TEXAS WATER DEVELOPMENT BOARD

REPORT 27

GROUND-WATER RESOURCES OF HARRISON COUNTY, TEXAS

By

M. E. Broom and B. N. Myers
United States Geological Survey

Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Development Board
and the
Harrison County Commissioners Court

August 1966

Published and distributed
by the
Texas Water Development Board
Post Office Box 12386
Austin, Texas 78711

FOREWORD

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

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

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

Texas Water Development Board
John J. Vandertulip
John J. Vandertulip
Chief Engineer

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLES

FIGURES

TABLE OF CONTENTS (Cont'd.)

GROUND-WATER RESOURCES OF HARRISON COUNTY, TEXAS

ABSTRACT

Harrison County is in the northeastern part of Texas and has an area of 892 square miles. Marshall, the county seat, is 40 miles west of Shreveport, 150 miles east of Dallas, and 75 miles south of Texarkana. Most of Harrison County is heavily forested and the surface is hilly to rolling. The average annual precipitation is about 47 inches.

The economy of the county is based chiefly on industry and agriculture. The agricultural economy is based principally on the raising of beef cattle. The principal industries are concerned with the production and processing of oil and gas.

The geologic units that are the principal source of ground water in Harrison County consist of the Wilcox Group, the Carrizo Sand, the Reklaw Formation, and the Queen City Sand, all of Eocene age. These units are, for the most part, hydraulically interconnected and generally function as a single aquifer; the aquifer is herein referred to as the Cypress aquifer. The aquifer, which thickens from about 200 feet along the eastern border of Harrison County to about 900 feet in the southwest corner of the county, consists principally of lenticular beds of sand, silt, and clay. The outcrop area of the Cypress aquifer includes practically all of the land surface area of Harrison County.

The Cypress aquifer contains a large quantity of fresh to slightly saline water in storage--the upper 400 feet of the aquifer contains an estimated 17 million acre-feet of water that can be developed economically.

The aquifer is recharged mainly from the rather heavy precipitation which falls on the county. At least 55,000 acre-feet (49.1 mgd), and perhaps significantly more, is available annually for development without depleting the aquifer. Of this total, at least 40,000 acre-feet (35.7 mgd), which might be salvaged, is rejected to streams from the outcrop of the aquifer. Salvage of a sizeable percentage of this water would require a large number of closely spaced small-capacity wells.

The ground-water supplies in Harrison County are virtually untapped. Of the 34 million acre-feet of ground water in transient storage, only about 2,700 acre-feet was pumped from the Cypress aquifer in 1964. Obviously, the present rate of ground-water withdrawal could be increased substantially.

The water in the aquifer generally is fresh (less than 1,000 parts per million dissolved solids) although in the deeper part of the aquifer the water

The northern one-half of the county is drained by Cypress Creek and its tributaries, and the southern half is drained by the Sabine River. The drainage divide trends roughly eastward through Marshall, thence southeastward.

Continuous records of streamflow on any stream within or bordering the county are scarce. The U.S. Army Corps of Engineers maintained a stream-gaging station near Jefferson on Little Cypress Creek (Figure 11) from 1946 to 1964 when the station was abandoned. The U.S. Geological Survey established a gaging station at approximately the same location in 1963. The combined streamflow records dating from 1946 through 1964 show an average annual discharge of Little Cypress Creek, with a drainage area of 675 square miles, to be 546 cfs (cubic feet per second) or about 394,000 acre-feet per year. For the period of record, the lowest average monthly flow (48.7 cfs) occurs in August, and the highest average monthly flow (1,258 cfs) in May.

The character of the precipitation and runoff and the favorable topography make feasible rather extensive development of the surface-water resources of Harrison County. As of January 1, 1965, approximately 4,000 small reservoirs, from $\frac{1}{2}$ acre to 40 acres in size, have been constructed principally for livestock water supplies. Several large-capacity reservoirs have been constructed for industrial and recreational uses.

Records of the U.S. Weather Bureau at Marshall, dating from 1933, show that the normal annual precipitation at Marshall is 46.96 inches, and the normal monthly precipitation, in inches, is:

Jan.	4.75	May	5.25	Sept.	2.70
Feb.	4.01	June	3.18	Oct.	3.01
Mar.	4.40	July	3.28	Nov.	4.41
Apr.	4.43	Aug.	2.53	Dec.	5.01

The normal January temperature is 47.1°F, and the normal July temperature is 83.8°F. The average date of the first killing frost is November 12 and the last is March 19. The mean annual growing season is 238 days. In Thornthwaite's (1952, p. 25-35, fig. 30) classification of the climate, Harrison County is humid.

Population and Economy

According to the U.S. Bureau of the Census, Harrison County had a population of 45,594 in 1960. The populations in 1960 of the principal cities and communities are: Marshall, 24,900 (1964 estimate); Waskom, 1,336; Karnack, 700; Hallsville, 684; Harleton, 300; Scottsville, 260; Elysian Fields, 250; and Uncertain, 200.

The economy of Harrison County is based principally on industry and agriculture. The principal industries are concerned with the production, processing, and distribution of oil and gas. Other industries of significance include: the mining of lignite, and production of activated carbon (Atlas Chemical Industries, Inc.); the mining of clay, and production of brick and pottery; and the production of solid-fuel rocket motors (Thiokol Chemical Corp. under the facilities of the Longhorn Army Ammunition Plant). Also, timber cutting and the production of wood products contribute significantly to the economy of Harrison County.

The raising of beef cattle, which has increased during recent years, has become the most important part of the agricultural economy. Resulting increases have therefore occurred in the production of feed crops (such as corn, grain sorghum, and hay), and in the conversion of timbered areas and row croplands to pasture. Dairying is followed in importance by poultry and swine production. The raising of cotton, vegetables, nuts, and fruits is likewise important locally.

Previous Investigations

Detailed studies of the ground-water resources of Harrison County have not been made prior to this investigation. Broadhurst and White (1942) discussed the water supplies available in the southwest corner of Harrison County. The water resources of Harrison County were described by Broadhurst and Breeding (1943). The report included a chapter on the supply of surface water available in the county from the Sabine River and Little Cypress Creek as well as the records of wells and springs, drillers' logs of selected wells, and the results of chemical analyses of water from wells and springs. The public water supplies of Hallsville, Karnack, Marshall, and Waskom were included in an inventory of the public water supplies in eastern Texas by Sundstrom, Hastings, and Broadhurst (1948, p. 150-154). A reconnaissance report on the ground-water resources of the Red River, Sulphur River, and Cypress Creek basins by E. T. Baker and others (1963), and one on the Sabine River basin by B. B. Baker and others (1963), contain information on Harrison County.

Well-Numbering System

The well-numbering system used in this report is one adopted by the Texas Water Development Board 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 prefix for Harrison County is LK. All of Harrison County falls within the 1-degree quadrangle 35. So the first two digits of all well numbers in the county is 35. Harrison County covers all or part of twenty-one 7½-minute quadrangles. On the well-location map of this report (Figure 11), the 7½-minute quadrangles are numbered in the northwest corner of each quadrangle. The 3-digit number shown at each well is the number of the 2½-minute quadrangle in which the well is located and the number of the well within the quadrangle.

Thus, well LK-35-30-701 (a standby industrial well at Marshall) is in Harrison County (LK), in the 1-degree quadrangle number (35), in the 7½-minute quadrangle (30), in the 2½-minute quadrangle (7), and was the first well (01) inventoried in that 2½-minute quadrangle.

GEOLOGY AS RELATED TO THE AVAILABILITY OF GROUND WATER

The geologic units pertinent to the ground water in the report area range in age from Paleocene to Recent. Their thickness, lithology, age, and water-bearing properties are summarized in Table 1. The geologic units crop out in belts that trend generally northeasterly across Harrison County and into adjacent counties (Figure 2).

The report area lies on the northwest flank of the Sabine Uplift, which crests along the Texas-Louisiana border. Consequently, the geologic units, except the Quaternary deposits, generally dip and thicken northwest toward the axis of the East Texas basin in contrast to the eastward slope of the land surface.

The availability of ground water in Harrison County is dependent entirely on the hydrologic characteristics of the geologic units overlying the Midway Group--chiefly those units which, in ascending order, comprise the Wilcox Group, the Carrizo Sand, the Reklaw Formation, and the Queen City Sand.

Following, in ascending order, are the Weches Greensand and the Sparta Sand, which occur only as outliers capping several ridges in the northwestern part of the county. These units, as well as the Quaternary terrace and alluvial materials which occur along and in the major stream flood plains of the county, provide only small quantities of fresh water to a few shallow wells. Consequently, the following discussions are devoted principally to those units--the Wilcox Group, Carrizo Sand, Reklaw Formation, and Queen City Sand--that furnish nearly all the ground water pumped in the county.

The Wilcox Group crops out over a large part of the eastern half of Harrison County (Figure 2). The group has a maximum thickness of about 700 feet and consists mostly of fine to medium sand interbedded with considerable amounts of clay and seams of lignite. Thick sand beds are present locally; however, the individual sand beds are not continuous, and therefore are difficult to correlate between wells, even wells a short distance apart. Thin beds of limonite are common on the surface. The Wilcox yields small (less than 50 gallons per minute) to moderate (50 to 500 gallons per minute) quantities of fresh water (less than 1,000 parts per million dissolved solids) to wells throughout the county. For practical purposes, the base of the Wilcox is approximately the base of fresh water, although slightly saline water (1,000 to 3,000 parts per million dissolved solids) can be obtained in the deeper parts of the aquifer.

The Carrizo Sand crops out in a narrow crescent-shaped belt across the east-central and southern parts of the county (Figure 2). The Carrizo has a maximum thickness of about 100 feet and consists chiefly of fine to medium sand, silt, and clay. In general, the Carrizo is difficult to distinguish from sand of the Wilcox Group below and the Reklaw Formation above. Where wells are known to tap the Carrizo, it yields small to moderate quantities of fresh to slightly saline water.

The Reklaw Formation crops out in a belt of variable width adjoining the outcrop of the Carrizo Sand on the west and northwest (Figure 2). The formation consists of clay and fine glauconitic and quartzitic sand, locally cross-bedded; thin beds of limonite are common in the outcrop. The Reklaw has a maximum thickness of about 100 feet and is capable of furnishing at least small amounts of fresh to slightly saline water to wells in the outcrop area.

Table 1.--Geologic units and their water-bearing properties, Harrison County

System	Series	Group	Unit	Approximate maximum thickness (feet)	Character of rocks	Water-bearing properties
Quaternary	Recent and Pleistocene		Alluvium and terrace deposits (undivided)	50	Predominantly clay, silt, and fine sand. Terrace material locally fine to coarse sand.	Yields small quantities of water to a few wells
Tertiary	Eocene	Claiborne	Sparta Sand	25	Fine sand and sandy clay. Limonitic ironstone seams common in outcrop area.	Do.
			Weches Greensand	50	Fine to medium sand, glauconitic and quartzitic, laminar to cross-bedded. Limonitic ironstone seams and concretions common in outcrop area.	Do.
			Queen City Sand	200	Very fine to medium sand, quartzitic, interbedded with silt and clay, laminar to cross-bedded. Contains minor amounts of lignite. Limonitic ironstone seams common in outcrop area	Cypress aquifer
			Reklaw Formation	100	Clay and fine sand, glauconitic and quartzitic, mostly laminar but locally cross-bedded. Locally contains marine fossils. Limonitic ironstone seams common in outcrop area.	
			Carrizo Sand	100	Fine to medium sand interbedded with silt and clay. Laminar to cross-bedded. Limonitic ironstone seams common in outcrop area.	
		Wilcox		700	Fine to medium sand interbedded with considerable amounts of clay. Commonly contains seams of lignite. Limonitic ironstone seams common in outcrop area.	
	Paleocene	Midway		900	Predominantly marine clay; becomes silty in upper part.	Not known to yield fresh water in Harrison County.

The Queen City Sand crops out in a large part of the northwestern quarter of the county (Figure 2) and consists of very fine to medium sand interbedded with silt and clay and impure lignite. Limonite forms on the weathered outcrops of the Queen City. The sand is typically lenticular and cross-bedded. The Queen City has a maximum thickness of about 200 feet and yields moderate quantities of fresh to slightly saline water to wells.

CYPRESS AQUIFER

General Physical Features

An aquifer is defined as a geologic formation, group of formations, or a part of a formation that is water bearing. In the report area, the Wilcox Group, Carrizo Sand, Reklaw Formation, and Queen City Sand are, for the most part, hydraulically interconnected and generally function as a single aquifer. The aquifer is herein referred to as the Cypress aquifer and is approximately equivalent to the Cypress aquifer in Camp, Franklin, Morris, and Titus Counties as defined by Broom and Alexander (1965, p. 23-24).

The outcrop of the Cypress aquifer in Harrison County includes about 900 square miles, or nearly all the land surface of Harrison County. The thickness of the Cypress aquifer ranges from about 200 feet along the eastern boundary of the county to about 900 feet in the southwestern part of the county. The base of the aquifer, which also is the base of the Wilcox Group and approximately the base of fresh water, slopes westward, ranging from an altitude of 193 feet above sea level in the east-central part of the county to more than 750 feet below sea level in the northwest corner of the county (Figure 3).

The rock materials comprising the Cypress aquifer, particularly the sand and clay, are not uniformly distributed laterally or vertically; thus, correlation of individual sand and clay beds from well to well is difficult. In general, the beds are lenticular, the lenses of clay, sand, and silt pinching out, coalescing, or grading into each other within short distances. The range in thickness of individual beds and the discontinuity of the beds are shown on the geologic sections (Figure 4), which were constructed from electric logs. On the logs, the sand beds are represented by high resistivities and the clay and silt beds by low resistivities.

Source and Occurrence of Ground Water

The source of ground water in the Cypress aquifer is precipitation on the outcrop of the aquifer in Harrison County. 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 percolates downward by gravity through the zone of aeration to the zone of saturation (or the level at which all the voids or pore spaces are saturated).

Ground water occurs under unconfined or water-table conditions and confined or artesian conditions. 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 outcrop area of the geologic units that comprise the Cypress aquifer.

Confined or artesian water occurs where an aquifer is overlain by rocks of lower permeability, such as clay, that confines the water under a pressure greater than that of the atmosphere. Such artesian conditions occur generally downdip from the outcrop of the geologic units of the Cypress aquifer. A well penetrating sands under artesian pressure becomes filled with water to a level above the base of the confining 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. 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 area of the aquifer, the piezometric surface, as used in this report, is applicable only in the artesian area.

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 watercourse, and from the infiltration of water from streams or lakes. Artificial recharge processes include infiltration of irrigation water, industrial waste water, or sewage. Improperly treated waste water and sewage may pollute the supply of fresh ground water, especially at shallow depths.

Among the more important factors governing the rate of natural recharge are 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. 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 the 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.

Although the quantity of recharge to the Cypress aquifer has not been determined, an estimate of the minimum figure available 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, some of the water that 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 low flow of Little Cypress Creek (tributary to Cypress Creek) measured at two gaging stations, one near Ore City in Gregg County and the other near Jefferson in Harrison County (Figure 11), and on the basis of a low-flow investigation of Potters Creek (tributary to the Sabine River), the volume of flow contributed to the streams by rejected recharge is about 40,000 acre-feet per year or 35.7 mgd (million gallons per day). This figure is conservative because it does not include the water that has been consumed by evapotranspiration. The quantity of water that becomes recharge can be estimated knowing the transmissibility of the aquifer and the approximate hydraulic gradient. On the basis of estimates of these values, the quantity moving through the aquifer under the present gradient (5 feet per mile) is approximately 15,000 acre-feet per year, or 13.4 mgd.

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 horizontal component in the direction of decreasing pressure (or head). The movement is, however, 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 general direction of movement as well as the hydraulic gradient of the water in the Cypress aquifer in the report area are shown by a contour map (Figure 5) of the piezometric surface. The map does not reflect the altitude of water levels in a particular geologic unit comprising the aquifer, but rather a composite of the water levels of the units tapped. Thus, the water level at any particular location may be somewhat different than that shown on the map. The movement, which is at right angles to the contours, generally is toward the major streams. According to the contours, the ground water moves outwardly from a mound at Marshall. In the western part of the county, some water moves eastward to a trough that trends northeast through Hallsville; thence the water moves northward to Cypress Creek and southward to the Sabine River.

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 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 40,000 acre-feet per year, or 35.7 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 2,700 acre-feet in 1964.

Hydraulic Characteristics

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). 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 that part of the aquifer tapped by the well (the screened interval in Table 2). The wells tested in Harrison County did not penetrate the entire thickness of the water-bearing unit; thus they do not reflect the true transmissibility of the aquifer.

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. 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. When 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 approximately the same as the specific yield.

The yield or discharge rate of a well usually is measured in gallons per minute (gpm), gallons per hour, or gallons per day (gpd). The 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, is of value in estimating the probable yield of a well.

Aquifer tests were made in five 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 2. The data from the tests were analyzed using

Table 2.--Results of aquifer tests in Harrison County

Well	Screened interval (feet)	Average discharge during test (gpm)	Coefficient of trans- missibility (gpd/ft)	Specific capacity (gpm/ft)	Remarks
LK-35-22-706	272 - 316	20	1,900	1.1	Drawdown of pumped well.
LK-35-23-801	186 - 287	100	1,700	1.0	Recovery of pumped well; test by Layne-Texas Co.
LK-35-28-804	195 - 235	80	1,300	3.0	Drawdown of pumped well.
		--	1,300	--	Recovery of pumped well.
LK-35-37-803	191 - 207 226 - 241 367 - 394	170	4,200	1.8	Drawdown of pumped well.
LK-35-39-304	181 - 247	45	5,500	1.9	Drawdown of pumped well.
		--	4,300	--	Recovery of pumped well.

the Theis nonequilibrium method as modified by Cooper and Jacob (1946, p. 526-534) and the Theis recovery method (Wenzel, 1942, p. 94-97). The coefficients of transmissibility ranged from 1,300 to 5,500 gpd per foot, discharge rates ranged from 20 to 170 gpm, and specific capacities ranged from 1.0 to 3.0 gpm per foot of drawdown. Where the full thickness of the aquifer is available, the coefficient of transmissibility probably is about 8,200 gpd per foot.

The coefficients of transmissibility and storage may be used to predict the future drawdown of water levels caused by pumping. Figure 6 shows the relation of drawdown to 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 8,200 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 the drawdown would be 1.5 feet after 30 days of pumping, 9.5 feet after 1 year, and about 19 feet after 10 years.

The storage coefficient of 0.10 used in the preparation of Figure 6 is a water-table-storage coefficient. This graph should be used in predicting the long-term effects of pumping from wells in the area or for predicting the effects of short-term pumping in shallow wells where water-table conditions clearly prevail. Although artesian conditions prevail in the deep wells, with long continuous pumping the aquifer is expected ultimately to perform as a water-table aquifer. Therefore, in the long-range predictions, the values shown on Figure 6 should be used. For predicting the effects of short-term pumping from deep wells, Figure 7 has been prepared showing the relation of drawdown to 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 the drawdown would be 26 feet after 30 days of pumping, 36 feet after 1 year of pumping, and 46 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

The use of ground water from the Cypress aquifer in Harrison County in 1964 was 2.4 mgd or 2,700 acre-feet (Table 3). Domestic use was about 40 percent of the total, industrial use about 36 percent, livestock use about 14 percent, public supply 10 percent, and irrigation about 1 percent.

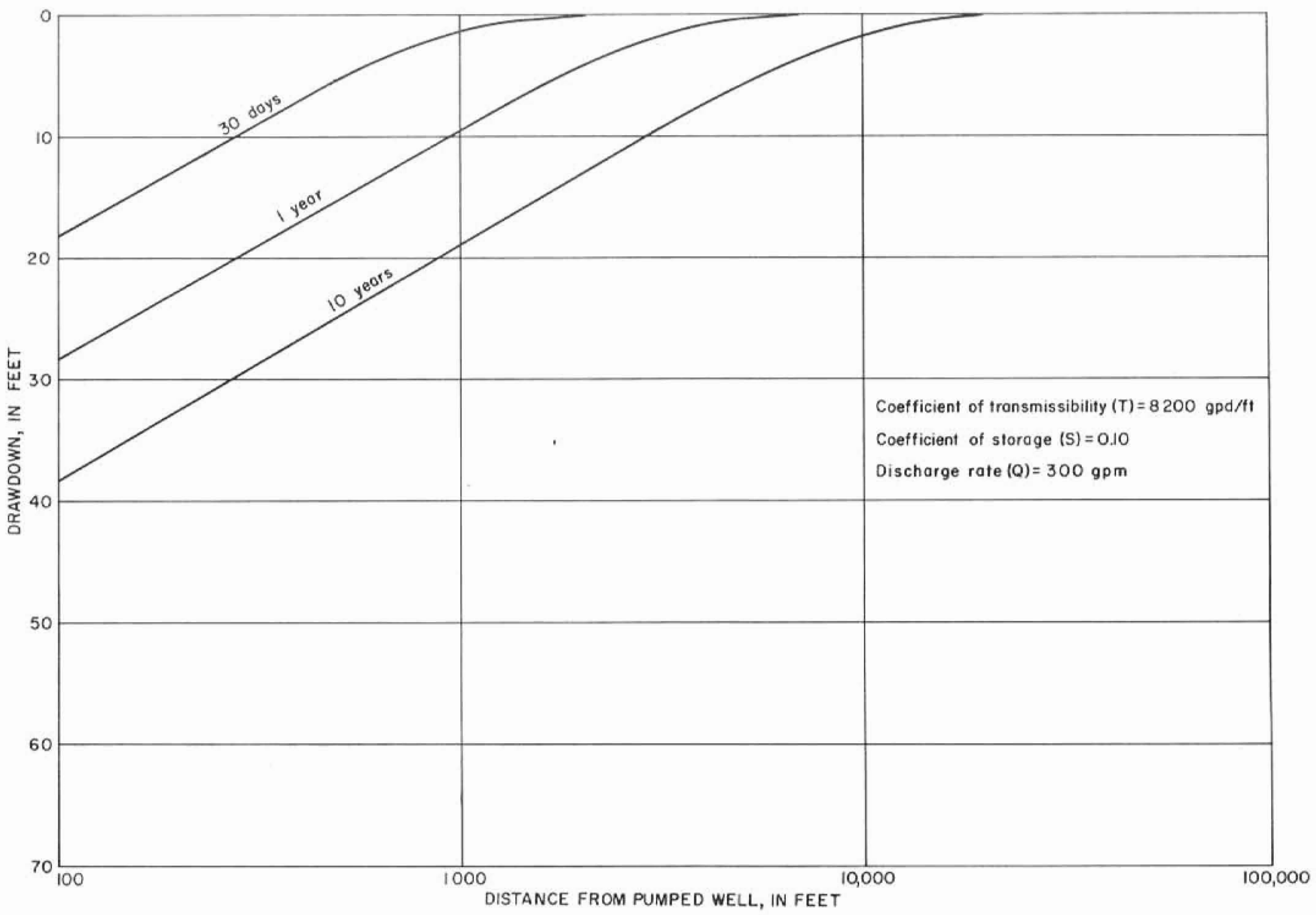


Figure 6

Relation of Drawdown to Distance and Time as a Result of Pumping Under Water-Table Conditions

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Harrison County Commissioners Court

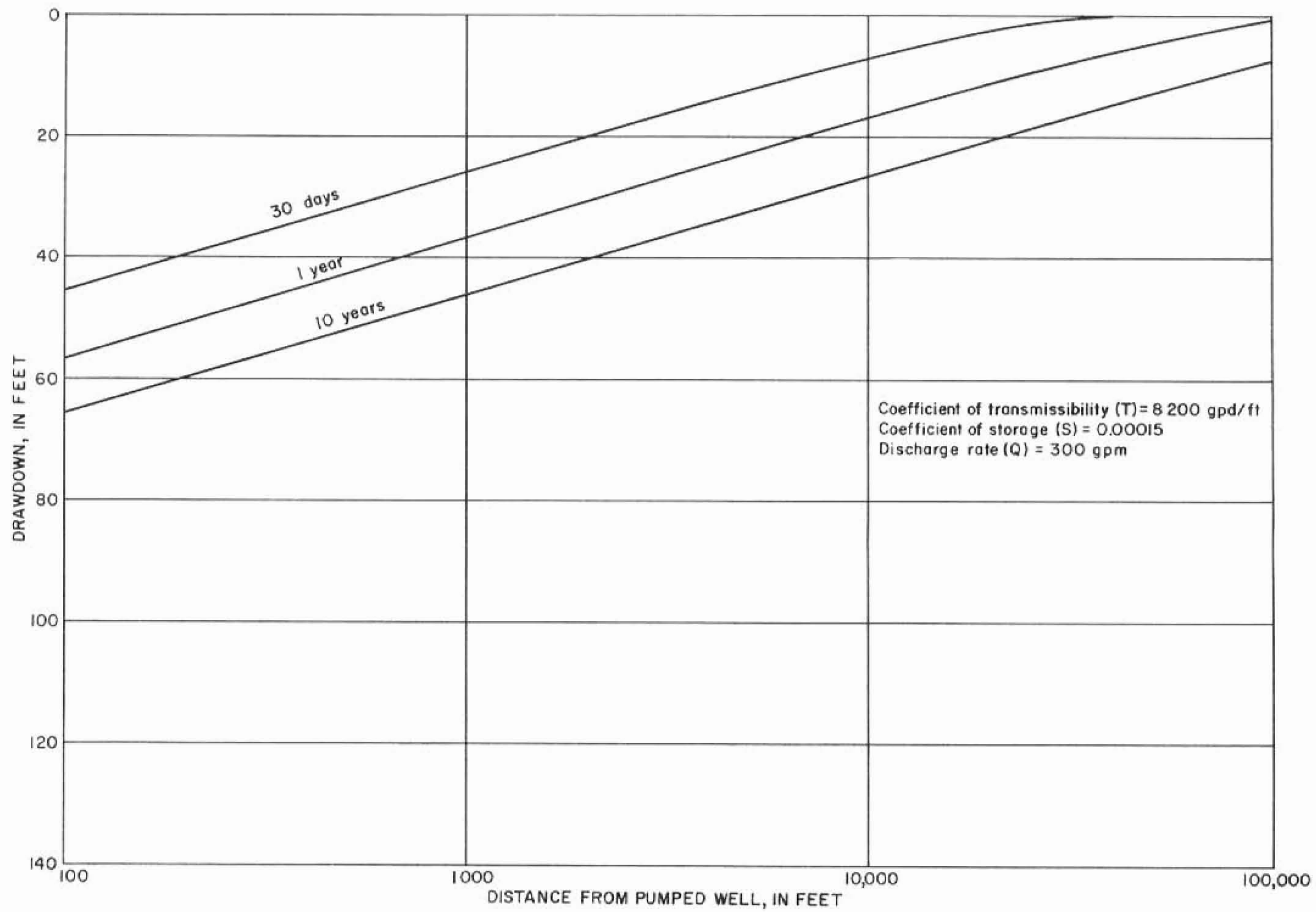


Figure 7

Relation of Drawdown to Distance and Time as a Result of Pumping Under Artesian Conditions

U.S. Geological Survey in cooperation with the Texas Water Development Board
and the Harrison County Commissioners Court

Table 3.--Use of ground water from the Cypress aquifer in Harrison County, 1964

Use	Million gallons per day	Acre-feet per year
Public Supply	0.24	269
Industrial	.86	964
Domestic	.97	1,087
Livestock	.34	381
Total*	2.4	2,700

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

Water for domestic and livestock uses was obtained from approximately 4,000 wells, of which about 3,000 were less than 50 feet deep. Water for industrial use was obtained from 22 wells ranging in depth from 158 to 850 feet. The yields of these wells ranged from about 20 to 250 gpm. Practically all of the industrial water was pumped by the petroleum industries; about 0.52 mgd, or 60 percent, was for repressuring oil reservoirs, and about 0.34 mgd, or about 40 percent, served cooling and other industrial purposes.

Water for public supply was obtained principally from six wells in the following cities:

City	No. of wells	Screened intervals	Yield (gpm)	Average pumpage (mgd) in 1964
Hallsville	3	205 - 245	80 - 100	0.10
Karnack	1	287	100	.02
Waskom	2	150 - 151	25 - 133	.12

The water needs for Elysian Fields, Harleton, Scottsville, and Woodlawn are obtained largely from small capacity domestic wells which are privately or cooperatively owned; a small part of the population is supplied from wells owned by oil companies.

In 1964, only one well (LK-35-31-703) was used for irrigation. The well (yield about 200 gpm) pumped slightly more than 20 acre-feet of water. The quantity of water pumped for irrigation of lawns and small gardens has been included in the water used for domestic purposes (Table 3).

Prior to 1949, relatively large amounts of ground water for municipal and industrial use were pumped by wells in and near Marshall. According to Broadhurst and Breeding (1943, p. 9), Marshall pumped about 1 mgd from 10 wells, six of which were about 3 miles northeast of the city. The depth of the wells ranged from 200 to 300 feet and the yields from 88 to 145 gpm. The rest of the wells were in the city limits. The depths of these wells ranged from 351 to 473 feet and the yields from 145 to 210 gpm.

Industry, principally the Darco Corp. (now the Atlas Chemical Industries, Inc.) reportedly pumped about 400,000 gpd from seven wells on the western edge of Marshall. The depth of the wells ranged from 50 to 248 feet, and the yields ranged from 22 to 133 gpm.

In 1949, Marshall abandoned its wells and since then has supplied its water needs as well as those of several industries from Caddo Lake. In 1964, Marshall used 4.1 mgd, or 4,600 acre-feet, almost twice the quantity of ground water pumped for all purposes in Harrison County in 1964.

Construction of Wells

About 75 percent of the estimated 4,000 water wells in Harrison County are less than 50 feet deep. These shallow wells tap the Cypress aquifer and supply most of the ground water for rural domestic and livestock needs. Generally, the older wells were dug and curbed with native ironstone or with brick; diameters ranged from 3 to 4 feet. Most of the newer wells are excavated by bucket-type power augers to depths ranging from 20 to 50 feet, and are curbed with 3-foot lengths of 30-inch-diameter cement tile. These shallow wells generally are equipped with water-jet, cylinder, or centrifugal pumps which are operated by electric motors of 1/4 to 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, the deeper drilled and steel-cased wells for domestic and livestock use were rather uncommon in Harrison County. By 1964, however, almost 1,000 had been drilled by the hydraulic rotary method to depths ranging generally from 150 to 500 feet. A typical drilled domestic well is cased with a 4-inch-diameter steel pipe which is set at depths ranging from 200 to 300 feet. The annular space between the casing and wall is cemented, and then the well is drilled to the production interval. The method of completing the production interval varies, but both open-hole and screened production intervals are common. The trend in well construction is toward the use of screen and gravel pack in the production interval. The wells are equipped generally with water-jet, cylinder, or submersible pumps which are operated by electric motors of 1/2 to 1 horsepower. Lifts seldom exceed 100 feet. The pumps have capacities ranging from 5 to 10 gpm.

Well LK-35-28-803 (city of Hallsville) is typical of the construction of wells for municipal and industrial uses in Harrison County. The well site was selected from data provided by bit cuttings, drillers' logs, and electric logs of two test holes. The water-well test hole was drilled to 613 feet, although the drillers' log (Table 6) and the electric log indicated that the better water sands existed from about 162 to 200 feet. Briefly, the construction of the well is listed on the following page.

(1) The well was reamed to 160 feet and cased with 10-3/4-inch surface casing.

(2) The space between the surface casing and wall of the well was filled with cement under hydraulic pressure.

(3) The production interval was drilled to 205 feet and underreamed to a hole 26 inches in diameter that extended from the bottom of the casing to the bottom of the well.

(4) A total of 205 feet of 6-5/8-inch blank liner and screen was lowered to the bottom of the well; the screen (35 feet in length) was positioned opposite the water sands when the liner reached the bottom of the well.

(5) The space between the wall of the well and the blank liner and screen was filled with small-size gravel.

(6) The drilling mud was washed from the well and a preliminary production test was made on April 9, 1939. After pumping at 90 gpm, the drawdown was 35 feet--a specific capacity of 2.5 gpm per foot of drawdown.

Water Levels

Records of measurements of water levels in Harrison County are given in Table 5. Where water-table conditions prevail, the depths to water range from less than 5 to about 75 feet, but seldom exceed 30 feet except in hilly areas of relatively sharp relief. A comparison of the 1964 measurements with those of Broadhurst and Breeding (1943) indicates no general decline of water levels in the shallow wells (water-table conditions). The records do indicate seasonal fluctuations ranging from about 5 to 10 feet per year in response to rainfall. Well owners report, however, that in extended drought years such as the early 1950's, the water levels fluctuated over an even greater range.

Records of water-level fluctuations in wells tapping the deeper sands (artesian conditions) generally are too meager for comparative purposes. However, the available data indicate that in those wells that formerly supplied the water needs of Marshall, the water level declined approximately 15 feet per year until abandoned; whereas, in the wells supplying the needs of Hallsville, the water levels declined only about 2 feet per year.

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 content of ground water increases with depth. The temperature of ground water near the land surface is about the same as the mean air temperature of the region and increases with depth. The laboratory analyses of water from 130 wells and 1 spring tapping the Cypress aquifer are given in Table 7. Field determinations of iron, pH, and hardness of 61 samples from the Cypress aquifer are given in Table 8. Temperatures of most of the water samples are given in Table 5.

The major factors that determine the suitability of a water supply are the limitations imposed by the contemplated use of the water. The various criteria of water-quality requirements which have thus been developed 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 is given in Table 4. The source and significance of dissolved-mineral constituents and properties of water summarized in Table 4 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, in a public water supply the chemical constituents should not be present in excess of the listed concentrations shown in Table 4, except where other more suitable supplies are not available. When fluoride is naturally present in drinking water, the concentration should not average more than 1.0 ppm (parts per million), the appropriate upper limit based on the average maximum daily air temperature (67.1°F) at Marshall.

Water samples from 99 wells tapping the Cypress aquifer were analyzed for fluoride. Ninety-one wells, ranging in depth from 6 to 850 feet, contained 0.0 to 0.9 ppm. One well, 26 feet deep, contained 1.2 ppm and 7 wells, 200 to 500 feet deep, contained 1.1 to 2.4 ppm.

Water samples from 125 wells tapping the Cypress aquifer at depths ranging from 16 to 850 feet were analyzed for nitrate. A few of the shallow wells contained high concentrations of nitrate, one as much as 156 ppm, but most wells, including all those more than 35 feet deep, contained less than 20 ppm. The data indicate that the water of the Cypress aquifer is normally low in nitrate, but that some of the shallow wells were being polluted with human or animal wastes from surface sources.

Water having a chloride content exceeding 250 ppm may have a salty taste. The chloride content of 130 wells tapping the Cypress aquifer ranged from 1 to 760 ppm; in 87 samples, or 67 percent of the wells sampled, less than 50 ppm; and in 9 samples, or about 7 percent, more than 250 ppm. The wells ranged in depth from 6 to 850 feet. The samples containing more than 250 ppm indicated no general pattern of occurrence within the Cypress aquifer.

Sulfate in water in excess of 250 ppm may produce a laxative effect. Only 1 of 130 wells ranging in depth from 6 to 850 feet yielded water containing more than 250 ppm of sulfate. This well (LK-35-37-601) yielded water with a sulfate content of 899 ppm and is one of three shallow wells (6 feet deep) dug at a site known locally as Roseborough Springs. The water is used for medicinal purposes. In general, about 50 percent of the wells sampled contained 10 or less ppm of sulfate. Also, the larger sulfate content was found in wells which tapped the Cypress aquifer at depths ranging from about 100 to 300 feet.

Hardness in water was determined in samples from 130 wells by laboratory analysis and in 37 wells by field determination. The wells tapped the Cypress aquifer from depths of 6 to 850 feet. Hardness ranged from 0 to 959 ppm, but approximately 70 percent of the water samples showed a hardness of less than 50 ppm. Only about 5 percent of the samples indicated a hardness of more than 200 ppm. Hardness in excess of 200 ppm was found in water from a few shallow dug wells, which might be classified as "seep" wells, that did not have the yielding capacity to support an electric pump. In general, however, very hard water was obtained from wells that ranged in depth from about 100 to 300 feet. The

Table 4.--Source and significence 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 stains 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.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, fluoride may cause mottling of teeth, depending on the concentration, the age of the child, amount of drinking water consumed, and susceptibility of the individual. (Maier, F. J., 1950.) On the basis of average maximum daily air temperature at Marshall, fluoride should not exceed 1.0 ppm.
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. Nitrate also 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 noncarbonate 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: $RSC = (CO_3 + HCO_3) - (Ca + Mg)$ 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. The 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.

locations and depths of selected wells in the county and the hardness of water from the wells are shown in Figure 8.

Water used for industry may be classified as process water, cooling water, or 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 water 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. In boiler water the presence of silica 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 56 wells ranging in depth from 101 to 850 feet was 3.5 to 57 ppm. Thirty-six (about 65 percent) of the samples had a silica content of less than 20 ppm. Only 4 samples contained more than 40 ppm silica.

Iron in excessive concentrations is characteristic of the water from wells in the Cypress aquifer; in fact, the iron content is the most important factor in determining the suitability of the water for public supply and for many domestic and industrial uses. For the convenience of the reader, therefore, iron and the principal chemical factors controlling the solution of iron in the Cypress aquifer are discussed separately in the section on "Iron Water" in this report.

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 (specific conductance, Table 4) of the water and the sodium hazard as measured by the SAR (sodium-adsorption ratio). 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 effect 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." Furthermore, 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 48 wells tapping the Cypress aquifer from depths of 30 to 850 feet ranged from 0.3 to 70, and the conductivities ranged from 142 to 3,170 micromhos (Table 7). The data do not indicate a definite relation between the depth of the well and the SAR value of the water. Of 16 wells yielding water having SAR values of less than 10, the depths ranged from 30 to 411 feet; of 10 wells having SAR values of 10 to 20, depths ranged from 135 to 310 feet; of 8 wells having SAR values of 20 to 30, depths ranged from 205 to 850 feet; and of 14 wells having SAR values exceeding 30, depths ranged from 200 to 600 feet.

Another factor used in assessing the quality of water for irrigation is the RSC (residual sodium carbonate, Table 4) 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 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. Nevertheless, good irrigation practices and proper use of soil amendments might make possible the successful use of the marginal water 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 48 samples from wells tapping the Cypress aquifer at depths of 36 to 850 feet ranged from 0.0 to 11.6 epm (Table 7). Of 8 wells yielding water with RSC values of 0.0 to 1.25 epm, depths ranged from 36 to 411 feet; of 7 wells with RSC values of 1.25 to 2.50, depths ranged from 140 to 410 feet; of 33 wells with RSC values of 2.5 to 11.6, depths ranged from 95 to 850 feet.

On the basis of both SAR and RSC values, most of the water from the aquifer generally would be considered as undesirable for irrigation. On the other hand, because of the relatively high rainfall, the sandy soil, and the topographic relief in Harrison County, most of the water from the Cypress aquifer could be used probably for supplementary irrigation without serious detriment to the soils.

Boron (Table 4) does not seem to be a significant problem in water from the Cypress aquifer. The boron content of water from 22 wells ranged from 0.03 to 1.0 ppm; water from more than 50 percent of the wells contained less than 0.5 ppm boron.

Contamination of Ground Water in Areas of Oil- and Gas-Field Operations

The disposal of oil-field brines into unlined surface pits is a potential source of contamination of the ground water in Harrison County. The brine in the pit seeps into the ground and, over a period of time, may contaminate the water in the Cypress aquifer. The time required for the brine to affect the quality of water in nearby wells may vary considerably, depending upon the permeability of the soil and the rate of movement of the brine. The process may take several years or only a few months. Generally, contamination of the water is indicated by a significant increase in the salinity of the water, principally in the chloride content without an accompanying increase in the sulfate content. Once the source of contamination has been eliminated, purification, principally by leaching and dilution, may require a considerably longer time than the period of original pollution.

According to a salt-water disposal inventory by the Texas Water Commission and Texas Water Pollution Control Board (1963), 1,881,240 barrels (about 242 acre-feet, or 79 million gallons) of brine was produced in 1961 from the several oil fields in Harrison County. Of this total, 1,604,660 barrels or 85 percent of the total was disposed through injection wells, 216,156 barrels or 11 percent in open surface pits, 34,851 barrels or 2 percent by miscellaneous methods, 22,886 barrels or 1 percent by surface watercourses, and 2,687 barrels or 0.10 percent by unknown methods.

Another potential source of contamination is 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 Development Board has made recommendations to the oil operators concerning the depth 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. In general, the surface casing required in the field rules of the Railroad Commission, as of April 1964, is sufficient to protect the fresh to slightly saline water in the Cypress aquifer. However, in the northeast Hallsville field, casing is not required in the lower 150 feet of the aquifer.

No instances of contamination from brine pits or inadequate casing can be documented on the basis of the data collected. However, wells that supply the water needs of Waskom reportedly pumped water containing natural gas, indicating that at least in this area the fresh-water sands may be protected inadequately. Local residents report that gas in the water was noted during the development of the nearby gas field in the 1920's.

Iron Water

The following discussion is a summary of the chemical principles generally involved in the distribution of iron water in the Cypress aquifer. For more detailed discussions of the chemistry of iron in ground water and research on the subject, see Hem (1959, 1960a, and 1960b), and Hem and Cropper (1959).

Ground water commonly tends to have a low redox potential (Eh) and is chemically reducing because its dissolved oxygen has usually been depleted. In this redox environment iron is stable in the ferrous or reduced form. The oxidized or ferric form is stable in solutions in contact with air, but unless the pH is below about 5.0 this form will be almost entirely precipitated as ferric hydroxide. Relatively large amounts of ferrous iron can be retained in ground water, although if enough bicarbonate or sulfide ions are present the iron may be partly precipitated as ferrous sulfide or carbonate (Written communication, Hem, Oct. 1964). In general, decreasing the pH, the Eh, and the concentrations of bicarbonate or sulfide tends to increase the solubility of iron. Thus three factors--(1) reducing-oxidizing conditions (Eh), (2) degree of acidity or alkalinity (pH), and (3) amount of bicarbonate present--largely determine when and where ground waters will take iron into solution and when and where this iron will be precipitated.

On the basis of the available iron and pH determinations (Tables 7 and 8) and the chemical principles usually involved in the solution and precipitation of iron in ground water, the Cypress aquifer can be divided generally into three zones, designated for the purposes of this report as A, B, and C (Figure 9).

Zone A extends from the land surface to approximately the base of the local surface drainage network. Thus, the thickness of the A zone ranges from a few feet along the major streams to 150 feet or more in the hilly areas of the county. In general, the water in zone A contains little or no iron; and pH values range from 4.5 to 6.5. In this zone much of the ground water moves freely from sandy recharge areas to springs and seeps along the larger streams, and some of the water moves downward into zone B. The water in zone A contains dissolved oxygen and carbon dioxide. Any iron in the water or in the rocks would be converted mostly to insoluble ferric hydroxide, as evidenced by the relative abundance of limonite exposed at the land surface. Although the water has little or no iron in solution, the carbon dioxide is sufficiently high to result in low pH values and to cause corrosion of iron casings, pumps, and pipes. On the basis of chemical activity, A is a zone of relatively intense oxidation.

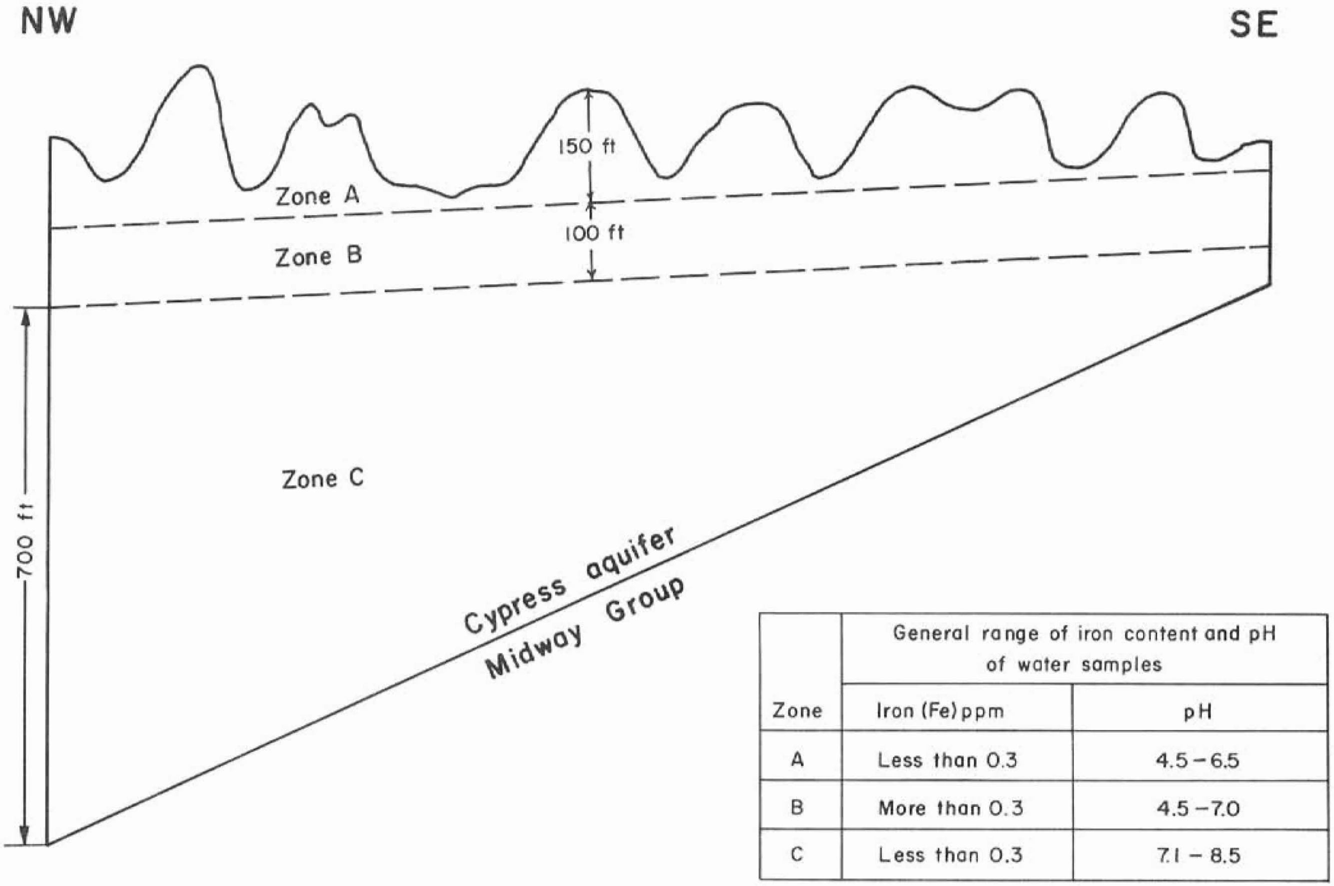
Zone B extends to a depth of about 100 feet below the base of zone A. Thus, from land surface and with respect to surface relief, the base of zone B will vary from a depth of about 100 feet along the major streams to 250 feet or more in the hilly areas of the county. The dissolved-iron content in the water in zone B ranges from 0.3 ppm to at least 59 ppm, and the pH from 4.5 to 7.0. On the basis of chemical activity, zone B is an intermediate zone of oxidation or a transitional zone from oxidizing to reducing conditions, unstable with respect to chemical equilibrium, where oxygenated and low pH water encounters a relatively reduced environment.

Zone C extends from the base of zone B to the bottom of the Cypress aquifer. The thickness of zone C ranges from about zero feet (locally in the eastern half of Harrison County) to about 700 feet in the northwestern part of the county. Generally the water in zone C contains less than 0.3 ppm iron, and pH values range from 7.1 to 8.5.

The locations and depths of selected wells in the county and the iron content of water from the wells are shown in Figure 8.

Guides for the Construction of Wells to Prevent Production of Iron Water

Shallow wells produce iron-free water if constructed to tap only freely circulating ground water in the A zone (Figure 9). Free circulation is necessary to maintain the oxidizing conditions, and the thickness of this zone of free circulation is greater beneath the hills and ridges than beneath the valley bottoms. Even very shallow wells in the valley bottoms are likely to penetrate the B zone and yield iron water. Shallow wells on the hills and ridges are likely to have a large fluctuation in water level and might possibly go dry during drought periods. As indicated previously, much of the



Zone	General range of iron content and pH of water samples	
	Iron (Fe) ppm	pH
A	Less than 0.3	4.5 – 6.5
B	More than 0.3	4.5 – 7.0
C	Less than 0.3	7.1 – 8.5

Figure 9

Relation Between pH and the Iron Content in Water in Zones A, B, and C in the Cypress Aquifer

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Harrison County Commissioners Court water produced from the shallow wells is sufficiently low in pH to cause corrosion of pipes and fixtures.

In most of Harrison County, deep wells can be constructed and developed to obtain iron-free water if four rules are followed: (1) set surface casing down to a clay bed or other relatively impervious rock below the B zone to minimize the downward movement of low-pH water through natural interconnections from the upper zones as the wells are pumped; (2) cement the full length of the surface casings--not only to prevent the downward movement of low-pH water along the casings from the upper zones as the wells are pumped, but also to retard corrosion of the surface casings in the upper zones of low-pH water; (3) set screens only in the C zone; and (4) pump wells at rates that allow pumping levels to stay well above the screens.

If the fourth rule is neglected, and the pumping levels are allowed to drop to the screens, iron will be released to solution by oxidation of the reduced iron minerals in the C zone. Along with the induced oxidation of the normally reduced iron minerals and the consequential release of iron to solution, the pH of the well waters will be lowered and oxidized iron will be precipitated on the screens, in the well columns, and in other water conduits of the well systems. Therefore, as the pumping levels draw near or drop to the well screens, the well waters can become increasingly high in dissolved iron and increasingly corrosive to the water conduits; also, the water conduits can be expected to become increasingly clogged with precipitated iron oxide. Although decreasing the pumping rates to raise the pumping levels above the screens should reverse the detrimental chemical trends, removal of the accumulated clogging material in the conduits probably would require further corrective action (such as treatment with acid).

AVAILABILITY OF GROUND WATER FOR FUTURE DEVELOPMENT

The availability of ground water for future development from the Cypress aquifer in Harrison County is dependent on several hydrologic, chemical-quality, and economic factors. The hydrologic factors of importance are the ability of the aquifer to store and transmit water and the rate of recharge to the aquifer. The most important chemical-quality factors are the low pH water in shallow wells (zone A), the high iron content in the water in zone B, and the predominantly high SAR and RSC values of water at various depths. Chloride may be a problem locally. The principal economic factor is the cost of the many wells that would be required to obtain large quantities of water.

The most important hydrologic factor is the low coefficient of transmissibility of the aquifer. Computations based on the saturated sand thickness (Figure 10) and a porosity factor of 30 percent indicate that approximately 34,000,000 acre-feet of water is in transient storage in Harrison County; however, only a part of this water is recoverable and available for development. If it is assumed that only the water in the upper 400 feet of the aquifer can be developed ecomomically and that these sands have a specific yield of 15 percent, then the amount of water available from storage would be about 17,000,000 acre-feet.

On the basis of the present hydraulic gradient (5 feet per mile), the aquifer would transmit annually on the order of 15,000 acre-feet, or 13.4 mgd. Also, at least 40,000 acre-feet or 35.7 mgd of potential recharge, which might be salvaged, is rejected to streams from the outcrop of the aquifer, and an unknown but probably large quantity is lost by evapotranspiration. Thus, at least 55,000 acre-feet (49.1 mgd), and perhaps significantly more, is perennially available for development without depleting the aquifer.

A considerable part of the 40,000 acre-feet of rejected recharge possibly could be salvaged by the installation of shallow wells throughout the recharge area; however, because of the low transmissibility, the wells would necessarily be closely spaced in order to capture a significant part of the water before it is discharged into the streams. Although salvage of a large part of this rejected recharge probably would not be practical, the present rate of ground-water withdrawal (2,700 acre-feet per year or 2.4 mgd) could be increased several times.

In general, the total thickness of the sands in the Cypress aquifer (Figure 10) ranges from zero feet in the eastern part of the county to 475 feet in the northwestern part. Other factors being equal, the quantity of water available to a well increases as the saturated sands increase in thickness; thus, the quantity of water that can be pumped from a well should increase in a westerly direction. Also, the best area for potential development would be in the western and northwestern parts of the county.

Many small-capacity wells would be needed to develop fully the water resources of the Cypress aquifer in Harrison County because of the low coefficient of transmissibility. Consequently the cost of drilling and equipping these wells would principally determine the economic feasibility of developing ground water. Furthermore, the cost would be even greater if treatment of the water is required, particularly the maintaining of the dissolved-iron concentrations and pH values within acceptable limits.

Harrison County, being in a high-rainfall area, has little need for irrigation. Water for a limited amount of supplemental irrigation is available from the Cypress aquifer and could be used during periods of low rainfall. Continuous irrigation may be detrimental to the soil because of the relatively high SAR and RSC values.

REFERENCES CITED

Baker, B. B., Dillard, J. W., Souders, V. L., and Peckham, R. C., 1963, Reconnaissance investigation of the ground-water resources of the Sabine River basin, Texas: Texas Water Commission Bull. 6307, 57 p., 7 figs., 8 pls.

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.

Broadhurst, W. L., and Breeding, S. D., 1943, Water resources of Harrison County, Texas: Texas Board Water Engineers duplicated rept., 53 p., 3 figs.

Broadhurst, W. L., and White, W. N., 1942, Water supply near Woodall, in southwestern corner of Harrison County, Texas: U.S. Geol. Survey open-file rept., 42 p., 1 fig.

Broom, M. E., and Alexander, W. H., Jr., 1965, Ground-water resources of Camp, Franklin, Morris, and Titus Counties, Texas: Texas Water Commission Bull. 6517, 153 p., 13 figs., 3 pls.

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.

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

Eaton, F. M., 1950, Significance of carbonates in irrigation waters: Soil Sci., v. 59, p. 123-133.

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

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.

_____1960b, Some chemical relationships among sulfur species and dissolved ferrous iron, _in_ Chemistry of iron in natural water: U.S. Geol. Survey Water-Supply Paper 1459-C, p. 57-73.

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.

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

Meinzer, O. E., 1923, 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.

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

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 Dist. 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.

Univ. Texas, Bureau Economic Geology, 1964, Geologic atlas of Texas, Tyler sheet: Univ. Texas map.

U.S. Geological Survey, 1963, Surface water records of Texas, 1963: Water Resources Div. duplicated 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. Agriculture, Agr. Handbook 60, 160 p., 32 figs.

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. Agriculture Circ. 969, 19 p., 4 figs.

Wilcox, L. V., Blair, G. Y., and Bower, C. A., 1954, Effects of bicarbonate on suitability of water for irrigation: Soil Sci., 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.

Table 5.--Records of wells and springs in Harrison County

All wells are drilled unless otherwise noted in remarks column.

Water level : Reported water levels given in feet; measured water levels given in feet and tenths.

Method of lift and type of power : A, airlift; B, bucket; C, cylinder; Cf, centrifugal; E, electric; G, gasoline, butane, or Diesel engine; H, hand; J, jet; N, none; T, turbine. Number indicates horsepower.

Use of water : D, domestic; Ind, industrial; Irr, irrigation; N, none; P, public supply; S, stock.

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
*LK-35-11-801	Clinton Morrow	--	1956	25	30	345	20.3	July 1, 1964	B,H	D	Dug well, curbed with cement tile.
802	H. P. McGaughey well 1	-- Grelling, et al.	1951	7,940	--	329	--	--	--	--	Oil test. 1/
803	N. Satterwhite well 1	Sunray D-X Oil Co.	1962	3,902	--	315	--	--	--	--	Do.
† 901	S. Walker	--	1910	16	42	315	8.6 10.2 13.3	Jan. 29, 1942 Sept.28, 1960 July 1, 1964	B,H	D	Dug well, curbed with brick. Reported never goes dry. Temp. 56°F.
† 902	H. W. McCoy, Sr.	-- Ford	1957	101	4	300	49.1	July 1, 1964	J,E, 2	D,S	
903	-- McIntosh unit 1	-- Tipton, et al.	1963	3,955	--	349	--	--	--	--	Oil test. 1/
19-201	-- Treadwell well 1	do	1963	3,900	--	372	--	--	--	--	Do.
† 301	John Chadd Estate	--	--	39	36	360	27.1	Jan. 29, 1942	C,H	N	Dug well, curbed with cement tile. Old well.
302	J. A. Bounds	-- Tipton, et al.	1963	3,900	--	372	--	--	--	--	Oil test. 1/
† 501	A. D. L. Price	--	--	35	36	320	25.4 28.1	Jan. 29, 1942 Sept.29, 1960	J,E	D	Dug well, curbed with brick. Old well.
502	do	--	1963	310	4	320	69.5	July 1, 1964	N	D	
503	T. W. Davidson well 1	H. O. Gossett, Jr.	1960	3,769	--	315	--	--	--	--	Oil test. 1/
† 601	Morton Baptist Church	--	--	32	48	340	27.0 27.1 28.5	Jan. 29, 1942 Sept.29, 1960 July 2, 1964	J,E, 1/4	D	Dug well, curbed with concrete. Supplies water for church and rectory.
602	W. H. Newton well 1	Texas Eastern Transmission Corp., et al.	1960	3,820	--	330	--	--	--	--	Oil test. 1/
901	-- Bosch well 1	Sinclair Oil & Gas Co.	1957	7,665	--	--	--	--	--	--	Do.
20-101	-- Allen well 1	Placid Oil Co.	1947	8,000	--	320	--	--	--	--	Do.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
*LK-35-20-401 †	--	--	--	18	48	375	5.7 10.8 13.1	Jan. 29, 1942 Sept.28, 1960 July 2, 1964	B,H	D	Dug well, open hole. Temp. 67°F.
† 402	Hunt Oil Co.	Hunt Oil Co.	--	850	8	340	96.4	Oct. 21, 1964	A	Ind	Temp. 71°F.
† 403	Whelan Oil Co.	-- Cox	1957	583	6	315	--	--	T,E, 5	Ind	Casing perforated near bottom. Gravel-packed to surface. Reported discharge 25 gpm.
404	-- Dunn well 2	Placid Oil Co.	1946	8,000	--	390	--	--	--	--	Oil test. 1/
405	-- Dunn well 1	do	1946	7,950	--	380	--	--	--	--	Do.
406	-- Craver well 1	do	1948	6,931	--	350	--	--	--	--	Do.
407	E. K. Knox well 1	Whelan Oil Co.	1947	8,002	--	310	--	--	--	--	Do.
408	-- Hunt well 1	do	1947	7,925	--	320	--	--	--	--	Do.
409	-- Knox well 1	Placid Oil Co.	1946	8,300	--	318	--	--	--	--	Do.
† 501	Harleton Independent School	--	1964	36	30	325	20.8	July 2, 1964	J,E, 1/2	P	Bored well, curbed with cement tile.
† 502	J. T. Clark	--	1956	310	4	310	90.6	do	T,E, 1/2	D	
† 503	-- Crockett well 1	Whelan Oil Co.	1948	7,940	--	345	--	--	--	--	Oil test. 1/
601	-- Rogan well 1	Edson Petroleum Co.	1939	866	--	270	--	--	--	--	Do.
701	Belle Newman well 1	Whelan Oil Co.	1948	7,892	--	264	--	--	--	--	Do.
* † 801	T. Whitehead	--	1941	61	30	320	58.0 54.3	Jan. 29, 1942 Sept.29, 1960	J,E, 1/2	D,S	Dug well, curbed with clay tile. Temp. 65°F.
* † 901	C. A. Clark	--	1910	34	36	230	14.0 19.3 24.3	Jan. 29, 1942 Oct. 3, 1960 July 6, 1964	C,E	D,S	Dug well, curbed with brick. Reported water gets low in dry weather, but never fails.
* 902	Athey Baptist Church	--	1961	150	4	355	74.5	July 6, 1964	J,E, 1	P	
* 21-401	Friendly School	--	1950	60	30	320	34.2 35.5	Sept.29, 1960 July 6, 1964	J,E, 1/3	P	Dug well, curbed with cement tile. Supplies water for school.
* 402	Friendly Church	--	1950	30	30	320	20.6	Sept.29, 1960	J,E, 1/3	P	Dug well, curbed with cement tile.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
LK-35-21-701	East Harleton Gas Unit 2, well 1	Humble Oil & Refining Co.	1960	7,410	--	205	--	--	--	--	Oil test. 1/
702	-- Oney well 1	Edson Petroleum Co.	1939	828	--	220	--	--	--	--	Do.
† 901	Hickory Grove Church	--	--	16	36	280	3.6 11.5 12.2	Jan. 30, 1942 Oct. 3, 1960 July 2, 1964	B,H	N	Dug well, open hole. Old well.
*† 902	St. James Church	--	--	Spring	--	290	+	July 30, 1964	Flows	P	Estimated flow ½ gpm. Temp. 66°F.
* 22-301	Bill Largent	--	1964	39	30	220	15.8	July 16, 1964	J,E, 1/2	D,S	Bored well, curbed with cement tile. Supplies water for house and about 100 head of cattle.
302	-- Veatch well 1	Humble Oil & Refining Co.	1952	6,488	--	204	--	--	--	--	Oil test. 1/
* 401	R. B. Cawood	--	1956	21	30	250	16.8 18.7	Oct. 3, 1960 Aug. 7, 1964	C,E, 1/3	D	Dug well, curbed with cement tile.
402	Woodlawn School	Wm. Brummett	--	300	4	325	--	--	C,E, 1	P	Cased to 169 ft, open hole to bottom. Supplies water for school.
† 403	Woodlawn Community Center	do	--	260	4	315	--	--	C,E	P	Cased to 172 ft, open hole to bottom.
404	C. H. Gray well 1	Trice Production Co.	1955	6,632	--	287	--	--	--	--	Oil test. 1/
† 501	--	--	1930	30	36	280	21.7	Oct. 4, 1960	C,H	N	Open hole. School gone, pump broke.
502	A. J. Meeks	--	1958	100?	4	292	41.3 26.6	do July 16, 1964	J,E, 1/2	N	Casing perforated near bottom. Reported yields water with iron taste. House burned down; pump disconnected.
* 503	Mrs. W. E. Odum	-- Brummett	1952	200	4	315	30	1959	J,E, 1/2	D,S	Casing perforated from 160 ft to bottom. Gravel-packed to surface.
† 504	G. H. Sanders	Wheelis Drilling Co.	1951	365	4	265	50	1951	J,E, 2	D,S	Cased to bottom, open end. Supplies water for dairy.
† 505	Mrs. Kate Nesbett	--	1939	45	30	305	40.4 43.4	Feb. 11, 1942 Oct. 4, 1960	B,H	S	Dug well, open hole. Reported dry July 16, 1964.
* 506	F. Granberry	-- Bell	1958	85	2	310	68	1958	J,E, 1/3	D,S	Cased to bottom, open end.
† 601	Beckham Church	--	1938	17	30	270	2.1 8.8 10.2	Feb. 11, 1942 Oct. 4, 1960 July 17, 1964	C,E	D	Reported well deepened in 1955 or 1956 and curbed with cement tile.
602	H. L. Eldridge well 1	Humble Oil & Refining Co.	1952	6,810	--	304	--	--	--	--	Oil test. 1/

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
LK-35-22-701	C. M. Davis	Wayne Hightower	1958	189	3	300	30	1959	J,E	N	Casing perforated near bottom. Reported water has iron taste.
702	do	--	--	24	42	300	12.8	Oct. 3, 1960	J,E	D	Dug well. Old well.
* 703	Geo. Ives	Wm. Brummett	1954	220	4	320	80.4 89.8	Apr. 2, 1958 Aug. 7, 1964	J,E, 1	S	Casing and cement to 120 ft, open hole to bottom.
† 704	San Jacinto Gas Processing Co.	do	1954	215	4	310	85	1960	T,E, 3/4	D	Casing and cement to 156 feet. Pump set at 119 ft.
† 705	Mississippi River Fuel Corp. well 1	do	1960	215	8, 4	305	59.3 60.8	June 22, 1964 Oct. 7, 1964	T,E, 1	Ind	Casing 8-in. to 35 ft, 4-in. liner and cement to 105 ft, screen and gravel-walled to bottom. Used as standby well. Temp. 70°F.
† 706	Mississippi River Fuel Corp. well 2	do	1960	316	4	305	60.6 74.6	Dec. 2, 1960 Oct. 7, 1964	T,E, 1	Ind	Casing and cement to 272 ft. Screen and gravel-walled to bottom. Reported discharge 15 gpm. Temp. 71°F.
† 707	Mississippi River Fuel Corp.	do	1955	200	4	285	30.8	June 22, 1964	J,E, 3/4	D	Casing and cement to 105 ft, open hole to bottom. Supplies water for domestic use and warehouse.
801	Geo. Slaughter well 1	Stanolind & Continental Co.	1947	10,374	--	283	--	--	--	--	Oil test. 1/
23-401	B. E. Ritter	-- Bell	1958	181	2	208	20.3	Oct. 6, 1960	C,E, 1/4	D	Screen 8 ft at bottom.
* 501	L. L. Alcorn	Wm. Brummett	1960	214	4	295	--	--	J,E, 2	D	Casing and cement to 158 ft.
† 502	Caddo Lake State Park	Civilian Conservation Corps	1935	315	7	310	163.3 163.5 162.9	Oct. 27, 1941 Oct. 4, 1960 June 17, 1964	T,E, 1	P	Casing perforated from about 255 ft to bottom.
503	W. M. Coats	--	1952	180	6	175	6.5	Oct. 4, 1960	T,E, 2	D	Supplies water for 3 houses.
* 504	Karnack School	--	1955	265	6	265	65	1955	J,E, 2	P	Casing and cement to 160 ft, open hole to bottom. Standby well. School uses municipal water.
* 601	R. Heath	Wm. Brummett	1960	135	4	192	19.6	Oct. 4, 1960	J,E, 3/4	D	Casing and cement to 71 ft, open hole to bottom.
† 602	Longhorn Ordnance Works	B. F. Eddington	1942	133	5	233	22.5 26.9 27.9 28.5	May 5, 1958 June 4, 1958 Oct. 6, 1960 June 17, 1964	N	N	Screened from 85 ft to bottom. Reported discharge 20 gpm with drawdown of 42 ft when drilled. Used as standby well. Plant uses water from Cypress Bayou for potable and industrial needs. 2/

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
†LK-35-23-701	T. J. Taylor Estate	A. G. Foster	1931	--	12	185	+ +	Oct. 28, 1941 Oct. 6, 1960	Flows	S	Oil test; converted to water well. Measured flow 1½ gpm. Temp. 68°F.
702	T. J. Taylor Estate well 1	Humble Oil & Refining Co.	1951	6,890	--	202	--	--	--	--	Oil test. 1/
† 801	Karnack Water Supply Corp.	B. F. Eddington	1942	430	12, 6	275	70.6 83.5	Mar. 10, 1942 Feb. 26, 1963	T,E, 15	P	Well reworked by Layne-Texas Co. in 1963. Reported discharge 100 gpm with drawdown of 96.5 ft. Pump set at 200 ft. 2/
802	Charles Haynes	Wm. Brummett	1956	265	4	285	64.0 65.6	Mar. 31, 1958 July 17, 1964	J,E, 1/2	D	Cased to 135 ft, open hole to bottom. Used as standby well.
803	T. J. Taylor Estate well B-1	Humble Oil & Refining Co.	1953	6,765	--	301	--	--	--	--	Oil test. 1/
* 901	P. L. Patterson	Wm. Brummett	1960	240	4	240	--	--	J,E, 3/4	D	Casing and cement to 156 ft, open hole to bottom.
† 902	Geo. Washington Carver School	B. F. Eddington	1940	105	6	240	--	--	C,E, 3/4	P	Standby well. School uses municipal water.
† 24-101	Oscar Haddad	do	1940	103	6	185	18	June 1940	C,E, 3/4	D	Cased to 98 ft, open from 98 ft to bottom. Supplies water for 7 houses and one cafe.
102	-- Smith well 1	-- Barnwell, et al.	1938	--	--	180	--	--	--	--	Oil test. 1/
† 401	Mrs. V. M. Curtis	A. G. Foster	1940	103	4	182	--	--	J,E, 1/2	D	Cased to 90 ft, open hole from 90 ft to bottom.
402	-- Moore	-- Moore	--	301	4	190	13.5 17.5	Nov. 3, 1941 July 20, 1964	N	N	Reported supply insufficient for domestic use. Unused. Obstruction in well at about 20 ft.
501	Texas State unit no. 13	R. A. Whittington, et al.	1963	2,382	--	186	--	--	--	--	Oil test. 1/
† 701	Elizabeth Church	--	1936	36	36	215	6.1 7.3 11.6	Feb. 12, 1942 Nov. 6, 1960 July 20, 1964	B,H	D	Dug well, curbed with brick.
801	La-Tex Oil Co. well A-1	Stanolind Oil & Gas Co.	1956	--	--	266	--	--	--	--	Oil test. 1/
27-201	Alton Page	--	1871	28	36	390	22.9	Sept.29, 1960	C,E, 1/4	D,S	Dug well, open hole completion.
202	-- Bowers well 1	Sells Petroleum Co.	1952	7,000	--	343	--	--	--	--	Oil test. 1/
† 301	Hebron School	--	1930	16	24	310	12.0 14.0	Jan. 29, 1942 Sept.29, 1960	B,H	P	Dug well, curbed with cement tile since 1942. Dry July 21, 1964. Temp. 59°F.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
†LK-35-27-302	J. W. Griffith	--	1963	424	4	325	--	--	T,E, 2	S	
303	M. P. Isom well 1	Atlantic Refining Co.	1949	8,000	--	255	--	--	--	--	Oil test. 1/
801	T. A. Rae well 1	Fairway Operating Co.	1962	7,607	--	352	--	--	--	--	Do.
† 901	Grove Valve Regulator Co.	--	1960	274	6	360	86.8	July 24, 1964	T,E, 1	Ind	Reported water used only for utilities; not used for drinking purposes. Temp. 70°F.
† 28-101	Cartersville Church	--	1941	25	30	290	2.9 18.1 22.3	Jan. 30, 1942 Sept.29, 1960 July 21, 1964	B,H	D	Reported well deepened from 20 to 25 ft in about 1956, and curbed with cement tile. Supplies water for church. Reported several families in area haul water from well.
† 102	J. T. Bufkin	--	1964	200	3	325	--	--	J,E, 1-1/2	S	Supplies water for chicken farm.
201	D. R. Floyd	--	1930	30	30	260	23.8	Sept.29, 1960	C,E, 1/3	D,S	Dug well, curbed with cement tile.
301	Sam B. Hall, et al. well 1	Bill Tipton	1958	7,305	--	280	--	--	--	--	Oil test. 1/
302	Mattie Conwright well 1	Jackson Oil Co.	1958	7,305	--	324	--	--	--	--	Do.
401	Truitt Davis	W. Hightower	1957	280	6	350	80.1	Apr. 3, 1958	N	N	Reported well never used.
† 402	B. Frazier	--	1936	30	30	365	16.4 20.9 22.6	Jan. 28, 1942 Sept.29, 1960 July 21, 1964	J,E, 1/3	D,S	Dug well. Reported goes dry in summer.
403	Noonday Camp Ground	--	--	Spring	--	305	+	July 21, 1964	Flows	D	Estimated flow 1 gpm. Chemical analysis for old abandoned spring about 100 yards upstream. Temp. 65°F.
701	-- Cowles well 1	P. N. Wiggins, Jr.	1954	7,500	--	377	--	--	--	--	Oil test. 1/
801	City of Hallsville	Layne-Texas Co.	1938	932	--	415	--	--	N	N	Supply reported insufficient for city use. Dry and abandoned. Water test. 1/
† 802	do	do	1954	242	10, 6	360	101 102.4	1954 July 4, 1958	T,E, 15	P	Reported discharge 100 gpm. Screen from 195 to 233 ft. Temp. 70°F.
† 803	do	do	1939	201	10, 6	350	64	1939	T,E, 10	P	Reported discharge 85 gpm. Screen from 160 to 201 ft. Drilled to 613 ft, plugged back to 201 ft. Temp. 69°F. 2/
† 804	do	do	1963	245	13, 6	360	115.2	Oct. 9, 1964	T,E, 10	P	Measured discharge 80 gpm. Screen from 195 to 235 ft. Drilled to 280 ft, plugged back to 245 ft. Temp. 69°F.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
LK-35-28-901	U. C. Lowry, Jr.	D. Delahunt	1960	44	30	375	22.5	Oct. 26, 1960	J,E, 1/4	D,S	Bored well, curbed with cement tile.
† 902	H. D. Rogers	B. F. Eddington	1941	250	7	375	102.4	do	N	N	Abandoned.
† 903	-- Bedell	do	1941	272	7	370	96.3	do	N	N	Do.
* 29-101	New Zion Church	--	1960	34	30	310	24.7 28.2	Oct. 3, 1960 July 29, 1964	B,H	D	Bored well, curbed with cement tile. Temp. 65°F.
† 102	J. E. Haynes	Wm. Brummett	--	240	4	285	25.4 25.3 37.0	Apr. 2, 1958 Dec. 30, 1960 July 29, 1964	C,E	D,S	Casing and cement to 188 ft. Open hole to bottom.
† 103	Hunt Oil Co.	Mustang Drilling Co.	1963	590	8, 4	285	24	1963	T,E	Ind	Reported discharge 240 gpm with 106 ft of drawdown after 4 hours pumping. Used for water-flooding. Screen from 498 to 568 ft.
104	W. T. Nesbitt well 2	Hunt Oil Co.	1959	6,935	--	272	--	--	--	--	Oil test. 1/
† 201	Hunt Oil Co.	Mustang Drilling Co.	1963	600	8, 4	350	86	1963	T,E	Ind	Reported discharge 180 gpm with 34 ft of drawdown after 8 hours pumping. Screen from 470 to 540 ft. Pump set at 200 ft. Used for water-flooding.
† 301	Macadonia Church	--	--	37	36	370	8.0 11.0 13.6	Jan. 30, 1942 Oct. 3, 1960 July 30, 1964	B,H	D	Dug well, open hole.
† 401	Potters Creek Church	--	1932	23	36	460	14.8 17.4	Feb. 17, 1942 Sept.29, 1960	B,H	D	Dug well, curbed with brick.
† 501	Ebenezer Church	--	1910	30	36	380	11.2	Oct. 3, 1960	B,H	D	Do.
602	W. T. Hall well 1	S. Pinkston, Jr.	1960	4,879	--	365	--	--	--	--	Oil test. 1/
† 701	Joe Taylor	--	--	25	48	410	15.6 24.3	Jan. 28, 1942 Oct. 26, 1960	B,H	D	Dug well, curbed with brick.
702	P. Davenport	Henry Alford	1932	103	36	400	26.7 29.2	Oct. 26, 1960 July 30, 1964	N	N	Dug well, open hole.
† 703	Sam B. Hall, Jr.	W. Brummett	1955	220	4	345	67.0	July 30, 1964	J,E, 1	D	Cased to 150 ft.
* 704	Sam B. Hall, Sr.	do	1950	222	4	342	--	--	J,E, 1	D	Cased to 150 ft; gravel to bottom.
705	C. Huntsberger	do	1956	198	4	335	--	--	J,E, 3/4	D	Cased to 150 ft; open hole to bottom.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
LK-35-29-706	C. N. Collins well 1	Humble Oil & Refining Co.	1956	7,390	--	373	--	--	--	--	Oil test. 1/
707	Y. D. Harrison well 1	do	1957	7,448	--	398	--	--	--	--	Do.
* 801	Howard Yates	W. Brummett	1954	250	6	350	48.5 48.9	Apr. 2, 1958 July 30, 1964	T,E	D,S	Cased to 125 ft, open hole to bottom.
† 802	E. Kennedy	--	1934	30	60	330	10.7 24.0	Jan. 28, 1942 Oct. 26, 1960	J,E, 1/3	D	Dug well, curbed with brick.
901	R. Haynes	W. Brummett	1956	205	4	415	66.5	Oct. 27, 1960	T,E, 1/2	S	Cased to 105 ft, open hole to bottom.
† 902	Elbert Stauts	Barnwell Drilling Co.	--	444	4	420	139.5	Oct. 23, 1964	T,E	D	
† 903	Grange Hall School	W. Brummett	1950	315	4	412	126.8	Oct. 29, 1960	T,E, 1/2	P	Pump set at 165 ft. Supplies water for school.
† 904	Jack Green	Barnwell Drilling Co.	1963	410	4	395	106.5	Oct. 23, 1960	T,E	D	Casing: 4-in. to 328 ft. 2-in. liner and screen from 328 ft to bottom.
905	G. Huffman	W. Hightower	1956	443	6	400	49.4	Apr. 2, 1958	T,E, 1	N	Cased to 197 ft, perforated from 157 ft to 197 ft. Open hole to bottom. Reported discharge 20 gpm, but water has iron taste and not used.
*† 906	Atlas Chemical Industries, Inc.	--	1926	248	6	358	--	--	N	N	Abandoned.
*† 907	do	--	1927	192	6	358	--	--	N	N	Do.
*† 908	do	--	1927	201	6	354	--	--	N	N	Do.
*† 909	do	Walter A. Miller	1934	111	16, 9	356	--	--	N	N	Do.
*† 910	do	--	1940	50	48	358	--	--	N	N	Dug well. Abandoned.
*† 911	do	B. F. Eddington	1941	128	10	362	25	1941	N	N	Abandoned.
*† 912	do	do	1941	125	10	366	25	1941	N	N	Abandoned. 2/
30-201	May Harris well 1	Stanolind Oil & Gas Co.	1944	6,870	--	220	--	--	--	--	Oil test. 1/
202	P. O. Beard well 1	Humble Oil & Refining Co.	1951	6,696	--	311	--	--	--	--	Do.
† 401	City of Marshall	Ed Mills	1906	610	10	305	14.0	Nov. 17, 1941	N	N	Abandoned. Measured discharge 88 gpm in 1941. 2/

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
†LK-35-30-402	City of Marshall	Ed Mills	1925	300	10	310	19.7	Nov. 12, 1941	N	N	Abandoned. Measured discharge 145 gpm in 1941. Temp. 64°F.
† 403	do	Fred Fielder & Ed Mills	1928	300	8	315	--	--	N	N	Abandoned. Measured discharge 120 gpm in 1941.
404	do	Fred Fielder	1927	300	8	315	--	--	N	N	Abandoned. Measured discharge 145 gpm in 1941.
† 405	do	Ed Mills	1932	300	10	310	22.3	Nov. 12, 1941	N	N	Abandoned. Measured discharge 132 gpm in 1941. Temp. 64°F.
† 406	do	do	1936	240	8	305	--	--	N	N	Abandoned. Measured discharge 145 gpm in 1941. Temp. 65°F.
* 407	Paul Brown	--	--	300	--	330	39.6	June 10, 1964	J,E, 3/4	D	
† 408	City of Marshall	Layne-Texas Co.	1938	479	16, 8	325	--	--	N	N	Abandoned. Screened intervals 278-320, and 336-339 ft. Measured discharge 158 gpm in 1941. Pump set at 360 ft. Temp. 71°F.
* 409	Snider Lumber Co.	Banwell Drilling Co.	--	220	4	370	70.4	Oct. 13, 1964	T,E, 1/2	Ind	Screened interval, 160-200 ft. Water treated for iron before used.
* 601	Marshall Country Club	W. Hightower	1949	470	6	350	89.0	Apr. 1, 1958	--	--	Abandoned.
602	do	do	1960	285	4	350	--	--	T,E, 1/2	D	
† 701	Independent Ice Co.	J. C. Boling	1936	323	12, 8	362	66.0 64.3 66.7	Oct. 5, 1960 Feb. 7, 1963 Sept. 1, 1964	A,E, 20	Ind	Used as standby well.
† 702	City of Marshall	J. B. White	1936	351	18, 12	361	100 181.8	1936 Nov. 12, 1941	T,E, 30	P	Used as standby well. Screened from 264 ft to bottom. Measured discharge 145 gpm in 1941. Temp. 69°F.
† 703	do	Layne-Texas Co.	1937	375	16, 8	332	100 180.9	1937 Nov. 12, 1941	N	N	Abandoned. Screened from 254 ft to bottom. Measured discharge 198 gpm in 1941. Pump set at 340 ft. Temp. 69°F.
† 704	do	do	1937	473	16, 8	332	114	1937	--	--	Abandoned. Screened from 301 ft to bottom. Measured discharge 210 gpm in 1941. Pump set at 340 ft.
* 801	L. A. Fugler	Joe Gillespie	1960	335	6	382	86.5 98.4	Dec. 2, 1960 Aug. 7, 1964	T,E, 2	D	Pump set at 180 ft.
802	R. I. Fyffe	W. Hightower	1958	308	2	380	--	--	J,E, 3/4	D	Supplies water for minnow tanks at store. Pump set at 120 ft.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
†LK-35-30-803	K. H. Power	--	--	24	37	--	12.5 6.1	Feb. 17, 1942 Nov. 30, 1960	C,H	D	Dug well, curbed with clay tile. Old well.
† 804	Bill Greene	Sam Barwell	1963	364	4, 2	390	--	--	T,E, 1	D	Screen from 328 ft to bottom. Pump set at 150 ft.
† 901	Ida Bell Holmes	--	1925	31	36	370	15.8 19.0	Feb. 9, 1942 Oct. 5, 1960	C,H	D	Dug well, curbed with brick.
902	Verhalen Nursery	-- Cobb	1955	403	4	378	--	--	A,E	Irr	Used as standby well.
31-101	-- Blackman well 1	Hollandsworth, et al.	1960	6,730	--	320	--	--	--	--	Oil test. 1/
301	Antioch Church	--	--	16	36	230	12.7	Oct. 6, 1960	C,E, 1/3	D	Dug well, curbed with brick.
† 302	D. V. Blocker	-- Benson	1933	205	10, 6	300	--	--	T,E, 2	D,S	Pump set at 60 ft. Reported discharge 7 gpm.
303	H. High well 1	Humble Oil & Refining Co.	1952	6,503	--	236	--	--	--	--	Oil test. 1/
401	Harold Foster	W. Brummett	1959	284	4	--	--	--	J,E, 1	D,S	Pump set at 84 ft.
† 601	Hart School	--	--	17	42	320	7.0 9.8	Feb. 12, 1942 Oct. 6, 1960	N	N	Dug well, curbed with brick. Old well. School gone, well unused.
† 701	Verhalen Nursery	--	1935	28	120	385	--	--	J,E, 3/4	D	Dug well, curbed with brick. Supplies water for 2 houses and packing shed.
† 702	do	-- Cobb	1955	411	4	380	84.7	July 10, 1964	A,G	Irr	Standby well. Reported discharge 100 gpm.
† 703	do	-- Lace	1955	792	9	385	92.2 91.0	July 10, 1964 Nov. 12, 1964	T,E, 25	Irr	Oil test, converted to water well, and plugged back to 792 ft. Perforated from 250 to 410 ft. Measured discharge 127 gpm with 36.7 ft of drawdown after 2½ hours pumping. Pump set at 220 ft. Temp. 72°F.
704	do	-- Cobb	1955	409	4	385	--	--	A,G	Irr	Standby well. Reported discharge 70 gpm.
705	Kelly School	W. Brummett	1955	190	4	383	--	--	J,E, 1	P	Supplies water for school.
706	H. E. Wasom	W. Hightower	--	400	4	370	--	--	T,E, 1	D	
707	C. M. Beckett	--	1955	400	10	365	69.5 65.5	Nov. 10, 1960 Nov. 13, 1964	T,E, 20	Irr	Used as standby well.
† 708	Verhalen Nursery	--	1930	27	108	370	4.4 14.5	Feb. 9, 1942 Oct. 5, 1960	C,E, 1	D	Dug well, curbed with brick.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
†LK-35-31-709	Verhalen Nursery	--	--	415	4	370	76.4	June 22, 1964	T,E, 1	D	Pump set at 150 ft.
710	Robert Harkins	W. Brummett	1952	220	4	345	--	--	C,E, 1/2	D	Reported to discharge water with iron taste.
† 801	Shilo Baptist Church	--	--	19	30	290	8.8 8.1	Feb. 12, 1942 Oct. 6, 1960	B,H	D	Dug well, curbed with brick. Old well.
802	L. C. Brown, et al. well 1	Humble Oil & Refining Co.	1953	6,159	--	286	--	--	--	--	Oil test. 1/
803	L. R. Keeth, et al. well 1	do	1952	6,609	--	270	--	--	--	--	Do.
901	Le Cuno Oil Co.	W. Brummett	1957	220	7	310	--	--	T,E, 2	Ind	Reported used for water flooding.
32-101	Pleasant Hill Church	--	1945	21	36	290	18.1 18.7	Oct. 6, 1960 July 20, 1964	B,H	D	Dug well, curbed with brick. Supplies water for church.
201	W. A. Trice	W. A. Trice	1957	156	5	242	22.6 26.2	Mar. 31, 1958 May 5, 1960	J,E	D,S	Cased to 86 ft. Open hole to bottom.
202	-- Winston	Placid Oil Co.	1949	8,323	--	277	--	--	--	--	Oil test. 1/
† 501	Mt. Zion School	--	1939	18	30	242	5.9 5.2 10.3	Feb. 12, 1942 Oct. 6, 1960 July 20, 1964	B,H	D	Dug well, curbed with brick.
502	T. J. Taylor Estate well 1	Gulf Oil Corp.	1956	--	--	275	--	--	--	--	Oil test. 1/
701	Le Cuno Oil Co.	--	1950	190	7	290	--	--	T,E, 1-1/2	Ind	Reported water used for cooling gas lines.
801	A. Bookout well 3	A. L. Dawsey	1963	4,905	--	236	--	--	--	--	Oil test. 1/
802	J. T. Winston	Le Cuno Oil Co.	1954	2,362	--	220	--	--	--	--	Do.
803	Lon Green well B-2	--	1956	2,359	--	205	--	--	--	--	Do.
† 35-201	Dell Everett	J. C. Boling	1937	304	10, 5	410	--	--	C,E, 1	D,S	Casing perforated from 116 ft to bottom.
202	A. M. Russell	--	1955	20	30	340	1.3	Oct. 25, 1960	C,E, 1	D	Dug well, curbed with cement tile.
203	R. E. Latham well 1	The Texas Co.	1952	8,000	--	365	--	--	--	--	Oil test. 1/

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
LK-35-35-301	C. I. Southerland	C. G. Southerland	--	445	4	365	13.0	Oct. 25, 1960	J,E, 2	D	
† 601	P. W. Lee	--	1957	450	5	310	59.1	July 24, 1964	J,E, 2	S	
* 602	do	--	1934	31	30	310	20.5	do	J,E, 3/4	D	Dug well, curbed with brick.
* 603	Le Tourneau Ranch	--	1958	40	24	300	23.6	Oct. 25, 1960	J,E, 1/2	D	Bored well, curbed with cement tile.
† 604	do	-- Cobb	1954	500	6	290	--	--	T,E, 15	S	Reported well originally drilled for irrigation, but pumped too much sand, and is now used for stock.
* 605	do	--	--	150	6	295	39.6 41.4	Oct. 25, 1960 July 24, 1964	J,E	D	
606	Cora Latham well 1	E. R. Jackson, et al.	1955	7,450	--	275	--	--	--	--	Oil test. 1/
* † 36-101	K. R. Morgan	--	--	35	48	370	19.6 25.3	Oct. 26, 1960 July 28, 1964	J,E, 1	S	Dug well, curbed with cement tile. Supplies water for 25,000 chickens.
102	Maple Springs School	C. I. Southerland	1936	16	24	360	5.4 9.5 10.7	Jan. 27, 1942 Oct. 25, 1960 July 28, 1964	N	N	Dug well, curbed with clay tile.
103	R. L. Sypert well 1	Fohs Oil Co.	1940	4,547	--	300	--	--	--	--	Oil test. 1/
† 201	J. B. Cullen	Henry Alford	1940	32	36	380	23.9 27.9	Jan. 27, 1942 Oct. 26, 1960	N	N	Dug well, curbed with brick. Abandoned.
† 202	Mrs. George Welch	--	1910	26	21	340	11.5 15.0	Jan. 27, 1942 Oct. 25, 1960	C,E, 1/6	D,S	Dug well, curbed with brick. Reported discharge 400 gpm.
* 203	D. L. Allen	W. Brummett	1956	200	4	340	--	--	C,E, 3/4	D,S	
204	C. A. Ball well 1	Paul Scott, et al.	1942	3,015	--	360	--	--	--	--	Oil test. 1/
205	-- Holloway well 1	Lyons McCord, et al.	1955	7,410	--	268	--	--	--	--	Do.
† 301	Sweet Home Church	--	1936	20	36	345	5.3 11.1 16.7	Jan. 28, 1942 Oct. 28, 1960 July 28, 1964	B,H	D	Dug well, curbed with brick.
302	--	Bay Oil Corp.	1941	3,000	--	325	--	--	--	--	Oil test. 1/
303	-- Neahms well 1	Hollandsworth Oil Co.	1955	7,209	--	295	--	--	--	--	Do.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
†LK-35-36-401	J. W. Scott	--	1927	27	40	325	16.4 20.8	Nov. 4, 1941 Oct. 26, 1960	J,E, 1/6	D	Dug well. Open hole to bottom.
† 501	Cooperville School	Bob Newhouse	1925	28	40	340	19.1 24.3 27.1	Jan. 27, 1942 Oct. 26, 1960 July 28, 1964	J,E, 1/2	P	Do.
502	-- Le Tourneau	Atlantic Refining Co.	1955	6,946	--	241	--	--	--	--	Oil test. 1/
† 601	Louise Waldron	W. Brummett	1956	220	4	320	--	--	C,E	D	Sand from 205 ft to bottom.
602	-- Cullen well 1	Hollandsworth Oil Co.	1952	7,135	--	265	--	--	--	--	Oil test. 1/
† 701	Le Tourneau Ranch	J. E. Wesson	1937	18	--	245	--	--	C,H	N	Driven well. Well not used in 1964.
* † 901	R. B. Jay	E. O. Butler	1935	200	10	235	+	June 12, 1964	Flows	S	Oil test; converted to water well at about 200 ft. Estimated flow 15 gpm. Temp. 68°F.
* † 37-101	J. T. Crawford	W. Hightower	1960	465	4	370	95.8	Oct. 26, 1960	T,E, 1	D,S	Supplies water for 3 houses and dairy barn.
102	Red Oak School	--	1939	26	48	371	17.1 20.4	Jan. 28, 1942 Oct. 26, 1960	C,E	D	Dug well; open hole to bottom. Reported dry July 31, 1964.
103	-- White well 1	H. Strief	1944	2,806	--	340	--	--	--	--	Oil test. 1/
201	Canaan School	--	--	300?	4	345	64.7	Aug. 3, 1964	T,E, 1	P	Supplies water for school.
301	Mrs. R. C. Mosely	--	--	30	30	--	20.7	Oct. 27, 1960	B,H	D	Dug well.
† 401	Atlas School	--	--	22	48	300	14.1 17.6	Jan. 28, 1942 Nov. 10, 1960	B,H	D	Dug well; open hole to bottom. Reported dry July 31, 1964.
† 402	W. H. Lee	--	1964	370	4	360	103.4	Aug. 3, 1964	T,E, 1	D,S	Perforated from 310 ft to bottom.
* † 601	--	--	--	6	--	330	--	--	--	D,S	One of three dug wells located at a spring site known as Roseborough Springs. Reported water is red, and contains a comparatively high mineral content. Temp. 68°F.
602	Mrs. Era Levy	B. F. Eddington	--	214	4	335	--	--	C,E	D,S	
† 701	Bessie Gary	--	--	25	24	305	4.6 8.1	Nov. 10, 1960 July 31, 1964	B,H	D	Dug well, curbed with brick. Old well.
† 801	Atlas Chemical Industries	W. Hightower	1958	200	4	285	31.0	Nov. 10, 1960	T,E	Ind	

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
†LK-35-37-802	Natural Gas Pipeline Co. of America	Layne-Texas Co.	1951	429	10	310	56	Sept. 1960	T,E, 40	Ind	Supplies water for 18 houses and camp station. Screen from 212-243, 361-376, and 381-397 ft.
† 803	do	do	1951	420	10	315	41.0	Oct. 8, 1964	T,E, 40	Ind	Screen from 191-207, 225-241, and 362-393 ft. Temp. 71°F.
804	-- Matthews well 1	C. H. Murphy, Jr.	1947	7,257	--	375	--	--	--	--	Oil test. 1/
† 38-101	Van McClellan	--	1910	43	36	330	4.9 12.1	Feb. 17, 1942 Nov. 10, 1960	B,H	D,S	Dug well, curbed with concrete.
* 102	Fred Jarrell	W. Brummett	1960	285	4	330	--	--	T,E, 1/2	D	Cased to 235 ft, open hole to bottom.
301	I. C. Underwood	--	1960	274	4, 1	330	47.5	Nov. 30, 1960	J,E, 3/4	D,S	
302	Rosenwald School	--	1946	30	36	340	--	--	J,E, 1/4	P	Dug well.
303	Blocker Estate well 1	W. I. Sage	1964	3,560	--	338	--	--	--	--	Oil test. 1/
401	R. H. Harrison	-- Bell	1956	327	2	--	--	--	J,E, 1-1/2	D,S	
402	-- Brown	D. Benson	1964	250	4	340	26.2	July 6, 1964	T,E, 1/2	D	
403	Hattie Cole well 1	Stanolind Oil & Gas Co.	1945	6,800	--	310	--	--	--	--	Oil test. 1/
601	J. B. Ware	W. C. Barnwell	1959	325	4	340	--	--	T,E, 3	D	
*† 602	Humble Pipeline Co.	-- Applebaum	1931	150	5	290	15.7	Mar. 31, 1958	J,E, 1	D	
† 603	Mrs. H. C. Cadenhead	--	1912?	--	6	260	+	Aug. 6, 1964	Flows	S	Temp. 68°F.
* 604	do	Waterman Lumber Co.	1910	275	6	260	+	do	Flows	S	Estimated flow 1 gpm. Temp. 70°F.
* 605	do	do	1910	275?	6	260	+	do	Flows	S	Estimated flow 10 gpm. Temp. 68°F.
* 606	do	La Gloria Oil Co.	1952	300	10	266	+	do	Flows	S	Oil test drilled to 6,810 ft, converted to water well, and completed at 300 ft. Estimated flow 1 gpm. Temp. 69°F.
607	Cairo Washington well 1	Le Cuno Oil Co.	1960	4,375	--	326	--	--	--	--	Oil test. 1/

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
†LK-35-38-701	Arthur Fisher	V. E. West	1937	105	3	320	--	--	C,H	N	Unused well. Screen from 96 ft to bottom.
702	do	--	--	41	36	320	27.5	Nov. 10, 1960	B,H	D	Dug well, curbed with brick. Old well.
703	Doyle Harris	--	--	25	36	290	9.1	Oct. 11, 1960	J,E	D,S	Dug well.
704	B. S. Harrison	J. H. Brummett	1952	267	4	270	--	--	T,E	D,S	
* 705	Oscar Harris	W. M. Brummett	1956	217	4	250	14.2	Nov. 10, 1960	J,E, 3/4	D,S	
* † 801	Mrs. Barrett Gibson	--	1924	73	8	280	27.3 37.4	Nov. 10, 1960 Aug. 6, 1964	B,H	D,S	Cased with clay tile. Temp. 66°F.
† 802	do	--	1918	91	4	290	24.3	Aug. 6, 1964	N	N	
*† 803	do	The Texas Co.	1919	--	12	230	+	do	Flows	S	Oil test; converted to water well.
* † 804	E. V. Williams	Sabine Drilling Co.	1925	--	12	230	+	do	Flows	S	Oil test; converted to water well. Estimated flow ½ gpm. Temp. 68°F.
805	Henry Brown well 1	La Gloria Oil Corp.	1952	6,802	--	224	--	--	--	--	Oil test. 1/
† 39-201	Long Ridge School	--	--	33	30	365	4.9 11.1	Feb. 13, 1942 Nov. 30, 1960	B,H	D	Dug well, curbed with brick.
† 301	Waskom Natural Gas Corp.	--	1953	190	8	285	89	1960	J,E	D	Plant shut down, well converted to domestic use. Reported discharge 120 gpm.
302	do	--	1951	190	6	285	61.0	July 13, 1964	T,E, 3	N	Reported discharge 30 gpm.
303	do	W. C. Barnwell	1959	190	8	285	--	--	T,E, 15	N	Reported discharge 120 gpm.
† 304	La Gloria Oil Co.	--	1962	247	7	320	82.8	Sept.29, 1964	T,E, 3	Ind	Casing perforated from 181 ft to bottom. Measured discharge 44½ gpm. Reported used for water flooding. Temp. 68°F.
† 401	Mrs. H. W. Scott	--	1840	35	30	310	4.4 11.2	Feb. 17, 1942 Nov. 30, 1960	J,E, 1	D	Dug well.
* 402	H. W. Holt	--	1958	190	4	313	18.7	Aug. 11, 1964	J,E, 1/3	D	
* 403	Wayne Griffin	W. Hightower	1958	192	2	310	--	--	J,E, 1	D	
501	T. C. Lindsey well 1	Fred Whitaker	1955	6,442	--	380	--	--	--	--	Oil test. 1/

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level		Method of lift	Use of water	Remarks
							Below land-surface datum (ft)	Date of measurement			
*LK-35-39-601	P. G. Lake Oil Co.	--	1963	264	7	395	96	May 1963	T,E, 7-1/2	Ind	Casing perforated from 224 ft to bottom. Reported discharge 60 gpm. Gravel-packed from bottom to surface. Pump set at 241 ft. Temp. 69°F.
* 602	do	--	1963	295	7	390	152.5	Nov. 13, 1964	T,E, 7-1/2	Ind	Casing perforated from 225 ft to bottom. Gravel-packed from bottom to surface. Pump set at 246 ft. Reported used for water flooding. Temp. 69°F.
603	do	--	1963	299	7	385	118.9	do	N	Ind	Used as standby well. Casing perforated from 222 ft to bottom. Gravel-packed from bottom to surface.
604	Robert Frazier	Robert Frazier	1946	20	30	385	9.4	Nov. 30, 1960	B,H	D	Dug well, curbed with cement tile.
† 605	La Gloria Oil Co.	--	1962	245	7	355	105.8	Sept.29, 1964	T,E, 5	Ind	Reported discharge 80 gpm. Screen from 183 ft to bottom. Temp. 70°F.
* 701	-- Carter	W. Hightower	1964	180	2	340	--	--	J,E, 3/4	D	Screen from 172 ft to bottom.
* 702	Mrs. W. Woodley	--	--	--	4	294	+	July 17, 1964	Flows	S	Temp. 67°F.
† 801	John D. Furrh	W. Brummett	1956	259	6	365	--	--	J,E	D	Sand from 164 ft to bottom. Water treated for iron before used.
901	W. L. Rudd	--	--	17	36	370	1.7 2.8	Feb. 13, 1942 Nov. 30, 1960	B,H	D,S	Dug well, curbed with brick.
† 902	Elysian Fields High School	W. Hightower	1961	280	4	365	--	--	T,E, 2	P	Pump set at 80 ft. Water treated for iron before used.
903	-- Baker well 1	Arkansas-Louisiana Gas Co.	1945	6,501	--	380	--	--	--	--	Oil test. 1/
† 40-101	Arkansas-Louisiana Chemical Corp.	Montgomery Drilling Co.	1957	205	8	225	40	1960	T,E, 30	Ind	Screen from 165 ft to bottom. Reported discharge 200 gpm. Pump set at 180 ft. Temp. 70°F.
† 102	T. W. Vaughn	Eddington Drilling Co.	--	208	6	257	--	--	J,E, 3	Ind,D	Supplies water for cotton gin, store, and 5 houses. Pump set at 80 ft.
103	Amanda Fields	Arkansas-Louisiana Gas Co.	1940	--	--	300	--	--	--	--	Oil test. 1/
104	E. Little Heirs	do	1940	--	--	280	--	--	--	--	Do.
† 201	Arkansas-Louisiana Chemical Corp.	Clifford & Davis	1950	135	13, 8	135	66.5	May 31, 1957	T,E, 15	Ind	Screen from 95 ft to bottom. Reported discharge 74 gpm. Pump set at 110 ft.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
†LK-35-40-202	Arkansas-Louisiana Chemical Corp.	Clifford & Davis	1948	125	13, 8	236	79.2	May 31, 1957	T,E, 30	Ind	Standby well. Reported discharge 100 gpm. Screen from 75 ft to bottom. Pump set at 115 ft.
203	City of Waskom	R. L. Clifford	1953	150	10, 7	295	119.5	Mar. 22, 1960	N	N	Abandoned.
† 204	do	W. M. Waterman	1924	151	6	285	--	--	T,E, 7-1/2	P	Pump set at 120 ft. Temp. 69°F.
205	do	--	1948	150	8	285	122.2	June 18, 1964	N	N	Abandoned.
† 206	do	M. O. Tucker	1959	150	14, 8	282	--	--	T,E, 25	P	Reported discharge 133 gpm. Screen from 110 ft to bottom. Temp. 68°F.
† 207	United Gas Pipe-line Co.	Magnolia Petroleum Co.	1927	170	6	260	--	--	T,E, 1	D	Supplies water for 3 houses.
208	J. M. Furrh well 1	Arkansas-Louisiana Gas Co.	1940	3,220	--	290	--	--	--	--	Oil test. 1/
† 401	Edwin Spears	--	--	40?	30	348	9.2 2.9	Feb. 13, 1942 Nov. 30, 1960	B,H	D,S	Dug well, curbed with brick.
† 402	La Gloria Oil Co.	--	1962	190	7	330	78.4	Oct. 6, 1964	T,E, 3	Ind	Screen from 115 ft to bottom. Reported discharge 30 gpm. Used for water flooding. Temp. 69°F.
403	Essex Vance	Bert Fields Oil Co.	1947	6,225	--	330	--	--	--	--	Oil test. 1/
* † 501	Gainesville Church	--	1925	22	24	290	14.6 13.3 21.7	Feb. 13, 1942 Nov. 29, 1960 Aug. 11, 1964	B,H	D	Dug well, curbed with brick. Temp. 66°F.
† 502	Bert Fields Oil Co.	W. Hightower	1957	158	4	282	--	--	J,E, 1/2	Ind	
503	do	do	--	150	6	237	9.3	Oct. 20, 1964	N	N	Used as standby well.
504	A. Abercrombie well 1	Bert Fields Oil Co.	--	6,126	--	225	--	--	--	--	Oil test. 1/
505	-- Vincent well 1	--	1945	6,299	--	250	--	--	--	--	Do.
506	-- Vincent well 2	Bert Fields Oil Co.	1946	6,210	--	300	--	--	--	--	Do.
701	New Hebron Baptist Church	W. Hightower	1956	240	4	362	13.9	Nov. 29, 1960	J,E, 1/4	D	Reported water treated for iron before used. Sand from 210 ft to bottom.
702	Z. V. Hightower	Z. V. Hightower	1942	32	32	345	16.1	do	C,E, 1/4	D,S	Dug well.

See footnotes at end of table.

Table 5.--Records of wells and springs in Harrison County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft)	Diameter of well (in.)	Altitude of land surface (ft)	Water level: Below land-surface datum (ft)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*LK-35-40-703	Mrs. Guy Hayes	--	1940	112	4	348	--	--	J,E, 1/2	D	Casing perforated from 40 ft to bottom.
* † 704	do	--	--	25	36	348	3.0 3.5 9.5	Feb. 13, 1942 Nov. 29, 1960 Aug. 11, 1964	B,H	S	Dug well, curbed with brick. Old well.
* 801	Raymond Smith	W. Hightower	1960	150	2	320	--	--	J,E, 1/2	D	Pump set at 60 ft.
* 802	do	--	1940	187	30	330	8.7 14.2	Nov. 29, 1960 Aug. 11, 1964	B,H	D	Dug well, curbed with brick.
803	J. W. and J. D. Furrh	Bert Fields, et al.	1946	--	--	319	--	--	--	--	Oil test. 1/
46-101	-- Bergin well 1	Union Production Co.	1949	6,730	--	210	--	--	--	--	Do.
201	Oscar Prince	W. Brummett	1954	192	4	284	--	--	J,E, 3/4	D	Reported water treated for iron before used.
* † 202	Sabine Bishop Co-op.	A. E. Fawcett	1940	147	4	290	42.5 42.0	Nov. 10, 1960 Aug. 5, 1964	J,E, 1	D	2/
301	J. R. McClendon	W. Brummett	1958	250	4	335	--	--	C,E, 1	D	
302	do	Seismograph Crew	--	120	4	325	--	--	C,E, 1	S	
† 47-201	B. G. Hooker	W. Hightower	1957	310	2	340	--	--	J,E, 1	D	
* 202	Elysian Fields Community Center	do	1954	228	4	339	15.9 18.1	Nov. 29, 1960 July 22, 1964	J,E, 1	P	
203	Booker T. Washington School	do	1954	220	4	342	--	--	J,E, 1	P	Reported iron in water.

* For field determinations of analyses of water from wells and springs in Harrison County see Table 8.
† For chemical analyses of water from wells and springs in Harrison County see Table 7.
1/ Electric logs in files of Texas Water Development Board.
2/ For drillers' logs of wells in Harrison County see Table 6.

Table 6.--Drillers' logs of wells in Harrison County

Well LK-35-23-602

Owner: Longhorn Ordnance Works. Driller: B. F. Eddington.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface soil	15	15	Shale, sandy, water-bearing	31	106
Sand, fine brown, gravel and iron ore	30	45	Rock	2	108
Shale, blue	30	75	Sand	25	133

Well LK-35-23-801

Owner: Karnack Water Supply Corp. Driller: B. F. Eddington.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface soil	22	22	Lignite	5	165
Shale, blue	33	55	Shale	38	203
Sand	11	66	Shale with streaks of sand	87	290
Shale	34	100	Rock	1	291
Shale, sandy	37	137	Gumbo and shale	139	430
Rock	1	138			
Shale, sandy	22	160			

Well LK-35-28-803

Owner: City of Hallsville. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, white, sandy	3	3	Shale, blue	44	244
Clay, yellow	10	13	Rock	1	245
Shale, black, sticky	106	119	Shale, sandy	7	252
Rock	1	120	Sand, black	17	269
Shale and boulders	22	142	Shale, sandy	6	275
Shale, sandy	20	162	Sand	10	285
Sand, white	38	200	Shale, sandy	33	318

(Continued on next page)

Well LK-35-28-803--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale, brittle----------	68	386	Shale-----------------	10	602
Shale, black------------	69	455	Rock------------------	1	603
Shale, sandy------------	46	501	Shale and lignite-------	10	613
Sand, gray, fine-grained----------	91	592			

Well LK-35-29-912

Owner: Atlas Chemical Industries, Inc. Driller: B. F. Eddington.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay, red---------------	6	6	Sand, white, water------	12	115
Sand, red, water--------	59	65	Lignite----------------	2	117
Sand, green, water------	38	103	Sand and lignite--------	8	125

Well LK-35-30-401

Owner: City of Marshall. Driller: Ed Mills.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface soil------------	1	1	Sandstone--------------	1	101
Sand and clay-----------	11	12	Clay, gray-------------	11	112
Rock, red and yellow-----	14	26	Sand, gray-------------	4	116
Lignite-----------------	1	27	Lignite----------------	1	117
Sand, gray--------------	17	44	Clay, gray-------------	4	121
Clay, gray--------------	23	67	Sandstone--------------	3	124
Clay, soft dark-brown----	8	75	Clay, gray-------------	6	130
Lignite-----------------	5	80	Lignite----------------	1	131
Clay--------------------	4	84	Sand, gray-------------	8	139
Lignite-----------------	8	92	Rock, hard-------------	21	160
Clay, white-------------	8	100	Sand and clay-----------	12	172

(Continued on next page)

Table 6.--Drillers' logs of wells in Harrison County--Continued

Well LK-35-30-401--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Lignite-----------------	3	175	Lignite----------------	2	332
Sand and gray clay-------	15	190	Sand and clay-----------	1	333
Lignite-----------------	3	193	Rock, shelly-----------	3	336
Sand, white-------------	17	210	Sand, sharp------------	31	367
Lignite-----------------	1	211	Sandrock, soft gray-----	51	418
Sand, gray--------------	26	237	Sandrock, hard----------	1	419
No record---------------	1	238	Rock, soft gray---------	86	505
Sandstone---------------	1	239	Rock, hard-------------	3	508
Clay, gray--------------	3	242	Sandrock---------------	2	510
Sand, coarse-grained-----	7	249	Sand and clay-----------	10	520
Lignite-----------------	4	253	Rock, hard-------------	6	526
Sand, white, water-------	4	257	Clay, pipe-------------	22	548
Lignite-----------------	1	258	Rock, hard-------------	1	549
Sand, gray--------------	17	275	Sand, gray-------------	28	577
Lignite-----------------	5	280	Clay, pipe-------------	6	583
Clay, gray and sand------	10	290	Lignite----------------	1	584
Sand, gray--------------	20	310	Sandrock, gray---------	11	595
Clay and lignite--------	10	320	Lignite, clay and sand--	15	610
Clay, gray--------------	10	330			

Table 6.--Drillers' logs of wells in Harrison County--Continued

Well LK-35-30-408

Owner: City of Marshall. Driller: Layne-Texas Co.

	Thickness (feet)	Depth (feet)
Clay, red	26	26
Sand, gray, coarse-grained loose	38	64
Sand and shale, gray, fine-grained	87	151
Rock	1	152
Sand	5	157
Lignite	3	160
Shale, soft, blue, and sand, fine-grained	42	202
Rock	5	207
Shale, brown, hard, with layers of sand	33	240
Lignite	5	245
Sand, fine-grained, silty	17	262
Shale, soft, and fine-grained dark-gray sand	67	329
Sand and shale, fine-grained dark-gray	37	366
Sand	6	372
Rock, hard	1	373
Sand, dark-gray	30	403
Rock	2	405
Shale, brown, sticky	74	479

Well LK-35-46-202

Owner: Sabine-Bishop Co-Op. Driller: A. E. Fawcett.

	Thickness (feet)	Depth (feet)
Topsoil and clay	10	10
Shale, blue	10	20
Lignite and rock	2	22
Shale, dark-colored	5	27
Sand	13	40
Shale, dark-colored	53	93
Sand and sandy shale, tested for water, no good	22	115
Shale, dark-colored	14	129
Sand, good, water	18	147

Table 7.--Chemical analyses of water from wells and springs in Harrison County

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

Well	Depth of well (ft)	Date of collection	Silica (SiO$_2$)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	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
LK-35-11-901	16	Jan. 29, 1942	--	--	--	6.8	17	*36	0.0	97	32	--	22	--	211	85	--	--	--	--	--
902	101	Oct. 20, 1964	43	10	--	21	14	*19	3	112	23	0.1	.0	--	233	110	28	0.8	0.00	337	5.0
19-301	39	Jan. 29, 1942	--	--	--	21	b/	*30	134	3	4.5	.2	c/	--	126	55	--	--	--	--	--
501	35	do	--	--	--	a/	b/	*22	12	10	16	--	26	--	85	16	--	--	--	--	--
601	32	do	--	--	--	15	15	*90	18	2	196	.1	c/	--	328	99	--	--	--	--	--
20-401	18	do	--	--	--	8.8	b/	*3.7	6	3	14	.2	c/	--	40	25	--	--	--	--	--
402	850	July 2, 1964	15	1.5	--	6.0	2.2	235 4.0	272	11	221	.4	3.8	0.29	633	24	95	21	3.98	1,160	7.4
† 403	583	July 6, 1964	14	3.4	--	6.2	2.3	394 4.1	288	.0	455	.3	2.8	.32	1,020	25	97	34	4.22	1,870	7.5
501	36	July 2, 1964	--	.01	--	--	--	--	25	--	6.1	--	--	--	--	30	--	--	.00	98	6.2
502	310	Oct. 21, 1964	10	.67	--	13	5.2	*345	312	.0	388	.6	.8	--	916	54	93	20	4.03	1,700	7.3
801	61	Jan. 29, 1942	--	--	--	6.0	4.4	*26	37	30	20	.3	c/	--	105	33	--	--	--	--	--
901	34	do	--	--	--	a/	b/	*13	6	10	12	--	c/	--	41	5	--	--	--	--	--
21-901	16	Jan. 30, 1942	--	--	--	a/	b/	*15	6	3	24	.1	c/	--	49	11	--	--	--	--	--
902	Spring	do	--	--	--	a/	b/	*8.7	12	2	4.5	.1	c/	--	22	0	--	--	--	--	--
22-403	260	Aug. 7, 1964	12	.08	0.04	4.0	1.7	125 2.2	274	54	8.8	.3	.0	.77	344	17	93	1.3	4.15	563	7.9
501	30	Feb. 11, 1942	--	--	--	a/	3.6	*4.4	18	2	3.0	.1	c/	--	29	17	--	--	--	--	--
504	365	Oct. 23, 1964	13	.26	--	2.5	.2	*123	282	30	9.0	.2	.2	--	317	7	97	20	4.48	506	7.9
505	45	Feb. 11, 1942	--	--	--	14	b/	*5.8	55	2	4.5	--	c/	--	55	41	--	--	--	--	--
601	17	do	--	--	--	a/	b/	*5.1	12	2	3.0	.1	c/	--	18	6	--	--	--	--	--
e/ 704	215	Sept. 16, 1964	17	--	--	28	10	*110	166	164	22	.4	3	--	436	111	--	--	--	691	7.5
705	215	June 22, 1964	23	.48	--	8.5	4.6	87 5.4	172	48	31	.1	5.8	.25	299	40	80	6.0	2.02	485	6.5
706	316	Dec. 30, 1960	13	--	--	1.0	.1	*146	235	98	18	.2	.0	--	392	3	99	37	--	651	8.1
706	316	June 22, 1964	13	.15	--	1.8	.1	150 1.7	240	107	19	.2	3.0	.31	414	5	98	29	3.83	672	7.8
707	200	do	17	.19	--	10	3.4	163 5.6	162	221	24	.1	9.8	.21	534	39	89	11	1.88	837	6.9
23-502	315	Oct. 27, 1941	--	--	--	a/	b/	*128	256	25	38	.4	c/	--	320	11	--	--	--	--	--
502	315	June 17, 1964	25	1.0	--	7.2	2.7	*115	232	32	37	.2	2.2	--	335	29	90	9.3	3.22	538	7.2
602	133	Feb. 21, 1942	--	--	--	6.8	3.6	*174	360	10	74	.1	c/	--	446	32	--	--	--	--	--

See footnotes at end of table.

Table 7.--Chemical analyses of water from wells and springs in Harrison County--Continued

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	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
LK-35-23-701	--	Oct. 28, 1941	--	--	--	a/	b/	*234	354	4	168	--	c/	--	587	22	--	--	--	--	--
801	430	Feb. 21, 1942	--	--	--	10	b/	*142	299	30	44	0.1	c/	--	375	31	--	--	--	--	--
801	430	July 17, 1964	13	0.16	0.01	7.2	1.9	144 2.0	307	21	47	.0	1.8	0.18	389	26	92	12	4.51	661	8.0
902	105	Oct. 27, 1941	--	--	--	24	20	*91	262	42	52	.2	c/	--	367	142	--	--	--	--	--
24-101	103	Oct. 28, 1941	--	--	--	a/	b/	*121	220	23	50	--	c/	--	305	11	--	--	--	--	--
401	103	Nov. 3, 1941	--	--	--	a/	b/	*108	201	31	34	.3	c/	--	275	11	--	--	--	--	--
701	36	Feb. 12, 1942	--	--	--	a/	4.9	*26	6	17	34	.2	c/	--	91	20	--	--	--	--	--
27-301	16	Jan. 29, 1942	--	--	--	a/	b/	*6.7	6	2	11	.1	c/	--	29	10	--	--	--	--	--
302	424	Oct. 21, 1964	6.8	2.1	--	4.2	1.1	*271	284	1.2	262	.3	.0	--	687	15	98	30	4.35	1,260	8.2
901	274	July 24, 1964	43	6.6	.04	48	3.0	42 3.7	215	41	9.3	.0	.8	.16	297	132	40	1.6	.88	443	7.4
28-101	25	Jan. 30, 1942	--	--	--	a/	b/	*12	12	3	8.0	.2	c/	--	32	0	--	--	--	--	--
102	200	Oct. 22, 1964	30	11	--	12	7.5	*31	105	27	10	.1	.2	--	170	61	53	1.7	.50	255	6.2
402	30	Jan. 28, 1942	--	--	--	a/	b/	*9.0	6	10	4.0	--	c/	--	32	5	--	--	--	--	--
802	242	June 12, 1964	10	.09	--	2.8	.7	*99	176	63	9.7	.1	2.5	--	275	10	96	14	2.69	448	7.8
803	205	Oct. 17, 1941	--	--	--	2.8	1.7	*114	156	105	17	--	0	--	331	14	--	--	--	--	--
803	205	June 12, 1964	11	.21	--	2.5	.9	*110	152	94	16	.1	4.0	--	314	10	96	15	2.29	507	7.6
804	245	do	10	.09	--	1.5	.5	*110	160	89	13	.1	3.8	--	307	6	98	20	2.51	495	7.5
902	250	Oct. 17, 1941	--	--	--	9.6	6.1	*59	98	69	18	.1	c/	--	210	49	--	--	--	--	--
903	272	do	--	--	--	14	7.3	*47	79	69	21	.3	c/	--	197	65	--	--	--	--	--
29-102	240	July 29, 1964	11	.32	.00	1.5	1.1	254 2.1	647	8.0	8.2	2.4	3.2	.61	610	8	98	39	10.4	992	8.1
103	590	do	13	.36	--	1.5	.6	229 1.2	511	36	40	.7	1.2	.57	575	6	99	41	8.26	955	8.2
201	600	do	13	.05	--	.5	.5	207 .9	408	52	47	.5	2.0	.56	525	3	99	52	6.63	875	8.1
301	37	Jan. 30, 1942	--	--	--	a/	b/	*17	6	26	8.0	.1	c/	--	56	7	--	--	--	--	--
401	23	Feb. 17, 1942	--	--	--	a/	b/	*4.4	6	8	5.0	.3	c/	--	24	12	--	--	--	--	--
501	30	Jan. 30, 1942	--	--	--	a/	6.1	*17	18	20	25	.2	c/	--	81	34	--	--	--	--	--
701	25	Jan. 28, 1942	--	--	--	a/	b/	*11	6	3	14	.1	c/	--	37	7	--	--	--	--	--
703	220	July 30, 1964	11	.12	.01	3.0	.9	*196	378	108	7.0	.7	3.2	--	516	11	97	26	5.98	822	8.0
802	30	Jan. 28, 1942	--	--	--	6.0	4.4	*22	0	10	24	--	50	--	116	33	--	--	--	--	--

See footnotes at end of table.

Table 7.--Chemical analyses of water from wells and springs in Harrison County--Continued

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	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
LK-35-29-902	444	Oct. 23, 1964	12	0.12	--	1.8	0.4	*246	564	62	7.9	1.1	0.2	--	608	6	99	44	9.14	968	8.3
903	315	Oct. 28, 1960	12	--	--	7.5	3.5	122 3.6	267	63	10	.4	2.5	--	356	33	88	9.2	--	574	7.5
904	410	Aug. 5, 1964	12	.12	0.01	.8	.0	170 1.1	417	23	4.1	.4	.2	0.53	417	2	99	52	6.79	681	8.2
906	248	Nov. 18, 1941	--	d/ 35	--	22	9.0	*11	0	23	64	--	c/	--	129	91	--	--	--	--	--
907	192	do	--	d/ 55	--	23	24	*45	0	50	182	0	c/	--	324	155	--	--	--	--	--
908	201	do	--	d/ 50	--	19	24	*84	0	88	185	--	c/	--	400	145	--	--	--	--	--
909	111	do	--	d/ 55	--	20	20	*46	0	81	208	--	c/	--	377	132	--	--	--	--	--
910	50	do	--	d/ 2.5	--	10	b/	*17	12	4	42	--	c/	--	82	37	--	--	--	--	--
911	128	do	--	d/ 15	--	20	13	*16	85	46	14	.2	c/	--	151	103	--	--	--	--	--
912	125	do	--	d/ 15	--	44	25	*5.3	116	100	16	--	c/	--	247	210	--	--	--	--	--
30-401	610	Nov. 17, 1941	--	--	--	10	5.4	*4.8	6	40	8.0	.2	c/	--	71	48	--	--	--	--	--
402	300	Nov. 12, 1941	--	--	--	a/	6.6	*16	24	42	7.0	.1	c/	--	88	39	--	--	--	--	--
e/ 403	300	Dec. --, 1944	31	2	.08	8	5	*22	18	53	12	f/	f/	--	144	41	--	f/	--	--	5.6
405	300	Nov. 12, 1941	--	--	--	10	5.4	*2.8	0	96	6.5	0	c/	--	121	48	--	--	--	--	--
e/ 405	300	Dec. --, 1944	32	4.1	.07	7	4	*7	0	55	11	f/	f/	--	108	34	--	f/	--	--	4.0
406	240	Nov. 12, 1941	--	--	--	7.6	9.0	*2.5	31	26	6.5	.2	c/	--	67	56	--	--	--	--	--
e/ 406	240	Dec. --, 1944	30	2.3	g/	9	9	*5	24	34	11	.4	f/	--	100	60	--	f/	--	--	6.3
e/ 408	479	July 22, 1940	29	.6	.1	43	9	*84	201	112	32	--	2.2	--	400	145	--	f/	--	--	7.4
408	479	Nov. 12, 1941	--	--	--	6	11	*109	195	103	20	0	c/	--	345	62	--	--	--	--	--
e/ 408	479	Dec. --, 1944	24	1.1	.13	40	9	*79	199	111	21	.44	1.8	--	407	137	--	f/	--	--	7.6
701	323	Nov. 18, 1941	--	--	--	104	9	*23	275	100	12	.3	c/	--	383	296	--	--	--	--	--
702	351	Nov. 13, 1941	--	--	--	15	b/	*100	189	77	16	.2	c/	--	302	40	--	--	--	--	--
e/ 702	351	Dec. --, 1944	14	.04	h/	12	3	*104	201	71	21	.5	f/	--	305	43	--	f/	--	--	7.8
e/ 703	375	July 22, 1940	24	.4	--	32	9	*90	195	94	39	f/	f/	--	370	117	--	f/	--	--	7.2
703	375	Nov. 12, 1941	--	--	--	10	3.9	*89	165	77	15	.2	c/	--	276	42	--	--	--	--	--
e/ 703	375	Dec. --, 1944	24	.14	.08	33	7	*73	189	75	27	.4	f/	--	308	112	--	f/	--	--	7.9
704	473	Nov. 12, 1941	--	--	--	18	b/	*103	177	100	18	.1	c/	--	328	51	--	--	--	--	--
e/ 704	473	Dec. --, 1944	22	.14	.09	27	6	*95	195	100	25	.4	f/	--	380	92	--	f/	--	--	7.9

See footnotes at end of table.

Table 7.--Chemical analyses of water from wells and springs in Harrison County--Continued

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	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
LK-35-30-803	24	Feb. 17, 1942	--	--	--	13	36	*36	12	146	69	0.1	c/	--	308	183	--	--	--	--	--
804	364	Oct. 23, 1964	22	1.4	--	21	7.2	*60	152	26	42	.2	1.8	--	255	82	61	2.9	0.85	421	7.1
901	31	Feb. 9, 1942	--	--	--	a/	6.1	*5.1	37	3	4	.1	c/	--	39	29	--	--	--	--	--
31-302	205	Feb. 14, 1942	--	--	--	a/	4.9	*11	49	2	1	.4	c/	--	53	20	--	--	--	--	--
601	17	Feb. 12, 1942	--	--	--	118	56	*108	232	2	401	.3	c/	--	800	525	--	--	--	--	--
701	28	Feb. 9, 1942	--	--	--	a/	b/	*18	12	17	20	--	c/	--	76	22	--	--	--	--	--
702	411	June 22, 1964	50	59	--	44	42	52 5.8	0	106	217	.1	.8	0.03	518	282	27	1.3	.00	931	4.0
703	792	Dec. 30, 1960	15	--	--	16	4.7	83 3.3	221	23	24	.2	3.0	--	281	59	74	4.7	--	464	7.4
703	792	July 10, 1964	17	.23	--	16	4.4	80 3.2	217	24	23	.2	4.8	.18	280	58	74	4.6	2.40	467	7.5
708	27	Feb. 9, 1942	--	--	--	a/	b/	*10	6	2	8.5	--	c/	--	46	12	--	--	--	--	--
709	415	June 22, 1964	14	.04	--	2.0	.2	141 1.5	316	3.2	38	.3	2.5	.34	358	6	97	25	5.06	607	8.0
801	19	Feb. 12, 1942	--	--	--	a/	11	*81	31	20	129	.2	c/	--	259	52	--	--	--	--	--
32-501	18	do	--	--	--	23	6	*14	85	11	9.5	.1	c/	--	104	67	--	--	--	--	--
35-201	304	Nov. 4, 1941	--	--	--	a/	b/	*79	165	46	7.5	.4	c/	--	220	22	--	--	--	--	--
601	450	July 24, 1964	8.1	1.1	0.00	4.5	1.7	686 3.1	564	1.8	760	--	.8	.49	1,740	18	99	70	8.88	3,170	7.7
604	500	do	12	.70	.01	4.5	1.5	447 2.3	664	4.8	305	1.4	4.2	.55	1,110	17	98	47	10.5	1,930	7.9
36-101	35	Jan. 27, 1942	--	--	--	a/	b/	*40	18	60	14	--	c/	--	129	12	--	--	--	--	--
201	32	do	--	--	--	a/	b/	*10	12	2	3.5	--	c/	--	32	3	--	--	--	--	--
202	26	do	--	--	--	6.0	7.1	*86	6	2	88	1.2	120	--	313	44	--	--	--	--	--
301	20	Jan. 28, 1942	--	--	--	a/	b/	*12	12	3	12	.1	c/	--	37	5	--	--	--	--	--
401	27	Nov. 4, 1941	--	--	--	a/	b/	*3.9	6	7	5.0	--	c/	--	22	11	--	--	--	--	--
501	28	Jan. 27, 1942	--	--	--	a/	3.6	*3.5	6	2	5.5	--	c/	--	30	17	--	--	--	--	--
601	220	July 28, 1964	12	.14	.01	3.0	.9	187 1.9	456	29	13	.5	2.5	.65	474	11	97	25	7.25	779	8.0
701	18	Jan. 27, 1942	--	--	--	17	13	*44	18	10	91	--	50	--	234	98	--	--	--	--	--
901	--	Nov. 14, 1941	--	--	--	a/	b/	*291	695	3	44	--	c/	--	684	2	--	--	--	--	--
37-101	465	Jan. 28, 1942	--	--	--	a/	b/	*2.1	6	2	7.5	.1	c/	--	25	17	--	--	--	--	--
401	22	do	--	--	--	a/	b/	*6.9	6	2	3.0	.1	c/	--	20	0	--	--	--	--	--
402	370	Aug. 3, 1964	17	--	--	3.0	1.1	*238	606	.8	20	1.6	.5	--	580	12	98	30	9.69	940	7.7

See footnotes at end of table.

Table 7.--Chemical analyses of water from wells and springs in Harrison County--Continued

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	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
LK-35-37-601	6	Feb. 14, 1942	--	--	--	130	83	*143	0	899	101	0.8	c/	--	1,361	666	--	--	--	--	--
701	25	Nov. 4, 1941	--	--	--	a/	6.6	*6.2	24	2	18	--	c/	--	48	34	--	--	--	--	--
801	200	Aug. 3, 1964	12	0.09	--	2.5	1.0	*301	723	.6	46	2.4	0.2	--	722	10	98	41	11.6	1,200	8.1
802	429	do	13	.07	0.00	.8	.5	283 1.1	608	.2	63	1.3	2.2	1.0	685	4	99	62	8.89	1,150	8.5
803	420	do	12	.1	--	.8	.7	*272	629	3.4	52	1.2	.8	--	652	5	99	53	10.2	1,100	8.2
38-101	43	Feb. 17, 1942	--	--	--	23	3.6	*25	122	15	7.0	--	c/	--	134	72	--	--	--	--	--
602	150	Feb. 13, 1942	--	--	--	a/	b/	*115	262	10	28	.1	c/	--	289	17	--	--	--	--	--
603	--	Nov. 4, 1941	--	--	--	a/	b/	*186	415	5	50	.3	c/	--	448	12	--	--	--	--	--
701	105	do	--	--	--	52	39	*35	372	2	41	--	c/	--	352	289	--	--	--	--	--
801	73	Nov. 14, 1941	--	--	--	128	155	*364	756	238	620	.1	c/	--	1,883	956	--	--	--	--	--
802	91	do	--	--	--	31	15	*174	519	12	57	--	c/	--	544	139	--	--	--	--	--
803	--	do	--	--	--	30	b/	*118	153	7	148	.8	c/	--	389	87	--	--	--	--	--
804	--	do	--	--	--	a/	b/	*173	433	4	24	--	c/	--	419	17	--	--	--	--	--
39-201	33	Feb. 13, 1942	--	--	--	a/	b/	4.8	12	4	4.5	.1	c/	--	25	12	--	--	--	--	--
301	190	July 13, 1964	--	.62	--	--	--	--	348	--	40	--	--	--	--	100	--	--	3.70	694	7.4
304	247	Oct. 6, 1964	23	2.2	--	20	8.3	*100	290	6.0	40	.2	.0	--	341	84	72	4.7	3.07	610	6.9
401	35	Feb. 17, 1942	--	--	--	20	18	*140	67	67	127	.2	156	--	561	126	--	--	--	--	--
605	245	Oct. 6, 1964	11	.05	--	1.5	.4	*169	362	28	33	.2	.2	--	421	5	99	33	5.83	641	7.8
801	259	Aug. 11, 1964	57	3.8	--	18	3.9	*15	108	.0	2.7	.2	.0	--	150	61	34	.8	.55	181	6.4
902	280	do	62	6.3	--	11	4.5	*26	102	.2	13	.2	.0	--	167	46	55	1.7	.75	210	6.4
40-101	205	July 10, 1964	11	.04	--	2.0	.7	179 1.1	368	5.8	60	.2	5.0	.45	447	8	98	28	5.87	752	8.0
102	208	Oct. 20, 1964	11	.06	--	4.5	1.7	*197	396	.8	85	.3	.0	--	495	18	96	20	6.13	845	8.0
201	135	July 10, 1964	11	.66	--	13	3.8	304 2.1	396	200	132	.2	.2	.50	862	48	93	19	5.53	1,400	7.9
204	151	Oct. 29, 1941	--	--	--	16	16	*172	262	77	130	--	c/	--	540	105	--	--	--	--	--
204	151	June 18, 1964	14	1.3	--	32	9.7	*178	272	78	143	.1	.0	--	589	120	76	7.1	2.06	1,000	7.4
206	150	do	15	.05	--	30	10	*294	256	136	282	.1	5.6	--	899	116	85	12	1.88	1,530	7.9
207	170	Oct. 31, 1941	--	--	--	13	15	*177	293	77	112	--	--	--	538	94	--	--	--	--	--
401	40	Feb. 13, 1942	--	--	--	a/	b/	*18	12	23	7.5	.1	c/	--	58	6	--	--	--	--	--

See footnotes at end of table.

Table 7.--Chemical analyses of water from wells and springs in Harrison County--Continued

Well	Depth of well (ft)	Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	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
LK-35-40-402	190	Oct. 6, 1964	19	0.64	--	43	12	*130	328	115	35	0.2	1.8	--	517	157	64	4.5	2.24	812	7.1
501	22	Feb. 13, 1942	--	--	--	8.4	b/	*45	92	10	24	.9	c/	--	136	26	--	--	--	--	--
502	158	Oct. 20, 1964	3.5	1.2	--	10	59	*492	622	.2	585	.1	1.0	--	1,460	268	80	13	4.85	2,550	8.8
704	25	Feb. 13, 1942	--	--	--	10	7.3	*84	37	8	141	--	c/	--	268	55	--	--	--	--	--
46-202	147	Nov. 14, 1941	--	--	--	7.6	b/	*119	317	8	12	.3	c/	--	304	26	--	--	--	--	--
47-201	310	Aug. 11, 1964	34	.46	0.02	2.0	.5	103 1.0	246	.0	24	.1	.0	0.11	286	7	96	17	3.89	443	7.8

* Sodium and potassium calculated as sodium (Na).

† Well 35-20-403 Phosphate (PO_4), 0.17.

a/ Less than 5 ppm.

b/ Less than 3 ppm.

c/ Less than 20 ppm.

d/ Iron determination on same date by Atlas Chemical Industries, Inc.

e/ Analyses by Texas State Dept. of Health.

f/ Less than 0.4 ppm.

g/ Less than 0.05 ppm.

Table 8.--Results of field determinations of water from wells and springs in Harrison County

(Analyses given are in parts per million except pH.)

Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH	Well	Depth of well (ft)	Iron (Fe)	Hardness as $CaCO_3$	pH
LK-35-11-801	25	0	30	5.5	LK-35-35-602	31	0	20	5.0
20-401	18	0	--	6.0	603	40	0	120	6.0
801	61	0	--	5.0	605	150	1.0	50	7.0
901	34	0	--	5.0	36-101	35	0	30	4.5
902	150	0	20	5.5	203	200	0	30	7.5
21-401	60	0	50	6.5	901	200	.5	--	7.5
402	30	0	100	6.5	37-101	465	0	20	7.5
902	Spring	0	--	6.0	601	6	--	--	4.5
22-301	39	0	30	5.5	38-102	285	0	20	7.5
401	21	0	50	6.0	602	150	0	--	7.5
503	200	1	20	6.0	604	275	0	30	7.5
506	85	1.5	30	6.0	605	275	0	20	7.5
703	220	0	20	7.5	606	300	1	20	7.0
23-501	214	0	50	7.5	705	217	0	30	7.5
504	265	0	20	7.5	801	73	0	--	6.5
601	135	1	30	7.0	803	--	0	--	8.0
901	240	0	20	7.5	804	--	0	--	8.0
29-101	34	0	50	5.5	39-402	190	0	20	7.5
704	222	0	20	7.5	403	192	0	20	7.5
801	250	1	350	7.0	601	264	2	120	7.0
906	248	35	--	6.3	602	295	5	70	7.0
907	192	55	--	6.1	701	180	1	--	7.0
908	201	50	--	6.2	702	--	5	120	6.5
909	111	55	--	4.3	40-501	22	0	--	6.0
910	50	2.5	--	6.2	703	112	2	--	6.5
911	128	15	--	6.6	704	25	0	--	5.5
912	125	15	--	6.9	801	150	4	70	6.5
30-407	300	0	20	7.5	802	18?	0	20	5.5
409	220	10+	--	5.5	46-202	147	0	--	7.5
601	470	.5	130	7.0	47-202	228	10+	--	6.5
801	335	1.0	120	7.0					