.00	149	5.1
102	34	do	--	--	--	--	--	--		34	--	358	--	--	--	--	--	324	--	--	--	1,250	5.8
201	30	May 26, 1942	--	--	--	12	1.2	*32		55	15	24	--	15	--	--	127	36	--	--	--	--	--
301	60	do	--	--	--	179	126	*126		12	1,025	115	0	3.0	--	--	1,580	968	--	--	--	--	--
302	60	do	--	--	--	134	39	*152		116	211	361	--	1.0	--	--	955	494	--	--	--	--	--
801	200	Feb. 25, 1963	13	0.13	--	6.8	2.0	*147		308	.0	65	.4	.0	--	--	385	25	93	13	4.55	703	7.3
802	31	do	--	--	--	--	--	--		22	4.0	238	--	44	--	--	--	181	--	--	.00	955	5.2
902	470	July 30, 1963	11	.13	--	3.2	.7	*326		406	.0	272	.9	1.5	--	--	815	11	98	43	6.43	1,410	7.5
903	27	May 26, 1942	--	--	--	82	63	*155		268	296	191	0	3.0	--	--	922	464	--	--	--	--	--
42-401	48	June 3, 1942	--	--	--	226	63	*421		549	33	890	--	0	--	--	1,903	824	--	--	--	--	--
702	22	do	--	--	--	12	5.8	*58		55	18	77	--	10	--	--	208	54	--	--	--	--	--
49-103	20	May 22, 1942	--	--	--	.8	1.0	*12		18	11	3.0	--	1.5	--	--	38	6	--	--	--	--	--
202	315	Feb. 20, 1963	51	22	--	9.8	3.2	*24		91	.0	11	.1	.0	--	--	144	38	58	1.7	.74	215	5.8
203	30	do	--	--	--	--	--	*275		64	1,420	700	--	--	--	--	--	1,920	24	2.7	.00	4,090	5.5
206	485	Feb. 25, 1963	14	.68	--	20	.7	*58		122	13	13	.2	1.0	--	--	162	8	94	8.9	1.84	284	7.3
301	24	May 26, 1942	--	--	--	2.4	1.2	*28		31	7	22	--	10	--	--	86	11	--	--	--	--	--
401	24	May 22, 1942	--	--	--	21	3.6	*13		43	26	20	--	7.0	--	--	112	67	--	--	--	--	--
402	395	Mar. 12, 1963	50	11	--	9.0	3.9	16	2.6	64	3.4	14	.2	0	--	0.00	130	38	45	1.1	.28	156	5.9
503	360	Feb. 20, 1963	54	12	--	9	3.2	*26		78	4.6	16	.1	.0	--	--	151	36	61	1.9	.57	218	5.8
601	22	May 25, 1942	--	--	--	49	19	*109		171	74	138	.2	33	--	--	506	202	--	--	--	--	--
603	350	July 30, 1963	11	.12	--	1.5	.1	*86		204	.0	16	.2	1.8	--	--	217	4	98	19	3.26	353	7.4
701	437	May 27, 1942	20	.07	--	3.7	1.2	*231		370	2	149	.2	2.0	--	--	594	14	--	--	--	--	8.2
701	437	June 22, 1949	15	.14	--	1.6	.7	196	1.6	a337	1.6	109	.1	2.2	--	.79	509	--	--	--	--	869	8.5
701	437	Feb. 19, 1963	12	2.8	--	1.5	.5	170	1.1	322	3.2	74	.2	.0	--	.20	421	6	98	30	5.17	758	7.4
702	597	May 27, 1942	20	.05	--	3.8	1.0	224	--	380	2	132	0	.0	--	--	567	14	--	--	--	--	8.4
702	597	Feb. 19, 1963	12	1.4	--	2.5	.7	218	1.2	368	.0	126	.3	.0	--	.27	542	9	98	32	5.85	991	7.7
706	430	May 14, 1942	39	5.6	--	14	6.6	30	--	126	2	15	.1	.5	--	--	176	62	--	--	--	--	--

See footnotes at end of table.

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
YA-16-49-708	460	Mar. 14, 1963	13	0.13	--	1.5	0.2	152	.8	298	3.2	62	0.2	0.0	--	0.10	380	5	98	30	4.78	651	8.0
804	18	May 14, 1942	--	--	--	10	1.2	*7.4		24	18	6.0	--	0	--	--	55	31	--	--	--	--	--
924	300	Apr. 25, 1963	33	2.7	--	20	4.0	*55		156	13	31	.5	.0	--	--	234	66	64	2.9	1.23	352	7.1
50-101	35	June 3, 1942	--	--	--	13	2.4	*46		49	12	14	--	86	--	--	197	42	--	--	--	--	--
102	31	do	--	--	--	79	35	*44		110	11	141	--	169	--	--	533	342	--	--	--	--	--
202	48	do	--	--	--	47	12	*38		49	2	125	--	39	--	--	287	168	--	--	--	--	--
403	310	July 30, 1963	18	.09	--	27	6.9	*107		284	57	26	.2	.0	--	--	382	96	71	4.8	2.73	601	7.2
404	10	May 25, 1942	--	--	--	31	28	*6.4		18	74	78	--	5.0	--	--	231	192	--	--	--	--	--
409	300	July 30, 1963	12	.05	--	4.2	.9	*116		270	23	13	.2	2.0	--	--	304	14	95	13	4.15	485	7.3
501	37	May 25, 1942	--	--	--	308	97	*76		488	274	460	0	2.0	--	--	1,457	1,170	--	--	--	--	--
703	18	June 3, 1942	--	--	--	1.6	3.2	*2.3		12	4	4.0	.3	2.0	--	--	23	17	--	--	--	--	--
57-102	246	Aug. 22, 1963	34	2.9	--	45	9.7	*34		130	75	29	.2	.2	--	--	291	152	33	1.2	.00	452	6.6
110	700	June 3, 1963	12	.09	--	4.5	1.2	*420		396	0	425	.5	.7	--	--	1,060	16	98	46	6.17	1,890	7.6
114	475	Aug. 22, 1963	13	.06	--	6.0	.7	*56		155	.0	8.5	.2	.5	--	--	161	18	87	5.7	2.18	272	7.2
301	20	May 13, 1942	--	--	--	4.8	3.6	*10		12	26	7.0	.2	2.0	--	--	60	27	--	--	--	--	--
302	420	July 31, 1963	13	.22	--	3.5	.5	*104		266	.2	15	.2	2.2	--	.06	271	11	95	14	4.14	440	7.3
401	300	Aug. 22, 1963	13	--	--	4.8	1.0	*157		286	.0	86	.6	.0	--	--	403	16	96	17	4.37	688	7.7
402	300	May 1, 1963	13	1.1	0.00	5.0	1.1	157	1.6	296	.2	88	.5	.0	0.94	.28	414	17	95	17	4.51	708	7.5
601	18	May 13, 1942	--	--	--	8.8	2.4	*11		18	5	18	.2	12	--	--	67	32	--	--	--	--	--
58-101	9	May 14, 1942	--	--	--	12	6.1	*31		12	63	29	.2	6.0	--	--	153	54	--	--	--	--	--
103	24	do	--	--	--	8.8	3.6	*13		6	12	20	--	25	--	--	85	37	--	--	--	--	--
203	21	do	--	--	--	13	2.4	*29		61	5	28	--	12	--	--	119	42	--	--	--	--	--
401	13	May 13, 1942	--	--	--	4.8	2.4	*8.1		18	2	10	.1	10	--	--	47	22	--	--	--	--	--
701	25	May 14, 1942	--	--	--	13	12	*38		12	2	35	--	130	--	--	236	83	--	--	--	--	--
17-48-102	26	Aug. 21, 1963	--	--	--	--	--	--		53	--	38	--	--	--	--	--	53	--	--	.00	299	5.6
202	18	Mar. 22, 1942	--	--	--	11	1.0	*104		12	30	84	--	120	--	--	356	31	--	--	--	--	--
202	18	Aug. 21, 1963	--	--	--	--	--	--		22	--	89	--	--	--	--	--	86	--	--	.00	696	5.6

See footnotes at end of table.

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
YA-17-48-801	13	May 22, 1942	--	--	--	11	4.9	*37		43	12	40	--	29	--	--	155	48	--	--	--	--	--
802	18	May 20, 1942	--	--	--	5.6	6.1	*17		31	7	12	--	33	--	--	96	39	--	--	--	--	--
901	25	May 22, 1942	--	--	--	13	4.9	*37		12	22	39	--	55	--	--	177	53	--	--	--	--	--
56-201	40	May 27, 1942	--	--	--	22	15	*17		12	2	18	--	141	--	--	221	114	--	--	--	--	--
303	20	May 20, 1942	--	--	--	26	4.6	*34		55	11	65	--	10	--	--	178	83	--	--	--	--	--
304	310	Aug. 13, 1963	18	1.8	--	7.5	2.6	*117		190	74	35	0.2	.0	--	--	347	29	90	9.4	2.53	560	7.2
401	11	May 27, 1942	--	--	--	16	7.3	*134		31	122	102	--	82	--	--	478	70	--	--	--	--	--
402	30	do	--	--	--	4.4	1.2	*19		18	30	4.0	.2	6.0	--	--	74	16	--	--	--	--	--
415	225	Jan. 17, 1963	12	.37	--	3.5	1.2	*132		248	71	15	.1	2.8	--	--	360	14	96	15	3.79	526	7.5
601	28	May 20, 1942	--	--	--	98	55	*67		171	185	199	.1	1.5	--	--	690	469	--	--	--	--	--
701	38	May 15, 1942	--	--	--	6.0	0	*5.1		18	4	5.0	0	0	--	--	29	15	--	--	--	--	--
† 707	260	Oct. 15, 1962	22	.1	--	6.7	2.5	*191.1		201.3	198	50.0	--	--	--	--	--	27	--	--	--	892	8.02
707	260	July 27, 1963	7.8	1.7	0.00	8.2	2.3	182	2.4	184	202	50	.1	2.8	0.24	0.09	548	30	92	14	2.42	866	7.0
801	Spring	May 15, 1942	--	--	--	8.8	2.4	*1.2		37	2	1.0	--	1.5	--	--	35	32	--	--	--	--	--
901	502	May 29, 1942	--	--	--	5.2	4.9	*297		323	2	288	.2	7.0	--	--	764	33	--	--	--	--	--
64-101	380	July 31, 1963	14	.09	--	3.8	.9	*82		187	1.8	24	.2	1.2	--	--	220	13	93	9.9	2.80	356	7.5
102	17	May 15, 1942	--	--	--	4.8	2.4	*22		49	3	15	.1	6.0	--	--	77	22	--	--	--	--	--
201	48	do	--	--	--	48	22	*124		43	30	254	--	66	--	--	565	208	--	--	--	--	--
301	40	do	--	--	--	205	126	*239		580	418	450	0	9.0	--	--	1,732	1,033	--	--	--	--	--
401	32	do	--	--	--	24	18	*127		98	30	195	--	32	--	--	474	136	--	--	--	--	--

* Sodium and potassium calculated as sodium (Na).
† Analyses by Curtis Laboratories.
a/ Includes the equivalent of 5 ppm as carbonate (CO_3).

Table 11.--Chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Red River County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
WB-17-39-602	293	July 24, 1963	33	0.03	--	5.0	0.4	*128		272	5.2	45	0.2	0.0	--	--	351	14	95	15	4.18	535	7.6
901	408	May 21, 1942	--	--	--	2.8	1.0	*413		544	2	326	.3	.2	--	--	1,031	11	--	--	--	--	--
901	408	July 24, 1963	11	.02	--	3.0	.6	*432		520	.0	370	.3	1.2	--	--	1,070	10	99	59	8.32	1,860	7.5

Wood County

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe) (total)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$	Percent sodium	Sodium adsorption ratio (SAR)	Residual sodium carbonate (RSC)	Specific conductance (micromhos at 25°C)	pH
**ZS-34-06-601	226	Apr. 30, 1963	10.1	0.1	--	2.3	0.4	7.6	--	9.8	7.0	6.0	--	--	--	--	55.2	7.4	--	--	--	47	4.5

* Sodium and potassium calculated as sodium (Na).
** Analysis by Curtis Laboratories.

Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties

Camp County

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
BZ-16-57-407	17	0	17	5.5
409	200	0.3	17	7.5
705	442	0	17	7.5
901	500	0	17	7.5
902	640	0	17	7.5
17-64-701	285	0	34	8.0
34-08-104	30	0	119	6.5
105	250	0	34	7.5
35-01-106	50	10.0	119	4.5
110	452	0	17	7.5
111	28	0	17	5.0
112	330	0	17	7.5
403	32	0	34	5.5
703	395	0	17	7.5
704	343	0	17	7.5
803	440	0	--	7.5
805	410	0	17	7.5

Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Franklin County

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
JZ-17-54-901	39	2.0	1,156	6.5
55-404	90	5.0	68	6.5
502	31	2.0	289	7.0
704	35	1	>1,700	5.0
705	180	0	85	7.5
707	30	0	119	6.0
804	23	0	85	6.5
805	33	0	119	6.5
806	95	>10	--	6.5
902	36	0	51	5.0
62-302	282	0	17	7.5
305	293	0	17	7.5
601	285	0	34	7.5
602	Spring	0	68	5.5
607	700	0	17	8.0
901	300	0	17	7.5
902	27	0.5	119	5.5
904	300	.5	51	7.5
905	300	.5	34	7.5
63-101	39	0	51	6.5
201	17	>10	85	5.5
203	15	0	34	6.0

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Franklin County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
JZ-17-63-301	40	0	17	5.5
303	11	0	34	4.5
806	460	0	17	8.0
808	40	0	34	6.0
810	300	0	34	7.5
34-06-305	108	1.0	34	5.0
307	45	0	34	5.5
309	27	0	34	6.5
07-202	160	0	51	7.0
204	240	1.0	51	7.0
205	25	0	136	6.5
206	240	0	34	7.0
207	254	0	51	7.5
208	110	1.5	68	7.0

Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Morris County

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
TU-16-42-602	165	0.3	17	7.5
902	17	0	17	6.5
43-702	32	>10	170	6.5
50-205	105	3.0	170	6.5
207	400	0	68	7.5
303	74	0	850±	6.5
304	225	0	17	7.5
511	18	0	41	6.0
512	28	0	34	5.5
513	22	0	51	6.0
604	270	0	136	7.5
605	300?	0	34	7.5
607	165	0	119	7.5
809	15	0	17	4.5
810	330	0	34	7.5
811	395	0	170	7.5
903	20	0	34	5.5
51-101	54	0	34	6.5
102	120	2.5	119	7.0
103	50	0	85	6.5
104	390	0	17	7.5
201	312	0	51	7.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Morris County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
TU-16-51-202	25	0	51	5.5
301	56	0	850	6.5
302	219	0	102	7.5
404	25	0	17	6.5
405	300?	0	119	7.5
506	305	0	34	7.5
507	27	0	51	5.5
508	58	0	34	5.5
702	250	0	102	7.5
703	240	0	34	7.5
805	14	0	--	--
58-204	22	0	34	4.5
206	41	0	68	6.5
207	39	0	--	6.5
301	900	0	34	7.5
505	365	0	34	7.5
509	18	0	34	6.5
809	25	0	170	5.5
901	28	0	170	6.5
902	390	0	34	7.5
903	12	0	34	5.5
904	202	0	17	8.0

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Morris County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
TU-16-58-905	27	0	17	4.5
906	Spring	0	17	4.5
59-102	555	0	34	7.5
201	10	0	17	4.5
602	30	0	85	4.5
603	120	>10	34	5.5
804	18	0	34	5.5
806	60	0	17	5.0
901	82	>10	51	6.5
35-02-303	47	0	102	5.5
03-101	88	0	34	5.5
301	23	0	34	4.5
302	530	0	34	7.5
402	336	0	51	7.5
405	189	0	51	7.5
407	26	0	119	6.5
601	500	0	170	7.5

Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-41-303	17	0	34	5.5
501	35	0	136	6.0
502	19	0	--	5.5
503	19	0	--	5.5
504	27	0	68	5.5
505	26	0	680	6.5
506	32	0	51	5.5
803	31	0	--	--
804	21	0	289	5.5
805	15	0	119	6.5
806	26	0	51	6.0
807	17	0	85	5.5
808	14	0	--	5.0
809	25	0	--	5.5
811	42	0	51	6.5
812	145	2	34	7.0
813	39	1	68	6.5
814	44	0	425	6.0
815	28	0	--	5.5
901	490	1.5	34	7.0
904	300	0	--	--
905	330	0	--	7.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-41-906	400	0	17	7.5
907	26	0	51	6.0
908	32	0	153	6.5
909	27	--	85	5.5
910	27	0	51	6.5
912	24	0	85	5.5
913	38	1.5	136	6.0
914	21	0	119	6.0
42-402	12	0	170	6.0
702	22	0	119	6.5
703	163	1.5	--	7.0
704	34	0	153	6.5
705	18	0	170	6.5
801	50	2	170	7.0
802	72	6	1,020	6.5
803	275	0	34	7.5
49-101	268	--	--	7.5
104	55	0	136	6.5
106	31	0	34	6.0
107	155	>10	357	6.5
108	51	0.5	289	6.5
201	Spring	0	17	5.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-49-204	13	0	68	5.5
208	260	0	--	--
209	25	0	221	6.5
210	160	8	51	6.5
307	380	0	17	7.5
308	380	0	17	7.5
309	30	0	51	6.5
403	34	0	34	5.5
406	350	0	--	8.0
407	18	0.1	51	5.5
408	21	>10	17	5.8
409	225	0	--	7.5
416	140	>10	102	6.5
417	30	0	102	6.0
420	350	0	--	--
421	42	1.5	170	6.5
502	31	0	119	6.5
505	42	3.0	--	6.5
507	36	0	170	6.0
508	52	1.5	374	6.5
510	37	--	102	6.5
512	360	0	17	8.0

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-49-514	Spring	0	17	5.5
604	27	0	476	6.5
605	27	0	85	6.0
606	22	0	34	6.0
607	127	2.5	238	6.5
608	195	0	51	7.5
704	345	0	--	7.5
710	400	0	17	7.5
711	160	2.5	34	6.5
712	30	0	85	6.0
713	60	0	--	6.0
801	22	0	510	6.5
802	185	.3	34	7.5
805	65	0	51	6.5
806	17	0	170	6.0
808	230	0	68	7.5
903	232	2.0	119	7.0
906	24	0	85	5.5
908	30	0	85	5.5
909	20	0	170	5.5
910	485	1	34	7.5
911	26	0	34	4.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-49-912	350	1	--	7.5
913	242	0.5	51	7.5
914	22	0	68	6.0
915	20	8	34	5.0
917	22	0	51	4.5
918	25	0	34	4.5
919	14	5	--	5.0
923	39	.5	170	6.0
50-102	31	0	340	5.5
103	50	0	119	6.0
104	34	1.5	85	6.5
105	34	0	374	6.0
106	26	0	34	5.5
107	49	1	170	6.5
201	53	0	85	6.5
203	37	0	68	5.5
204	29	--	85	6.5
406	210	0	--	7.5
407	310	0	--	8.0
410	296	0	68	7.5
411	294	0	34	7.5
412	24	0	136	6.0

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-50-413	14	--	350	5.0
416	23	0	102	6.5
418	18	0	250	6.5
420	24	0	2,000	7.0
421	107	7	--	6.5
422	285	0	--	7.5
424	305	0	34	7.5
503	270	0	51	7.5
504	163	7	102	7.0
505	59	1	68	6.5
506	29	0	120	6.5
507	20	0	935	7.0
510	35	0.5	119	6.5
701	380	.1	51	8.0
704	27	0	41	4.5
705	14	0	61	4.5
706	20	0	85	4.5
707	330	0	41	7.5
708	21	0	136	6.5
709	250	0	34	7.5
802	302	0	34	8.0
803	50	0	68	6.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-50-805	18	0	102	5.5
807	30	0	34	5.5
57-103	505	0	34	8
104	280	0.3	85	7.5
105	58	0	--	6.5
106	130	1	--	7.0
107	32	1	--	6.5
108	300	0	--	8.0
109	237	0	--	8.0
112	110	3	--	5.5
113	70	0	--	5.5
201	268	0	--	7.5
202	21	.5	--	5.5
203	Spring	0	--	5.5
303	16	0	--	5.5
305	390	0	--	7.5
306	21	0	32	6.5
401	300	0	--	7.5
402	300	0	--	7.5
403	325	0	--	8.0
603	25	0	68	5.5
604	22	0	51	6.0

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-57-605	29	0	340	6.5
606	18	0	272	6.5
607	25	0	82	5.5
58-102	310	0	51	7.5
104	300	0	17	8.0
105	25	0	17	4.5
106	250	0	170	7.5
107	40	1.5	153	6.0
108	25	0	--	6.5
109	380	0	17	7.5
110	23	0	51	5.5
201	28	0	68	4.5
202	17	0	17	6.0
402	Spring	0	17	5.5
403	13	0	--	4.5
501	26	4.0	51	5.5
503	38	2.0	68	6.0
504	20	0	85	5.5
702	30	0	51	6.5
703	33	0	68	5.5
704	500	0	68	8.0
705	40	0	51	6.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-16-58-801	14	0	204	6.5
802	24	0	85	6.5
803	25	0	85	5.5
17-48-102	26	0	--	--
202	18	0	--	--
804	18	0	51	6.0
56-301	385	0	--	7.5
307	320	0	--	7.5
414	177	0	--	7.5
504	300	0	--	7.5
606	270	0	--	7.5
608	270	0	--	7.5
611	175	0	--	7.5
612	350	0	34	7.5
613	27	0.5	170	6.0
702	310	.0	17	8.0
703	320	0	51	7.5
704	300	0	17	8.0
705	16	0	306	6.5
706	225	0	--	7.5
709	235	0	--	7.5
902	479	0	--	7.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-17-56-909	420	0	28	9.0
910	184	0	85	7.5
911	80?	0	765	6.5
912	26	0	102	6.0
913	46	2.0	82	5.5
914	180	0	51	7.5
915	284	.5	51	7.5
916	361	0	--	8.0
917	25	0	0	6.0
919	180	0	--	7.5
920	505	0	34	8.0
921	381	0	--	8.0
922	21	0	--	5.5
923	29	0	--	5.5
926	195	1.0	34	7.0
927	185	0	--	7.5
929	180	0	--	7.5
64-103	390	0	17	8.0
104	15	0	85	6.5
105	120	>10	51	6.5
106	16	0	17	5.5
107	45	0	170	6.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-17-64-108	26	0	143	6.5
201	48	0	170	5.0
202	300	0	17	8.0
203	85	>10	34	6.5
204	21	0	41	6.5
205	34	1.0	340	6.5
206	52	0	1,100	6.5
207	300	0	34	7.5
210	300	0	17	7.5
211	680	0	17	8.0
212	21	0	51	6.0
302	304	0	34	8.0
303	420	0	68	7.5
304	39	0	289	5.0
305	Spring	0	10	5.5
306	300	0	34	7.5
307	228	0	34	7.5
308	49	0	--	4.5
309	500	0	--	8.0
402	300	0	--	7.5
403	160	1	--	7.0
404	265	0	--	7.5

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Table 12.--Field chemical analyses of water from wells and springs in Camp, Franklin, Morris, Titus, and adjoining counties--Continued

Titus County--Continued

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
YA-17-64-405	150	0.5	--	7.0
406	150	0	--	6.0
407	210	0	--	7.5
408	300	0	85	7.5
409	17	0	136	6.5
410	15	0	170	6.5
501	38	7.0	850	5
502	310	0	85	7.5