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GEOLOGY AND GROUND-WATER RESOURCES OF TARRANT COUNTY, TEXAS

By

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Prepared by the Geological Survey,
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CONTENTS

	Page
Abstract	1
Introduction	3
Purpose and scope	3
Location of area	3
Methods of investigation	3
Economic development	5
Previous investigations	5
Acknowledgments	6
Climate	6
Topography	10
Drainage	10
Geology	11
Geologic history	11
Rock units and their water-bearing properties	11
Pennsylvanian system	11
Cretaceous system	15
Comanche series	15
Trinity group	15
Travis Peak formation	15
Glen Rose limestone	20
Paluxy sand	21
Fredericksburg group	24
Walnut clay	24
Goodland limestone	24
Kiamichi formation	27
Washita group	31
Duck Creek formation	31
Fort Worth limestone	33
Denton clay	34
Weno clay	35
Pawpaw formation	36
Main Street limestone	36
Grayson shale	37
Gulf series	37
Woodbine formation	37
Dexter member	38
Lewisville member	38
Eagle Ford shale	38
Quaternary system	39
Alluvium	39
Structure	39
Ground water	40
History of development of ground water	40
Occurrence and movement of ground water	42
Recharge of ground water	44
Recharge from precipitation	44
Recharge from lakes	44
Recharge from streamflow	48
Discharge of ground water	48
Natural discharge	48
Artificial discharge	52

CONTENTS

	Page
Fluctuations of water levels	52
Travis Peak formation	53
Paluxy sand	58
Woodbine formation	64
Ground-water reservoirs	64
Travis Peak formation	64
Yield of wells	64
Specific capacities of wells	65
Pumping tests	66
Results of tests	66
Application of results	67
Future development	70
Paluxy sand	71
Yield of wells	71
Pumping tests	72
Future development	73
Woodbine formation	73
Yield of wells	73
Pumping tests	75
Future development	75
Glen Rose limestone	75
Alluvium	75
Use of ground water	76
Public supplies	76
Industrial supplies	77
Agricultural supplies	78
Quality of ground water	78
Travis Peak formation	80
Paluxy sand	81
Woodbine formation	81
Alluvium	82
Temperature of ground water	82
Conclusions	82
References cited	85

ILLUSTRATIONS

Plate 1.	Geologic map of Tarrant County, Tex.	12
2.	Geologic cross section along line A-A'	16
3.	Geologic cross section along line B-B'	17
4.	Geologic cross section along line C-C'	18
5.	Geologic cross section along line D-D'	19
6.	Contact between Goodland limestone and Kiamichi formation north of Benbrook Reservoir, Tarrant County	26
7.	Exposure of Goodland limestone in Marys Creek, 0.8 mile south of Westland, Tarrant County	28
8.	Structure in Woodbine formation on Farm Road 157, 3.8 miles north of Arlington, Tex.	41
9.	Map of Tarrant County showing location of wells	182

ILLUSTRATIONS

			Page
Figure	1.	Map of Texas showing location of Tarrant County ------------	4
	2.	Annual precipitation at Fort Worth, Tex., 1900-54 ----------	8
	3.	Graphs showing precipitation and temperature at Fort Worth ---	9
	4.	Approximate altitude of the top of the Paluxy sand in Tarrant County ---	22
	5.	Comparison of lithologic properties and resistivity of the Fredericksburg group, Tarrant County -----------------	25
	6.	Goodland limestone along Marys Creek, 0.8 mile southeast of Westland, Tarrant County ----------------------------	29
	7.	Comparison of lithologic properties and resistivity of the Washita group, Tarrant County -----------------------	32
	8.	Generalized contours on the piezometric surface of the Paluxy sand, Tarrant County, 1954 -----------------------	43
	9.	Generalized contours on the piezometric surface of the Travis Peak formation, Tarrant County, 1954 --------------	45
	10.	Contour map on water table at River Oaks, Tex., 1954-55 ----	46
	11.	Profile of the piezometric surface of the Paluxy sand along line E-E' through Lake Worth, Tarrant County -------	47
	12.	Hydrograph of well C-19, water level of Grapevine Reservoir, and precipitation at Grapevine Reservoir, Tarrant County ---	49
	13.	Hydrograph of wells C-19 and F-38 screened in the Woodbine formation and precipitation at Fort Worth International Airport, Tarrant County -------------------	51
	14.	Altitude of water levels in the Travis Peak formation in packing house area, north Forth Worth, 1892-1954 ---------	55
	15.	Fluctuation of water levels in wells screened in the Travis Peak formation, Tarrant County -------------------	56
	16.	Fluctuation of water levels in wells E-157 and F-64, Tarrant County --	57
	17.	Approximate decline in artesian head in the Paluxy sand, Tarrant County, 1954-55 -------------------------------	59
	18.	Fluctuation of water levels in the Paluxy sand in the Arlington-Grand Prairie area, Tarrant County -------------	60
	19.	Fluctuation of water levels in eight wells in the Paluxy sand, Tarrant County ----------------------------------	62
	20.	Composite fluctuations of the water table in six wells, the departure from normal precipitation at Weatherford, and the minimum flow in the Clear Fork of the Trinity River at Aledo, Parker County ----------------------------	63
	21.	Drawdown and recovery data for wells F-64 and F-116 screened in the Travis Peak formation, Handley, Tex. -----	68
	22.	Theoretical drawdown in an infinite aquifer (Travis Peak formation) computed according to the formula for nonsteady-state flow ------------------------------------	69
	23.	Theoretical drawdown in an infinite aquifer (Paluxy sand) computed according to the formula for nonsteady-state flow --	74

ILLUSTRATIONS

		Page
Figure 24.	Quality of water from typical wells in the water-bearing formations of Tarrant County	79
25.	Temperature of water from wells in the Travis Peak formation and Paluxy sand, Tarrant County	83
26.	Map of part of downtown Fort Worth showing location of wells	181

TABLES

Table 1.	Monthly precipitation, in inches, at Meachum and Amon Carter Fields, Fort Worth, Tex., 1900-54	7
2.	Geologic formations in Tarrant County, Tex.	13
3.	Decline of water levels during 1954 in selected observation wells in the Arlington-Grand Prairie area	61
4.	Yield and specific capacity of wells in the Travis Peak formation in Tarrant County	65
5.	Coefficients of transmissibility and storage of the Travis Peak formation in Tarrant County	67
6.	Theoretical drawdown in wells produced by pumping an average of 140 gpm from each of four wells at Handley, Tex.	70
7.	Yield and specific capacities of wells screened in the Paluxy sand in Tarrant County	72
8.	Coefficients of transmissibility and storage of the Paluxy sand	72
9.	Average daily pumpage of ground water for municipal supply at Arlington, Tex., 1951-54	76
10.	Records of wells in Tarrant County, Tex.	87
11.	Drillers' logs of wells in Tarrant County, Tex.	133
12.	Water levels in wells in Tarrant County	164
13.	Analyses of water from wells and springs in Tarrant County	175

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ABSTRACT

Tarrant County, in north-central Texas, is underlain by beds of sand, clay, and limestone which dip gently eastward. The formations that yield water to wells are the Travis Peak formation, Glen Rose limestone, Paluxy sand, and Woodbine formation of Cretaceous age and the alluvial deposits of Pleistocene and Recent age.

The ground water in Tarrant County is derived primarily from precipitation on the outcrop of the water-bearing formations, and by seepage from streams and lakes. Ground water is discharged naturally by evapotranspiration and springs, and artificially through wells.

The withdrawal of ground water through wells from all aquifers in the county increased from 9 million gallons per day in 1941 to 17 million gallons per day in 1954. About 65 percent (11 mgd) of the pumpage in 1954 was from the Travis Peak formation and 30 percent (5 mgd) from the Paluxy sand. A large part of the increase in pumping since 1941 was in areas outside Fort Worth.

As a result of a marked increase in pumping from the Travis Peak formation and Paluxy sand in Tarrant County since 1952, as well as an increase in withdrawals in Dallas County, the artesian head declined over an extensive area. The decline of the artesian head in the Travis Peak during the period 1953-54 ranged from 110 feet in the eastern part of Tarrant County to 34 feet in the western part of Fort Worth. The decline in the artesian head in the Paluxy in 1954 ranged from 103 feet in the Arlington area to 0.5 foot in the Lake Worth area. Since 1890 the artesian head has declined a recorded maximum of 770 feet in the Travis Peak and 295 feet in the Paluxy.

Since 1950 the fluctuations of the water table in the area of outcrop of the Paluxy sand can be correlated directly with precipitation. A part of the decline in the water table, however, as well as a part of the decrease in rejected recharge to the Clear Fork of the Trinity River is due to the increased withdrawals from the Paluxy in Tarrant and Dallas Counties.

Results of pumping tests indicate that the coefficient of transmissibility of the Travis Peak formation ranges from 2,600 to 12,500 gallons per day per foot, increasing eastward. The coefficient of transmissibility of the Paluxy sand is fairly uniform, averaging about 4,500 gallons per day per foot. One pumping test in the Woodbine formation showed a coefficient of transmissibility of 2,700 gallons per day per foot. These low coefficients of transmissibility indicate that when closely spaced wells are pumped, relatively steep gradients must be developed over a wide area in a short time, resulting in considerable interference among wells.

Chemical analyses of water samples indicate that the Travis Peak, Glen Rose, and Paluxy formations generally yield soft water having a high bicarbonate content and a high percent sodium. The Woodbine formation yields water that is considerably more mineralized and has a high iron content.

Concentration of pumping rather than overdraft of the regional supply has been responsible for the large declines in water levels, which have resulted in some dewatering of both the Travis Peak formation and Paluxy sand in the Fort Worth area. Additional pumping in this area will result in the further expansion of the zone of dewatering and a decrease in the yields of most existing wells, but the rate of decline at a given rate of pumping will be less than in the past because the coefficient of storage of the dewatered portion of the aquifers is much larger than that of the artesian portion. It is possible that use of the ground-water resources of Tarrant County can be increased by wider spacing of wells or redistribution of pumping in the overdeveloped areas. Moderate amounts of additional ground water may be obtained from the Travis Peak and Paluxy east of Fort Worth, where the depth to the aquifers increases and consequently the amount of available drawdown is greater. Additional importation of surface water will be necessary to meet the larger demands, as the ground-water supply dwindles.

INTRODUCTION

PURPOSE AND SCOPE

Requirements of rapidly growing communities and the influx of new industrial plants have resulted in a sharp increase in the use of water in Tarrant County. The inadequacy of existing surface-water supplies to meet the demand emphasized the need for a thorough investigation of the ground-water resources of the county, which would include determination of the approximate amount of ground water in storage, the ability of the aquifers to yield water, the present use of ground water, the effect on the ground-water resources in Tarrant County of pumping outside the county, the source or sources of recharge to the ground-water reservoirs, the chemical character of the ground water, and the future outlook of ground-water development. The investigation was made possible through cooperation among the Texas Board of Water Engineers, the cities of Fort Worth and Arlington, and the U. S. Geological Survey, and is part of a Statewide program of ground-water investigations in Texas. The field work was begun in September 1949 by G. J. Stramel but was interrupted in 1950. The writer resumed the investigation in September 1953. George Porterfield assisted in the field work in 1954.

The study was made under the administrative direction of A. N. Sayre, chief, Ground Water Branch, U. S. Geological Survey, and under the direct supervision of R. W. Sundstrom, district engineer in charge of ground-water investigations in Texas.

LOCATION OF AREA

Tarrant County is in north-central Texas and is bounded on the north by Wise and Denton Counties, on the east by Dallas County, on the south by Johnson and Ellis Counties, and on the west by Parker County (fig. 1). The intersection of the parallel of latitude 32°45' north and the meridian of longitude 97°20' west falls near the middle of Tarrant County. The county is nearly square and has an area of 877 square miles.

The population of Tarrant County in 1950, according to the United States Bureau of the Census, was 361,253, of which 77 percent, or 278,778, were in Fort Worth, the county seat. Other cities and their populations are: White Settlement (10,827), Arlington (7,692), River Oaks (7,097), Haltom City (5,760), Grapevine (1,824), and Kennedale (1,046).

Transportation facilities in Tarrant County include an extensive network of paved Federal and State highways and farm-to-market roads. Nine railroad trunk lines serve Fort Worth and most of the smaller communities in the county, and air transportation is furnished by three major airlines and three feeder lines.

METHODS OF INVESTIGATION

Data for 729 wells were collected, including drillers' logs, records of casing and screen setting, use of water, well yield, and depth to water (tables 10 and 11). The locations of the wells are shown on plate 9 and figure 26. Periodic water-level measurements were made in selected wells (table 12), and

Texas Board of Water Engineers in cooperation with the
U. S. Geological Survey and the city of Fort Worth

Bulletin 5709

FIGURE I. - Map of Texas showing location of Tarrant County continuous records of the fluctuations of water levels in 8 wells were obtained by means of automatic water-stage recorders. Pumping tests were made in 20 wells to determine the hydraulic characteristics of the water-bearing formations throughout the area. Electric logs were used in the interpretation of the subsurface geology and the chemical character of the water in the deeper strata. Water samples for chemical analyses were collected from 168 wells, 1 spring, 2 lakes, and 1 river (table 13).

Seepage measurements were made on the West Fork of the Trinity River in order to determine whether the stream is effluent or influent between Lake Bridgeport, in Wise County, and Eagle Mountain Lake, in Tarrant County.

ECONOMIC DEVELOPMENT

Although the economy of Tarrant County is diversified, industry provides the largest source of income. Industries include the manufacture or processing of aircraft, automobiles, meat products, flour, cotton-seed oil, garments, furniture, Portland cement, leather goods, foundry and tool products, and petroleum. Most of the industrial production is concentrated in the Fort Worth area. Since 1951, however, the Bell Helicopter plant and the General Motors assembly plant were built in Hurst and Arlington, respectively. There are also two military installations, the Fort Worth General Depot and Carswell Air Force Base. Sand and gravel for construction purposes is obtained in the flood plain of the Trinity River and in the channels of numerous tributaries in Tarrant County. Since 1918, 26 oil tests have been drilled; however, oil in commercial quantity has not been found.

Tarrant County is one of the leading livestock and dairy-cattle-breeding counties in Texas. Dairying is practiced throughout the county, whereas beef cattle are raised principally in the rolling grasslands of the western part of the county. The county is also one of the leading poultry centers in Texas.

Farming is carried on in all parts of the county, but individual crops are restricted in areal extent. According to the Extension Service of the Texas A. & M. College, the principal farming area is in the southeastern part of the county, where the main crops are cotton, corn, clover, vetch, oats, and grain sorghum. Truck crops are grown on the sandy lands of the county, including the flood plains of the Trinity River and its tributaries. Alfalfa is raised on the flood plains where supplemental water for irrigation is available. Irrigation from wells and surface supplies generally is limited to the flood plains, and the area irrigated probably does not exceed 3,000 acres.

PREVIOUS INVESTIGATIONS

R. T. Hill in 1901 discussed the geology of Tarrant County with special reference to artesian waters. Winton and Adkins (1919), in a study of the geology of Tarrant County, briefly referred to the water resources. An investigation of the ground-water resources of Fort Worth and vicinity was made in 1942 by W. O. George and N. A. Rose. Most of the well data of that report are included in this report. In 1944 Lang 1/ prepared a preliminary report on the pos-

1/ Lang, J. W., 1944, A few facts regarding the ground-water supply of Fort Worth and vicinity, Tex.: U. S. Geol. Survey typewritten report.

sibility of obtaining additional ground water in the Fort Worth area. In 1949, Sundstrom, Broadhurst, and Dwyer reported on the public water supplies of Fort Worth, Arlington, Everman, Handley, and Mansfield.

ACKNOWLEDGMENTS

Appreciation is expressed to the many people who contributed data to this report. Well-drilling contractors in Fort Worth, Dallas, and Houston cooperated generously by furnishing well logs and performance-test data. Many industrial establishments, particularly the Texas Electric Service Co. and Leonard's Department Store, made their well installations available for various tests and observations.

The Soil Conservation Service of the United States Department of Agriculture and the Department of Geology of Texas Christian University loaned aerial photographs of Tarrant County, and the United States Corps of Engineers furnished considerable test- and core-hole data. Appreciation is expressed also for the information furnished by the officials of the cities of Fort Worth, Arlington, and Haltom City. The interest shown in the field geology by R. F. Perkins of the Department of Geology of Southern Methodist University, O. D. Weaver, Jr., of the Midwest Oil Corp., and Jesse Rogers of the Texas Co. is sincerely appreciated.

CLIMATE

Tarrant County has a subhumid climate characterized by moderate rainfall, mild temperatures, abundant sunshine, and low relative humidity. The days are hot in the summer, but temperatures exceeding 100 degrees are frequent only during periods when the rainfall is below normal. The hot summer days are moderated somewhat by the dryness of the air and by a steady south wind. The winters generally are mild, with short periods of freezing weather and relatively little snowfall.

According to records of the United States Weather Bureau at Meachum Field and Amon Carter Field, the annual precipitation at Fort Worth for the period 1900-54 averaged 31.76 inches, ranging from a low of 17.91 inches in 1921 to a high of 51.03 inches in 1932. (See table 1 and fig. 2.) However, only 15.56 inches was measured by the Weather Bureau at the Leonard Building in Fort Worth in 1954. The maximum, minimum, and average monthly precipitation at Fort Worth is shown in figure 3. Every month except January has an average rainfall exceeding 2 inches, and about 30 percent of the annual precipitation falls during the period April to June, inclusive.

The average annual temperature at Fort Worth is 66°F, and the highest and lowest temperatures recorded are 112°F and -8°F (fig. 3). Temperatures exceed 90°F and 100°F on an average of about 94 and 12 days per year, respectively. During 1954, however, when precipitation was the lowest on record in the Fort Worth area, temperatures exceeded 90°F and 100°F on 125 and 52 days, respectively. The average date for the first and last killing frosts are November 16 and March 13, respectively, although killing frosts have occurred as early as October 24 and as late as April 9. Thus the average length of the growing season is about 250 days.

Table 1.- Monthly precipitation, in inches, at Meachum and Amon Carter Fields, Fort Worth, Tex., 1900-54. Station moved to Carter Field on April 26, 1953

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1900	0.70	0.12	0.73	7.34	6.58	0.84	5.90	1.43	9.12	3.22	0.56	0.35	36.89
1901	.08	1.59	1.57	2.04	4.50	.33	1.99	1.29	1.67	1.90	2.10	.59	19.65
1902	.42	.36	3.80	1.81	4.31	.58	6.29	T	2.40	1.40	6.89	1.05	29.31
1903	1.83	4.63	2.03	.59	1.84	4.84	1.84	1.57	2.70	4.53	.00	.30	26.70
1904	1.30	1.79	4.01	2.21	3.86	5.42	2.15	3.26	2.63	5.29	.02	.36	32.30
1905	1.52	1.93	3.39	7.73	5.45	2.69	8.35	.56	.83	4.21	3.19	3.60	43.45
1906	.93	2.08	1.99	2.56	8.24	4.13	2.56	4.98	4.16	.91	2.19	1.22	35.95
1907	.51	1.90	.70	1.31	6.53	2.22	4.15	.29	1.92	3.01	5.81	2.18	30.53
1908	.96	2.45	2.95	9.63	10.69	2.90	2.66	2.74	3.52	4.49	2.05	.03	45.07
1909	.09	.11	.41	1.66	1.09	2.97	.02	2.38	2.08	2.20	5.11	2.81	20.93
1910	1.36	1.14	1.02	2.65	5.76	1.38	.14	.26	2.21	.68	.14	1.23	17.97
1911	.21	3.84	1.87	3.33	.22	.43	6.26	2.39	1.38	.99	1.05	5.06	27.03
1912	.17	1.22	3.34	3.20	2.71	4.26	.27	6.56	.83	1.51	.33	1.95	26.35
1913	2.30	.87	1.04	2.47	2.74	3.03	4.36	T	7.29	2.28	5.90	5.42	37.70
1914	.43	1.17	2.89	5.99	10.71	2.97	.73	9.02	1.61	.28	6.44	4.40	46.64
1915	1.32	2.18	1.40	4.98	2.49	6.88	.30	10.33	1.62	2.58	.29	1.99	36.36
1916	4.01	.01	3.68	6.99	3.70	3.30	1.38	3.84	.73	1.89	1.82	.11	31.46
1917	1.43	1.47	2.42	4.11	3.92	1.97	2.65	1.92	2.41	.17	1.35	.05	23.87
1918	1.36	.01	.93	6.21	1.99	5.16	1.10	.29	2.09	3.31	7.94	4.08	34.47
1919	3.03	2.03	3.34	2.06	3.99	3.72	5.25	5.00	4.12	9.44	3.32	.44	45.74
1920	3.48	.76	4.42	.51	8.66	2.33	3.49	4.22	2.76	6.52	1.70	1.31	40.16
1921	2.87	2.62	2.67	1.99	1.04	2.63	1.14	.95	.11	.31	1.24	.44	17.91
1922	1.63	2.00	1.57	17.64	4.58	1.76	1.35	.52	.41	2.33	2.57	.06	36.42
1923	4.60	2.05	1.52	5.30	.54	6.74	.99	1.68	2.06	6.05	1.63	4.68	37.84
1924	.89	1.97	4.66	2.33	4.00	1.25	.96	3.77	3.78	T	1.60	1.23	26.44
1925	1.44	.74	.02	3.59	8.11	.29	.98	.40	1.79	3.77	2.05	.04	23.22
1926	4.04	.08	3.60	3.73	3.79	3.32	4.13	4.39	1.41	3.16	.73	3.03	35.41
1927	1.45	1.77	2.19	3.66	.44	3.33	1.53	.80	4.00	4.47	.58	2.59	26.81
1928	.46	3.53	1.10	5.70	3.77	11.58	4.24	2.13	.45	4.15	1.97	5.50	44.58
1929	2.08	2.78	1.39	2.06	5.83	.20	.43	T	2.29	2.12	1.50	.41	21.09
1930	.84	1.08	2.86	2.37	10.37	1.87	.37	3.12	1.19	7.96	1.71	2.08	35.82
1931	1.79	2.84	4.20	1.97	2.42	2.43	.44	3.38	1.25	3.39	2.78	2.73	29.62
1932	9.07	4.92	.63	3.43	6.03	3.04	2.07	2.92	10.80	1.66	1.56	4.90	51.03
1933	1.96	2.47	2.18	1.57	4.67	.03	5.70	2.25	4.94	1.24	.66	2.13	29.80
1934	1.86	1.67	4.26	2.39	.82	T	.08	.13	4.90	.12	2.30	.56	19.09
1935	3.70	3.29	1.40	3.06	9.15	7.22	.89	.70	3.61	4.01	1.65	2.26	40.94
1936	.67	.45	.63	.99	9.48	.03	2.35	.23	7.30	3.72	.46	1.84	28.15
1937	1.71	.30	3.88	.58	1.00	5.74	1.93	1.02	.32	3.55	4.39	5.31	29.73
1938	2.74	4.57	3.89	3.03	2.80	1.61	2.16	.11	.78	.11	1.17	1.26	24.23
1939	2.66	2.42	1.64	1.48	2.54	4.04	2.02	1.44	.12	.55	2.72	.68	22.31
1940	.59	2.00	.40	5.97	7.15	7.30	2.86	2.16	.68	1.47	6.35	4.72	41.65
1941	1.45	3.42	1.52	3.52	2.02	7.12	1.49	2.71	1.28	3.68	1.08	1.88	31.17
1942	.39	.64	1.37	16.97	2.85	3.23	.62	4.69	3.82	6.18	.92	1.59	43.27
1943	.20	.51	4.05	1.63	7.83	3.93	.73	T	7.31	.73	.51	3.32	30.75
1944	2.58	4.81	1.30	2.70	6.42	.76	2.52	2.65	.80	2.53	3.82	3.60	34.49
1945	1.92	6.96	6.19	2.87	1.81	4.12	3.07	.62	2.17	2.31	1.13	.55	33.72
1946	2.79	2.93	2.80	2.49	12.09	.65	.90	6.84	2.69	1.31	6.50	3.40	45.39
1947	1.21	.55	2.92	2.98	2.50	4.08	.10	4.18	2.81	2.14	2.23	4.50	30.20
1948	.96	4.12	1.07	1.11	4.34	2.46	1.93	.90	.19	2.09	.50	.44	20.11
1949	5.45	4.75	3.69	2.47	10.64	3.52	.10	2.27	3.13	6.50	.09	1.04	43.65
1950	5.01	2.47	1.58	4.73	6.16	3.16	4.53	3.05	3.21	.30	.02	T	34.22
1951	1.39	2.42	1.33	2.27	4.60	4.12	2.22	.47	1.84	1.62	1.00	.09	23.37
1952	.58	1.12	1.39	6.51	3.21	T	.56	.44	.54	.01	5.84	2.49	22.69
1953	.54	1.34	2.52	4.82	3.55	.55	.97	1.09	1.68	4.27	2.09	1.32	24.74
1954	2.08	.73	.66	3.62	4.38	1.20	.24	.81	1.46	2.35	1.24	.78	19.55
MEAN	1.82	2.03	2.27	3.81	4.70	3.04	2.18	2.26	2.60	2.73	2.30	2.02	31.76

T, trace.

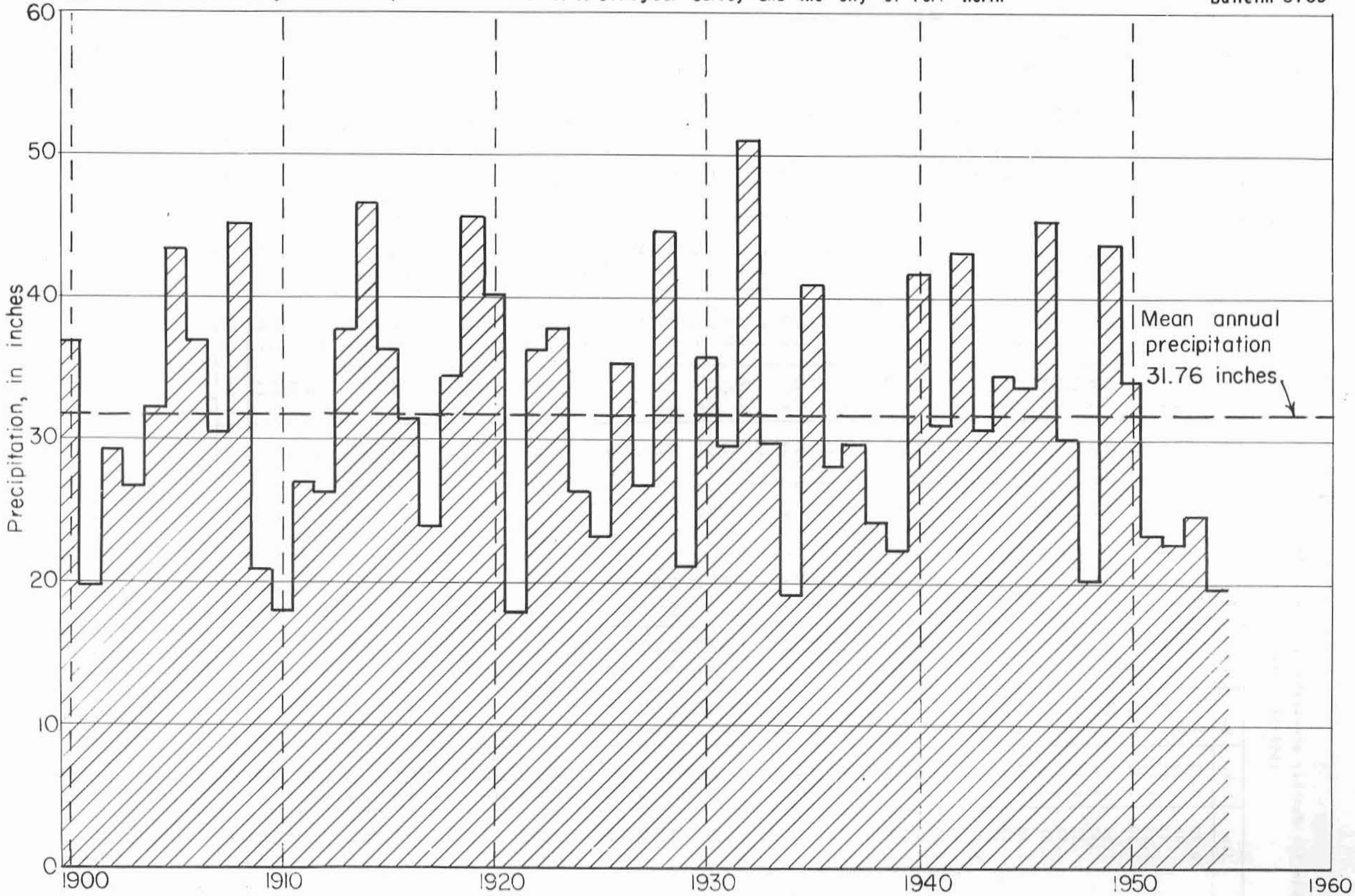

FIGURE 2.- Annual precipitation at Fort Worth, Tex., 1900-54.

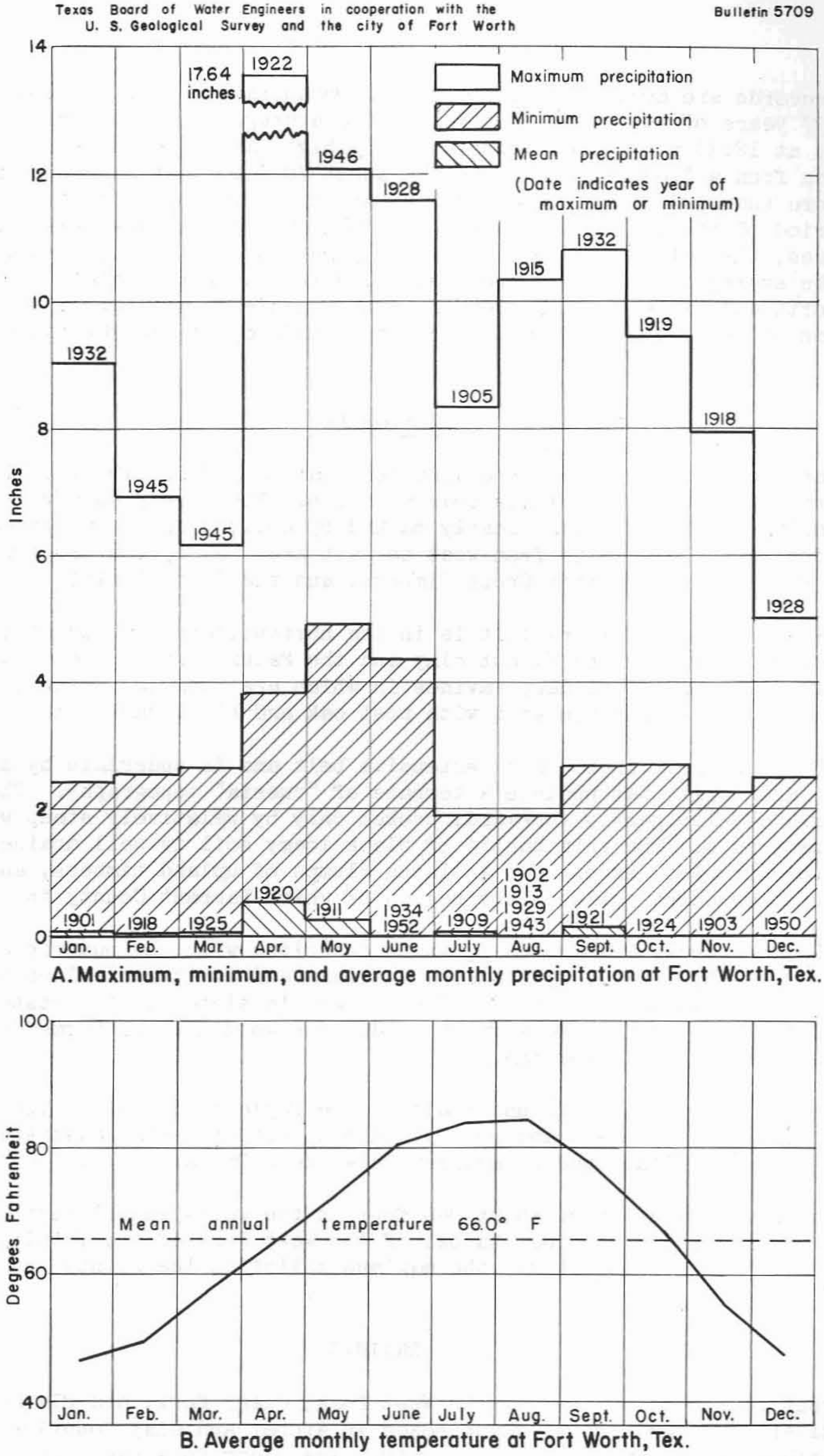

FIGURE 3. - Graphs showing precipitation and temperature at Fort Worth, Tex.

Few records are available on the rate of evaporation in Tarrant County. Based on 37 years of record at Fort Worth, the average relative humidity is about 53 percent at 12:30 p.m., indicating a fairly high rate of evaporation. The evaporation from a free water surface was about 78 inches at Benbrook dam in 1955. This is more than twice the annual precipitation. However, owing to the shortness of the period of record, the subnormal rainfall, and the above-normal summer temperatures, the rate of evaporation in 1955 may have been considerably larger than in the average year. Data from Denton, which is approximately 30 miles north of Fort Worth and has a similar average annual rainfall, indicate an average evaporation of 54.49 inches from a free water surface for the 36-year period 1917-52.

TOPOGRAPHY

Tarrant County lies within the area designated by Hill (1901, p. 27) as the East-Central Province of the Texas Coastal Plain. The county is divided into four north-trending belts which are clearly marked by soil, plant, and topographic characteristics. These belts from west to east are the Western Cross Timbers, the Grand Prairie, the Eastern Cross Timbers, and the Black Prairie.

The Western Cross Timbers belt is in the northwestern quarter of the county in the area underlain by the Walnut clay and the Paluxy sand. The area is dissected into steep hills and deep ravines in which are numerous waterfalls, and the sandy soil is heavily timbered with post oak and black-jack oak.

The Grand Prairie is the most extensive belt and is underlain by alternating limestones and marls that produce a terrace of "cuesta" topography. The surfaces of the terraces slop gently eastward, broken only by relatively steep westward-facing escarpments. The thin mantle of black loamy soil is well drained, is comparatively treeless except for isolated clumps of upland timbers, and is one of the most productive soils in the region of which Tarrant County is a part.

The Eastern Cross Timbers belt, which coincides with the outcrop of the Woodbine formation, is well dissected by streams and is characterized by low, rounded wooded hills on the western edge and gentle slopes of the eastern margin. Characteristic features of the western border are wooded knobs formed by outliers of the basal beds of the Woodbine.

The Black Prairie belt is underlain by the Eagle Ford shale. The surface, which is relatively treeless and poorly drained, slopes gently eastward to the base of a prominent limestone escarpment in western Dallas County.

The altitude ranges from about 940 feet in the west-central part of Tarrant County to about 420 feet in the channel of the West Fork of the Trinity River where it leaves the county; thus, the maximum relief in the county is approximately 520 feet.

DRAINAGE

Tarrant County is drained by the West Fork, Clear Fork, and Elm Fork of the Trinity River. The West Fork, which heads in Archer and Clay Counties, drains the northwestern part of Tarrant County. The Clear Fork heads in Parker County and drains the southwestern part of Tarrant County, joining the West Fork at Fort Worth. The eastern half of the county is drained by Sycamore, Village, Fossil, and Bear Creeks and other intermittent tributaries of the West Fork. The northeastern corner of Tarrant County and an area around Haslet are drained by Denton Creek, a tributary of the Elm Fork of the Trinity River.

The West Fork and Clear Fork are mature streams having fairly low but uniform gradients. From their entry into Tarrant County to their confluence at Fort Worth the gradients of the West Fork and Clear Fork are 4 and 7 feet per mile, respectively. The gradient of the West Fork from Fort Worth to Grand Prairie, however, is less than 2 feet per mile.

GEOLOGY

GEOLOGIC HISTORY

The geologic history of north-central Texas is somewhat complex. From Cambrian to Pennsylvanian time, sediments were deposited in the northwest-trending Fort Worth basin, the axis of which passes roughly through the northeastern part of Tarrant County. The Paleozoic era closed with considerable orogenic movement and westward tilting of the Pennsylvanian strata. This was followed by an uplift of the land surface which continued into the Triassic period. During the Triassic and Jurassic periods, withdrawal of the seas from the north-central Texas area and subsidence in the Gulf coast embayment resulted in a reversal in the direction of drainage. This led to extensive truncation of Pennsylvanian strata in the Fort Worth basin. At the close of the Jurassic period the rocks of Paleozoic age had been reduced nearly to a flat surface, which Hill (1901, p. 363) called the Wichita Paleoplain. This eroded surface was covered by marine sediments during the Cretaceous period, deposited along oscillating shorelines. Two major invasions of the seas during Cretaceous time are represented by the Comanche series and the younger Gulf series. Minor pulsations of the seas during Comanche time are indicated by the separate limestone and marl sequences of the Fredericksburg and Washita groups. At the close of the Cretaceous period, the seas withdrew gulfward, and the surface of Tarrant County rose above sea level. Throughout Tertiary time, except for minor periods of subsidence, the land surface was eroded and modified by streams. During Quaternary time the streams deposited alluvium, the older bodies of which are represented by terrace deposits above the alluviated valleys of the present streams.

Table 2 shows the thickness of the various geologic formations and gives a brief description of their character, topographic features, and water-bearing properties. The outcrops of the formations in Tarrant County are shown on plate 1.

ROCK UNITS AND THEIR WATER-BEARING PROPERTIES

Pennsylvanian System

Sedimentary rocks of Pennsylvanian age do not crop out in Tarrant County but are encountered in wells at depths that become progressively greater toward the east. These rocks are about 6,000 to 7,000 feet thick and are found at altitudes ranging from 60 feet below sea level at Lake Worth to 1,330 feet below sea level at Arlington. Throughout Tarrant County the truncated Pennsylvanian strata dip westward, in contrast to the succeeding Cretaceous strata which dip southeastward.

TABLE 2.- GEOLOGIC FORMATIONS IN TARRANT COUNTY, TEX.

System	Series and group	Formation and member	Thickness (feet)	Character of rocks	Topographic expression	Water-bearing properties
Quaternary	Recent and Pleistocene	Alluvium	0- 45	Sand, gravel, clay and silt.	Terrace and flood-plain deposits.	Small to moderate yields. Water unsatisfactory for domestic use unless treated.
Cretaceous	Gulf series	Eagle Ford shale	0-200	Bluish-black shale; thin sandstone and limestone beds.	Gently, rolling, treeless, black waxy soil. Forms Black Prairie belt.	Not known to yield water to wells in Tarrant County.
	Gulf series; Woodbine formation	Lewisville member	0-200+	Ferruginous sandstone, varicolored clay and sandy clay, lignite, and gypsum.	Low hills, sandy soils, heavily wooded with oaks. Forms Eastern Cross Timbers belt.	Yields small supplies of water, generally more mineralized than water from Dexter member. Water in some areas highly mineralized.
	Gulf series; Woodbine formation	Dexter member	0-110	Crossbedded ferruginous fine-grained sandstone, clay, and sandy clay.	do	Important source of water for domestic supplies in eastern Tarrant County. Water typically is high in iron.
		Unconformity				
	Comanche series; Washita group	Grayson shale	0- 85	Yellowish-brown and grayish-blue fossiliferous marl, clay, and thin limestone.	Slope, generally covered with wash from the Woodbine formation.	Not known to yield water to wells in Tarrant County.
	Comanche series; Washita group	Main Street limestone	0- 45	Hard white limestone and marl.	Conspicuous and extensive upland prairie, westward facing escarpment.	Do.
	Comanche series; Washita group	Pawpaw formation	0- 40	Reddish-brown shale characterized by dwarfed pyrite fossils.	Narrow treeless slope separating terraces on Weno and Main Street formations.	Do.
	Comanche series; Washita group	Weno clay	0- 75	Bluish-gray marl and limestone, fossiliferous.	Terrace topography produced by limestones of middle and upper parts of the Weno.	Do.
	Comanche series; Washita group	Denton clay	0- 35	Blue-gray marl, marly ledges, shell agglomerate in upper part.	Grassy slope between resistant Fort Worth and Weno formations.	Do.
	Comanche series; Washita group	Fort Worth limestone	0- 35	Alternating limestone and marl, fossiliferous.	Upland prairie and black-land soils.	Do.
	Comanche series; Washita group	Duck Creek formation	0- 90	Impure limestone and marl, which is blue when fresh and straw-colored when weathered. Fossiliferous with distinctive ammonites.	Bench topography produced by lower limestone unit. Upper marl forms slope separating the Duck Creek from Fort Worth limestone.	Do.
		Unconformity				
	Comanche series; Fredericksburg group	Kiamichi formation	0- 40	Blue and brownish - yellow marl, thin limestone and sandstone flags.	Grassy slope separating scarps of Goodland and Duck Creek formations.	Do.
	Comanche series; Fredericksburg group	Goodland limestone	0-130	Chalky-white, fossiliferous limestone, and blue to yellowish brown marl.	Prominent glaring-white escarpment along streams.	Do.

TABLE 2.- GEOLOGIC FORMATIONS IN TARRANT COUNTY--CONTINUED

System	Series and group		Formation and member	Thickness (feet)	Character of rocks	Topographic expression	Water-bearing properties
Cretaceous	Comanche series	Fredericksburg group	Walnut clay	0- 28	Shell agglomerate fossiliferous clay and limestone, sandy clay, and black shale.	Forms conspucuous escarpment and waterfalls in western Cross Timbers belt.	Not know to yield water to wells in Tarrant County.
		Unconformity					
		Trinity group	Paluxy sand	140-190	Fine-grained sand, shale, sandy shale, lignite, and pyrite.	Sandy soil, hummocky topography, heavily wooded with oaks.	Source of supply for most households, smaller cities, and some industries.
			Glen Rose limestone	250-450	Fine-grained lime, stone, shale, marl, and sandstone.	Not exposed in Tarrant County.	Sands yield small supplies to wells in Fort Worth and western Tarrant County. Water too highly mineralized east of Fort Worth.
			Travis Peak formation	250-430	Coarse to fine-grained sandstone, red shale, red and yellow clay at base.	do	Principal aquifer in Tarrant County. Yields large supplies for municipal and industrial purposes. Water in upper sands east of Fort Worth may be highly mineralized.
		Major unconformity					
Pennsylvanian	Undifferentiated			6,000-7,000	Gray, sandy shale, tight quartzitic sandstone, black limestone. Probably represents Strawn formation.	do	Not tested. Probably would not yield fresh water.

According to information furnished by oil companies and well-logging services, the Pennsylvanian rocks are probably of Strawn age and consist of black to gray shale, sandy shale, black limestone, and quartzitic sandstone. These rocks have not been tested as a source of water supply, but the interpretation of electric logs of oil tests, plus the reports by drillers that the sandstones are tightly cemented, indicates that the Pennsylvanian strata are not likely sources of ground water.

Cretaceous System

Comanche Series

The Cretaceous system has a maximum thickness of about 2,100 feet in Tarrant County, and is divided into the Comanche and the Gulf series. The Comanche series, which was named by Hill (1887, p. 298), includes eastward-dipping rocks of the Trinity, Fredericksburg, and Washita groups and forms the surface of the Western Cross Timbers and the Grand Prairie belts. Sedimentary rocks of the Comanche series are of near-shore or epicontinental origin and consist prevailingly of limestone. The Comanche series has a maximum thickness of about 1,600 feet at the eastern edge of Tarrant County.

Trinity group

The Trinity group, the outcrop of which underlies the Western Cross Timbers belt, includes the Travis Peak formation, the Glen Rose limestone, and the Paluxy sand and has a maximum thickness of about 1,070 feet in Tarrant County. The Travis Peak formation was deposited on an eroded surface by a shallow northward-transgressing sea. Seaward of this area of deposition, limestone, shale, and sand were deposited. These constitute the Glen Rose limestone, which thus represents the seaward facies of part of the Travis Peak formation, being deposited simultaneously to the north (Lozo, 1944, p. 518). Overlying the Glen Rose limestone is the Paluxy sand, which Scott (1930, p. 52) considers as a deposit of the regressive phase of the late Trinity seas.

The sands of the Trinity group are the most important sources of ground water in Tarrant County.

Travis Peak formation

The Travis Peak formation was divided by Hill (1901, p. 142) into the Sycamore sand member, the Cow Creek limestone member, and the Hensell sand member, in ascending order; but according to Hill (1901, p. 140) only the Sycamore and Hensell sand members or their equivalents are present in Tarrant County. The Travis Peak formation does not crop out in Tarrant County, and during the present investigation it was not found possible to differentiate the members of the Travis Peak on the basis of available drillers' and electric logs. The Travis Peak crops out in Parker County where the basal contact with the Pennsylvanian rocks is marked by a major unconformity. The upper contact with the Glen Rose limestone is apparently conformable, although the contact may be gradational and obscure.

The thickness of the Travis Peak formation increases downdip, ranging from about 250 feet at Lake Worth to 430 feet at Arlington (pl. 3). The formation maintains a fairly uniform thickness of about 370 to 400 feet along the strike (pl. 5).

The Travis Peak formation consists of a basal conglomerate of chert and quartz, grading upward into coarse-to fine-grained sand interspersed with varicolored shale. The sand strata generally are more thickly bedded in the lower part of the formation than in the upper part, and the percentage of sand varies laterally. Electric logs of 25 wells reveal that the total thickness of sand in the Travis Peak ranges from 80 feet in the western part of the county to 200 feet in the eastern part, or approximately one-third to one-half of the formation. Varicolored shale and clay, predominantly red, occur throughout the formation. The shale, which ranges in thickness from less than 5 feet to about 50 feet, grades vertically and laterally into sandy shale and sand, and individual shale beds cannot be correlated over a long distance (pls. 2 and 4).

The depth to the Travis Peak increases toward the east ranging from 550 feet at Lake Worth to 1,490 feet at Arlington. The average dip of the formation is about 40 feet per mile. West of Fort Worth the beds dip at a rate of 32 feet per mile whereas east of Fort Worth to the Dallas County line the beds dip at the rate of 44 feet per mile.

The Travis Peak formation is the most productive aquifer in the county. Although few wells are drilled to the Travis Peak, the quantity of ground water withdrawn from this formation greatly exceeds that taken from all other aquifers in the county. Water from the Travis Peak generally is satisfactory for most purposes, but the electric log of well F-79 in Arlington shows that the sands between 1,250 and 1,400 feet may contain highly mineralized water.

Glen Rose limestone

The Glen Rose limestone does not crop out in Tarrant County but is penetrated in wells drilled to the underlying Travis Peak formation. The Glen Rose consists primarily of calcareous sedimentary rocks of the neritic facies, but also sands and clays of the littoral facies. Local drillers include sands and shales of the upper part of the Travis Peak formation in the Glen Rose limestone but, as used in this report, the Glen Rose is restricted to the strata between and including the lowermost and topmost limestones in the Trinity group.

The Glen Rose limestone thickens eastward at a rate of about 7 feet per mile and southward at a rate of about 3 to 4 feet per mile. It ranges in thickness from about 250 feet in well D-6 to about 450 feet in well F-95, and has a reported maximum thickness of 595 feet in Dallas County, Adkins (1932, p. 308). The Glen Rose fingers out to the north (Adkins, 1932, p. 307) but thickens southward to about 800 feet near Waco. A moderate thickening southward in Tarrant County from 375 feet in well C-23 to 450 feet in well J-34 is shown in plate 5. The Glen Rose dips toward the southeast at a rate of about 40 feet per mile and is encountered at depths ranging from about 130 to 1,050 feet below the surface.

The Glen Rose is composed mainly of limestone but also contains sand, clay, sandy clay, and anhydrite. The limestones, which are medium to thick bedded, dense to highly porous, and in places sandy, are prominent in the lower part of the formation where they are interbedded with thin layers of clay and sandy clay. The limestones are thinner bedded in the upper part of the Glen Rose and are separated by beds of clay and sand which are considerably thicker than those in the lower part. The Glen Rose limestone becomes less calcareous and more sandy and clayey west of Fort Worth, thus marking the gradation from a neritic to a littoral environment. The sands in the Glen Rose west of Fort Worth are not as thickly bedded as those in the underlying Travis Peak formation and are generally fine grained and unconsolidated. A prominent sand bed underlying the uppermost limestone was found in well E-89 (pl. 3). Eastward the sand grades into a shaly sand and then into a limestone east of the county line; whereas westward toward the outcrop the limestone thins and the sand thickens to become a part of the Paluxy sand in Parker County. Anhydrite has been reported in varying thicknesses in the Glen Rose limestone. It ranges from a trace in well D-30 to a maximum reported thickness of 30 feet in well 5 at the city of Irving, Dallas County. Electric logs of the Irving well and others suggest that anhydrite may underlie a considerable part of Tarrant County.

The Glen Rose limestone is not an important source of water in Tarrant County. In the Lake Worth-Eagle Mountain Lake area the Glen Rose furnishes small quantities of water to wells for domestic use. East of Fort Worth wells were reported to obtain highly mineralized water from the Glen Rose. Highly mineralized water was reported by the driller to have been encountered in well F-89 at a depth of 1,120 to 1,140 feet. The drillers' logs and electric logs of nearby wells, however, reveal that the water is from a sand in the upper part of the Travis Peak formation. Electric logs indicate that the Glen Rose is not a source of fresh water in the eastern part of the county.

Paluxy sand

The Paluxy sand crops out in the northwestern part of the county; it forms the surface of the Western Cross Timbers belt in that area and underlies the rest of the county. About one-half to three-fourths of the Paluxy is sand; the remainder consists of clay, sandy clay, shale, lignite, silicified wood fragments, and nodules of pyrite. The sand is predominantly fine grained, homogeneous, in places crossbedded, and generally unconsolidated, although some sand strata are more indurated than others. In general, the coarse-grained sand is in the lower part of the Paluxy and grades upward into fine-grained sand with variable amounts of shale and clay. Mechanical analyses of 11 samples of sand from various horizons in the Paluxy indicate that approximately 80 percent of the sand is fine-grained. Weathered exposures of the clay generally are reddish and of an earthy texture; the unweathered clay generally is greenish and waxy.

The Paluxy sand ranges in thickness from 140 to 190 feet and averages about 160 feet in Tarrant County (pl. 5). Northward in Denton and Cooke Counties the Paluxy sand, Glen Rose limestone, and Travis Peak formation are not differentiated; southward the Paluxy thins and, according to A. M. Hull (personal communication), it is extremely thin at Whitney Dam, Hill County. The approximate altitude of the Paluxy sand in Tarrant County is shown in figure 4. The Paluxy dips uniformly E. 7° S. at a rate ranging from 35 to 40 feet per mile and averaging 37 feet per mile. It is encountered at increasing depths eastward, reaching a maximum depth of about 900 feet in well F-95.

The Paluxy sand may be divided into upper and lower sand members. Electric logs in plate 3 show that the upper sand member maintains a relatively uniform thickness of about 55 feet despite variations of lithology over short distances. The sands in the upper part of the Paluxy are reported by drillers to be fine-grained and shaly. Most wells drilled to the Paluxy, therefore, are completed in

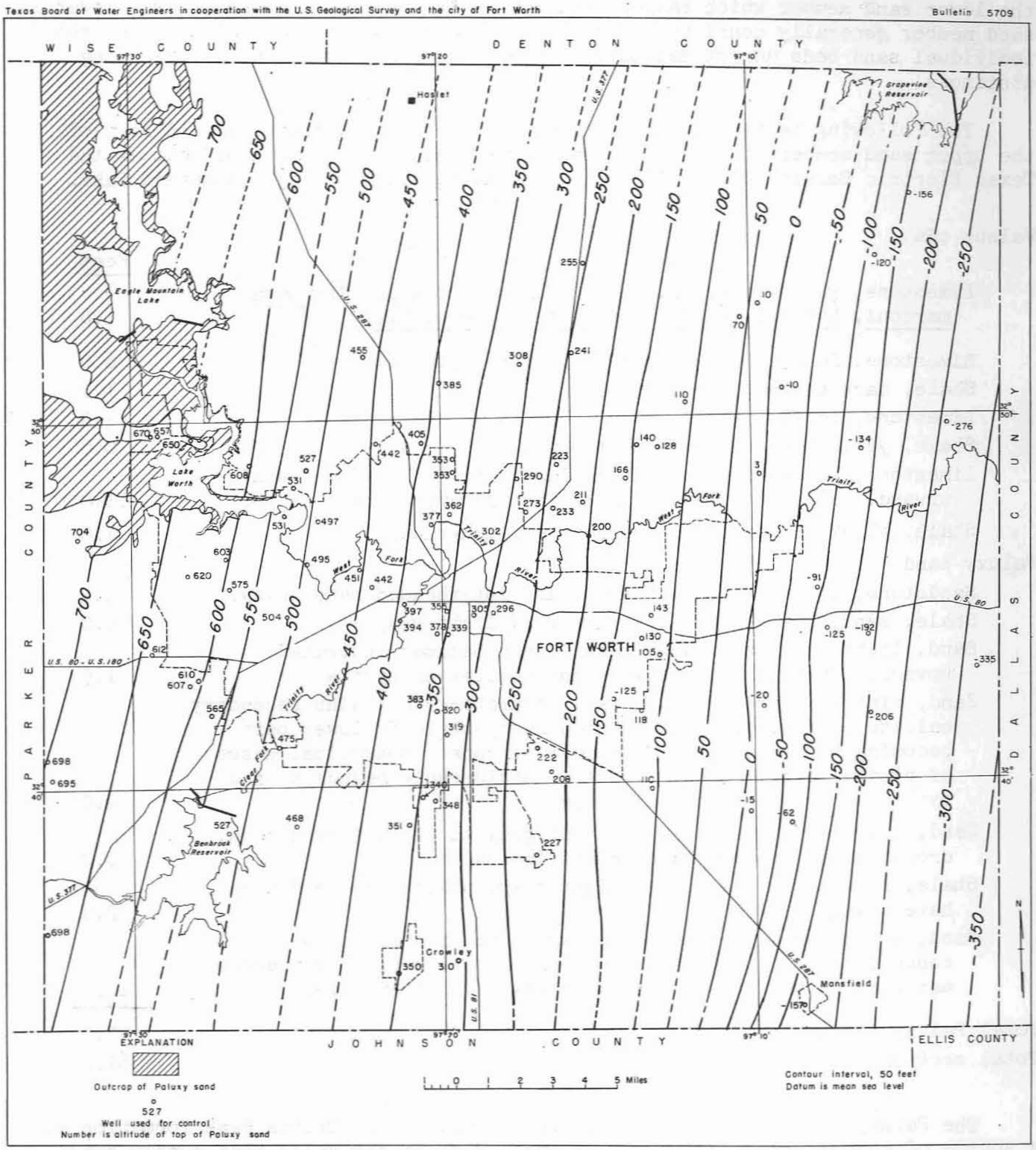

FIGURE 4.- Approximate altitude of the top of the Paluxy sand in Tarrant County, Tex.

the lower sand member which ranges from 100 to 120 feet in thickness. The lower sand member generally consists of two separate and distinct sand strata, but the individual sand beds do not maintain constant thickness or lithology over long distances.

The following section, which includes parts of the Walnut clay and most of the upper sand member of the Paluxy sand, was measured at a railroad cut at the Texas Electric Service Company's steam generating plant on Eagle Mountain Lake.

	Feet
Walnut clay	
Limestone, yellowish-buff, fossiliferous, contains *Gryphaea marcoui*, *Exogyra texana*, and *Pecten irregularis*.	1.0
Limestone, fossiliferous, and yellowish-buff shale.	6.0
Shale, dark brown to yellow.	1.0
Limestone, fossiliferous.	3.0
Shale, yellowish-buff, fossiliferous.	0.6
Limestone, blue-gray, indurated, fossiliferous, becomes shaly upward. Some interbedded black fossiliferous shale at top.	11.0
Shale, black, fossils, weathers to grayish-blue.	1.0
Paluxy sand	
Sandstone, indurated, light gray; and interbedded sandy clay.	1.5
Shale, sandy, dark gray, weathers very light gray.	5.0
Sand, light gray, and sandy clay. Sand becomes indurated upward. Contains concretions and nodules of pyrite.	1.5
Sand, pink to light gray and tan, indurated. Contains secondary calcite near top and interbedded sandy shale in lower part becoming more shaly toward middle of zone. Botryoidal masses of pyrite scattered throughout. Considerable magnesite and pyrite in basal sandstone member.	9.0
Sand, coarse-to fine-grained, light gray to pink, ferruginous, crossbedded, in part massive and indurated.	8.0
Shale, bluish-gray, weathers light gray; unweathered surfaces have a waxy texture.	2.5
Sand, varicolored, medium to fine-grained, indurated to unconsolidated. Contains inclusions of pyrite and carbonaceous material. Contains considerable shale in upper 4 feet.	10.0
Total Paluxy measured	37.5
Total section measured	61.1

The Paluxy sand is second in importance only to the Travis Peak formation as a source of ground water in Tarrant County. Most of the wells that supply homes, smaller municipalities, and industries that require small quantities of water obtain ground water from the Paluxy. In the Lake Worth-Eagle Mountain Lake area and west to the county line, the Paluxy in places yields somewhat mineralized water, and many domestic supplies are obtained from the underlying Glen Rose limestone and Travis Peak formation.

Fredericksburg group

The Fredericksburg group in Tarrant County includes the Walnut clay, the Goodland limestone, and the Kiamichi formation, in ascending order. During the deposition of the Fredericksburg group, the seas were epineritic, or shallow neritic, the depths ranging between 7 and 20 fathoms. (See Lozo, 1944, p. 520.) The sedimentary rocks of the Fredericksburg group are mainly limestone and marl and lesser amounts of sandstone flags, shale, and shell aggregate. The thickness of the group ranges from 135 to 185 feet, increasing southward; and the rocks dip southeastward at a uniform rate of 38 feet per mile. The Kiamichi wedges out toward the south between the Goodland and the overlying Washita group.

A comparison of the lithologic properties of the Fredericksburg group observed at exposures in western Tarrant County and the characteristic resistivity of these rocks is shown in the electric log of well F-89 (fig. 5).

The Fredericksburg group is not a source of ground water in Tarrant County.

Walnut clay

The Walnut clay lies unconformably on the Paluxy sand. The Walnut crops out in the west-central and northwestern part of the county where it forms the conspicuous caprock or escarpment of the Western Cross Timbers belt. It also forms the stream bed in much of the Clear Fork of Trinity River, in parts of the West Fork of Trinity River, and in Marys Creek.

The Walnut clay has a relatively constant thickness of 28 feet in the subsurface. This conforms closely to the 27 feet assigned to the Walnut by Scott and Hawley (in Adkins, 1932, p. 330), but is considerably less than the 134 feet of Hill (1901, p. 208) and the 100 feet of Winton and Adkins (1919, p. 27), both of whom have included part of the Paluxy sand in the Walnut clay.

The Walnut clay referred to as fossil lime or caprock by local drillers consists mainly of a characteristic and readily identified shell agglomerate containing an abundance of <u>Gryphaea marcoui</u> and <u>Exogyra texana</u>. The lower part of the shell agglomerate has asymmetrical ripple marks of relatively large amplitude, an excellent exposure of which may be seen in the bed of the Clear Fork of Trinity River at Wheatland. It also contains brown sandy clay, thinly-bedded fossiliferous clay, black fissile shale, and iron-stained earthy limestone.

The Walnut clay is not a source of ground water in Tarrant County.

Goodland limestone

The Goodland limestone, which was named by Hill (1891, p. 88), is considered to be the North Texas equivalent of the Comanche Peak and Edwards limestones of of Central Texas. The Goodland, which conformably overlies the Walnut clay and is exposed over a considerable area between the West Fork and Clear Fork of Trinity River west of Fort Worth, forms large rounded hills that are capped by the Duck Creek formation, low round-topped buttes in the flood plains, or steep westward-facing escarpments. Characteristic of the outcrop of the Goodland is the sharp contact between the glaring white Goodland limestone and the gentle grassy slope of the overlying Kiamichi formation (pl. 6). The Goodland thins downdip but thickens southward, ranging in thickness from 70 feet in well C-23 to 130 feet in well J-34.

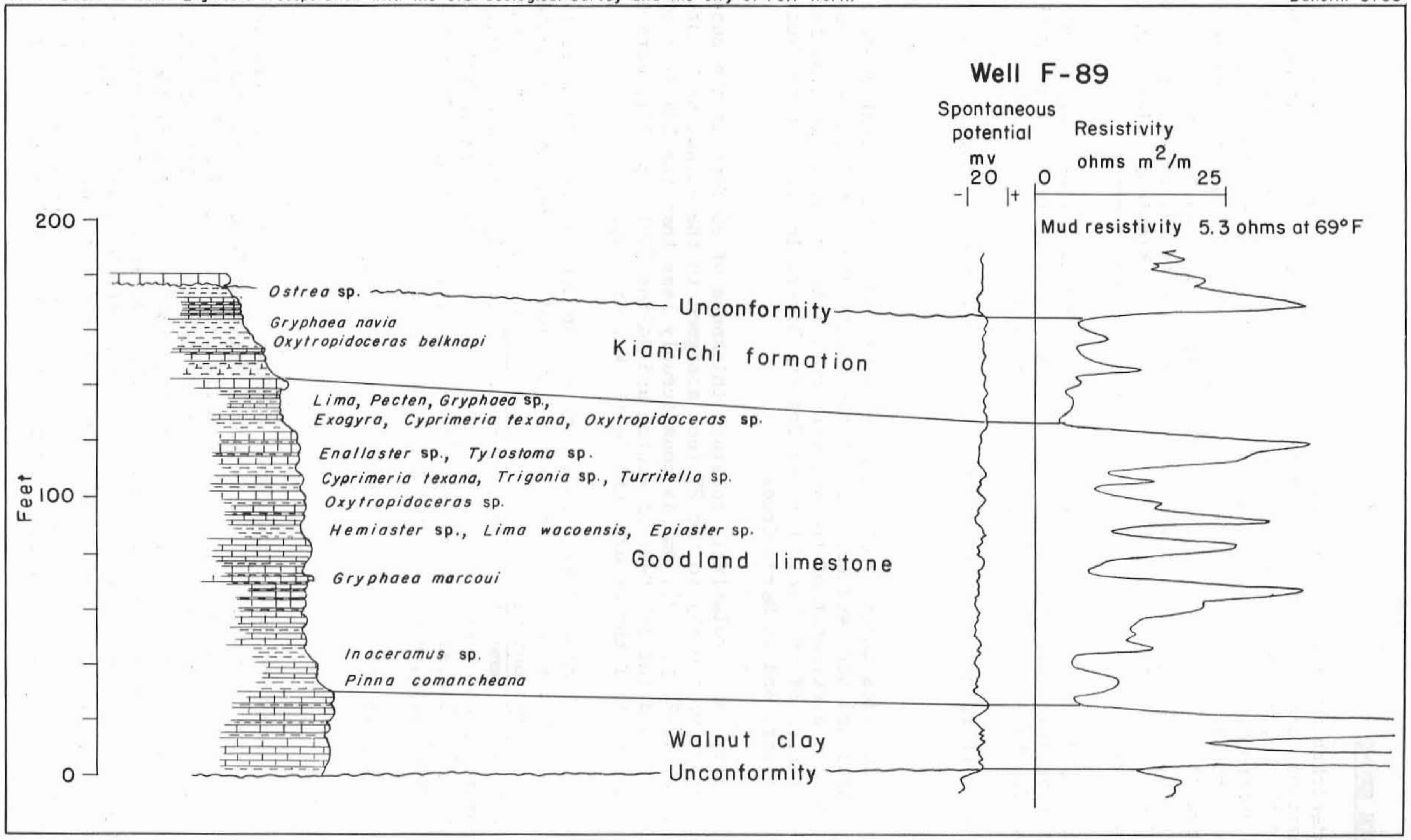

FIGURE 5.- Comparison of lithologic properties and resistivity of the Fredericksburg group, Tarrant County, Tex.

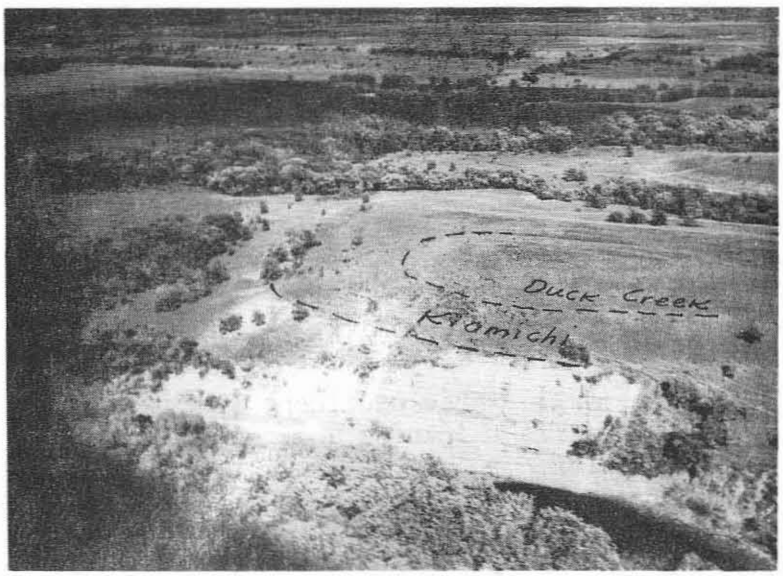

PLATE 6 - Contact between Goodland limestone and Kiamichi formation north of Benbrook Reservoir, Tarrant County

The Goodland limestone typically consists of chalky thin- to massive-bedded fossiliferous resistant limestone and blue to yellowish-brown marl. The limestone has a fractured appearance due to extensive jointing or flaking, and some of the limestone layers have a characteristic nodular or ropy texture. Fossils, mostly mud casts, are abundant except in the upper part of the limestone. Where exposed in Marys Creek (pl. 7) and near Benbrook the Goodland is capped by a hard, resistant crystalline rather unfossiliferous limestone. In the Benbrook area, Hill (1901, p. 223) considers the upper 4 feet to be the northern part of the Edwards limestone. About 40 feet above the base of the Goodland is a shell agglomerate 1.6 feet thick which has very much the same lithology and sequence of fossils as the shell agglomerate of the Walnut clay. The agglomerate in the Goodland is a persistent and mappable unit, although not readily identified in well logs.

The following section, which is shown diagramatically in figure 6, was measured on the south bank of Marys Creek, 0.8 mile southeast of Westland.

Goodland limestone	Feet
Limestone, chalky white, ropy or nodular, containing thin layers of marl. Upper part is more dense, massive, and compact, and is sparsely fossiliferous.	17.1
Marl, yellowish-white, and intervening chalky-white, ropy limestone.	23.9
Limestone and intervening marl. Three prominent limestone layers from 1.0 to 1.8 feet in thickness and marl layers not more than 0.4 foot thick.	12.9
Marl, bluish-gray on exposure.	7.6
Limestone, massive, nodular, chalky-white on exposure.	8.6
Limestone and thin marl layers. Basal limestone is *Gryphaea* zone, 1.6 feet thick; 2.3 feet above top of shell bed is a persistent though considerably less fossiliferous limestone.	6.5
Marl, blue-gray at base, followed by intervening limestone and marl layers, none of which are more than 2 feet thick. A slightly fossiliferous limestone is 6.5 feet above the base and 4.6 feet below the overlying *Gryphaea* zone.	11.3
Limestone, highly fractured, weathers to a chalky-white.	4.8
Talus covered slope. Borings indicate blue to gray marl and limestone layers.	24.3
Total thickness of Goodland	117.0

The Goodland limestone is not a source of ground water in Tarrant County.

Kiamichi formation

The Kiamichi formation crops out in a narrow, sloping band in the bluffs overlooking the Clear Fork and West Fork of the Trinity River and in the hillside between White Settlement and Wheatland. The contacts of the Kiamichi are sharply defined in Tarrant County by the glaring white Goodland limestone below and the scarp produced by the basal limestone of the Duck Creek formation above.

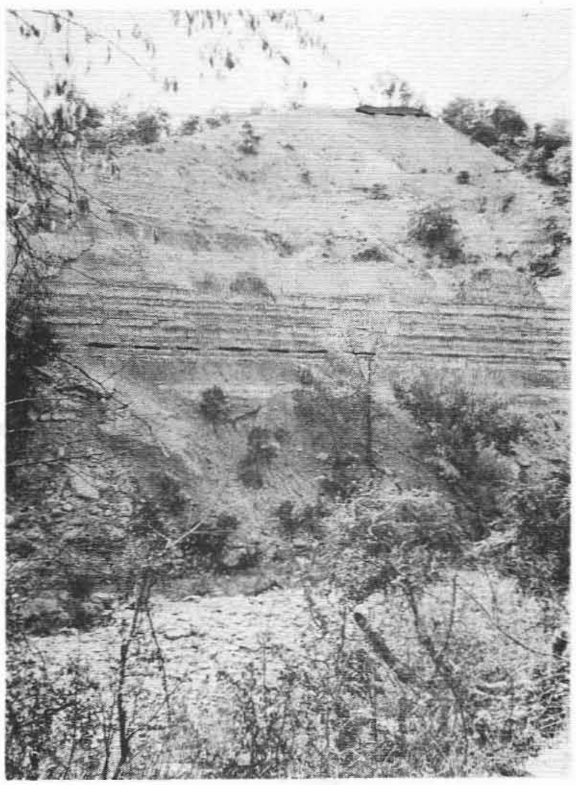

PLATE 7.- Exposure of Goodland limestone in Marys Creek, 0.8 mile south of Westland, Tarrant County

Texas Board of Water Engineers in cooperation with the U.S. Geological Survey and the city of Fort Worth — Bulletin 5709

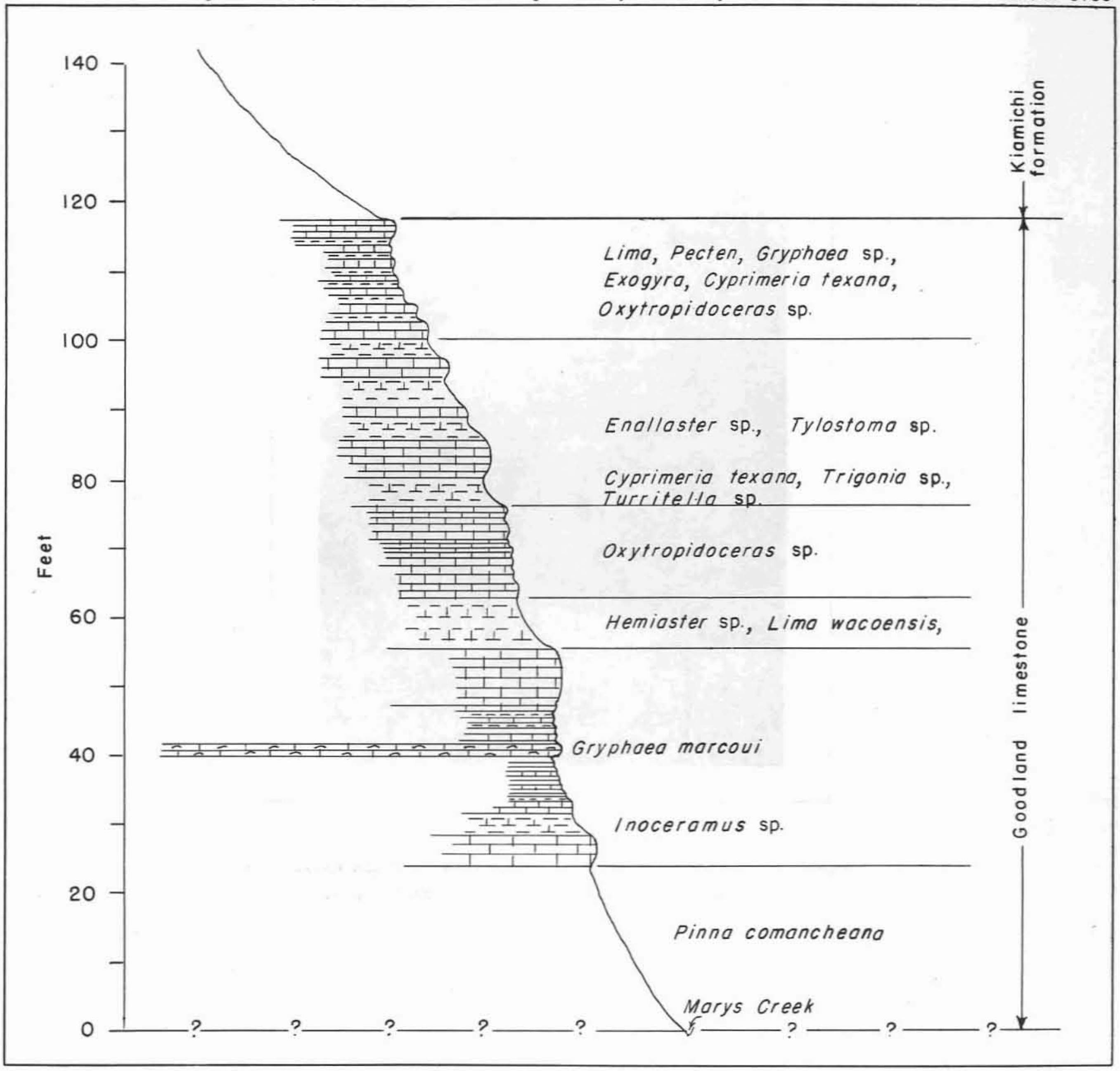

FIGURE 6.- Goodland limestone along Marys Creek, 0.8 mile southeast of Westland, Tarrant County, Tex.

The Kiamichi formation decreases in thickness southward, ranging from 40 feet in well C-23 to 32 feet in well J-34. At Fort Worth the formation has a measured thickness of 36.7 feet and appears to maintain approximately this thickness downdip (pl. 5).

The Kiamichi consists of dark blue to brownish-yellow marl, thin limestone, and flaggy sandstone. The lower half of the formation is marly, contains thin limestone and sandstone layers, overlain by 8 feet of thin limestone ledges alternating with marl in which Gryphaea navia is abundant and distinctive. The upper part of the formation is marly and less fossiliferous. The following section was measured in a quarry south of the Trinity Portland Cement Co. in north Fort Worth.

Kiamichi formation	Feet
Marl, yellowish-brown.	7.3
Shale, yellowish-brown, containing streaks of marly shale. At the middle is a thin layer (0.15 foot) of light-gray sandy marl. Contains Gryphaea sp.	5.8
Limestone, weathers to grayish-white, very fossiliferous at base, containing Gryphaea navia, G. corrugata, and Ostrea sp. Forms top of prominent ledge.	0.7
Shale, laminated, yellowish-brown, containing in the middle a thin seam of gray crystalline limestone.	1.6
Limestone, forms prominent ledge; fossiliferous.	0.3
Shale, yellowish-brown, somewhat marly and resistant at base. Large Gryphaea sp. at top.	1.0
Limestone, iron-stained, forms prominent ledge; light gray on fresh exposure; slightly fossiliferous.	0.4
Shale, thinly laminated, fossiliferous at top. Fossils are small and fragmental, largely Gryphaea sp.	0.8
Marl, limy, indurated, weathers to grayish-white; fossiliferous.	0.1
Shale, yellowish-brown, with two light gray sandstone flags less than 0.2 foot thick.	1.9
Limestone, gray, crystalline, non-fossiliferous, containing interbedded light gray to yellowish-gray shale.	1.1
Shale, bluish-gray to yellowish-brown, carbonaceous. Base is a fossiliferous marly shale containing secondary calcite. Gryphaea navia and Oxytropidoceros belknapi at top.	3.9
Shale, blue gray, weathering to dark carbonaceous color, containing a lime marl layer 0.15 foot thick.	6.3
Shale and marly clay, thinly laminated, predominantly bluish-gray but weathers to yellow brown. Several thin sandstone flags near base.	3.1
Marl, yellowish-brown, gray limestone and flaggy sandstone. Limestone 0.3 foot thick at base overlain by marl. Flaggy sandstone at top.	2.4
Total thickness	36.7

The Kiamichi formation is not a source of ground water in Tarrant County.

Washita group

The Washita group, which is the youngest group of rocks in the Comanche series, constitutes all the upland surface of the Grand Prairie belt. The group includes, in ascending order, the Duck Creek formation, the Fort Worth limestone, the Denton clay, the Weno clay, the Pawpaw formation, the Main Street limestone, and the Grayson shale. The Washita group consists of alternating limestone and marl of the normal neritic facies which produce a characteristic terrace or "cuesta" topography. The thickness of the Washita group ranges from 318 to 360 feet, decreasing southward.

The lithologic properties of the Washita group observed at outcrops in the vicinity of Fort Worth are compared in figure 7 to the resistivity of these sediments as shown in the electric log of well F-89.

The Washita group is not a source of ground water in Tarrant County.

Duck Creek formation

The Duck Creek formation, which was named by Hill (1891, p. 516), crops out in a narrow belt along the Clear Fork and West Fork of Trinity River and caps the upland areas between White Settlement and Wheatland. It is exposed also along numerous streams that cut into the uplands of the Grand Prairie belt. The Duck Creek appears to be conformable on the underlying Kiamichi formation, but Winton and Scott in Adkins (1932, p. 349) report rounded pebbles, grit, and transported debris at the contact, which suggest a disconformity.

The Duck Creek formation may be divided into two lithologic members: a lower thickly bedded, fucoidal limestone member, which is about 40 feet thick at the outcrop, and an upper marl member containing thin marly limestone layers, which is about 16 feet thick at the outcrop. The observed thickness of the formation in Tarrant County ranges from 56 feet at the outcrop to 90 feet in well C-23. It appears to thicken downdip but thins along the strike toward the south.

The lower limestone member of the Duck Creek formation consists of a series of compact soft impure fucoidal limestone beds, each 6 to 12 inches thick and separated by marl seams. The limestone and marl are blue to gray in fresh exposures but they weather to a straw color. The limestone is more resistant and forms prominent ledges on weathering. The lower member is characterized by an abundance of distinctive ammonites. The basal limestone unit contains the candy-cane ammonite Hamites sp., overlain by a zone of large Desmoceros brazoense. The remainder of the section contains an abundance of the ammonites Elobiceras sp. and Pervinquieria trinodosa.

The upper marl member of the Duck Creek is readily identified in the field, as it crops out in a gentle slope between the overlying Fort Worth limestone and the underlying lower limestone member of the Duck Creek formation. The upper marl member is characterized by large branching fucoids, numerous specimens of the large echinoid Hemiaster sp. Hemiaster sinplex, and the brachiopod Kingena wacoensis, the uppermost occurrence of which marks the approximate contact between the Fort Worth limestone and the Duck Creek formation. Ammonites are less common in the upper marl member than in the lower limestone member.

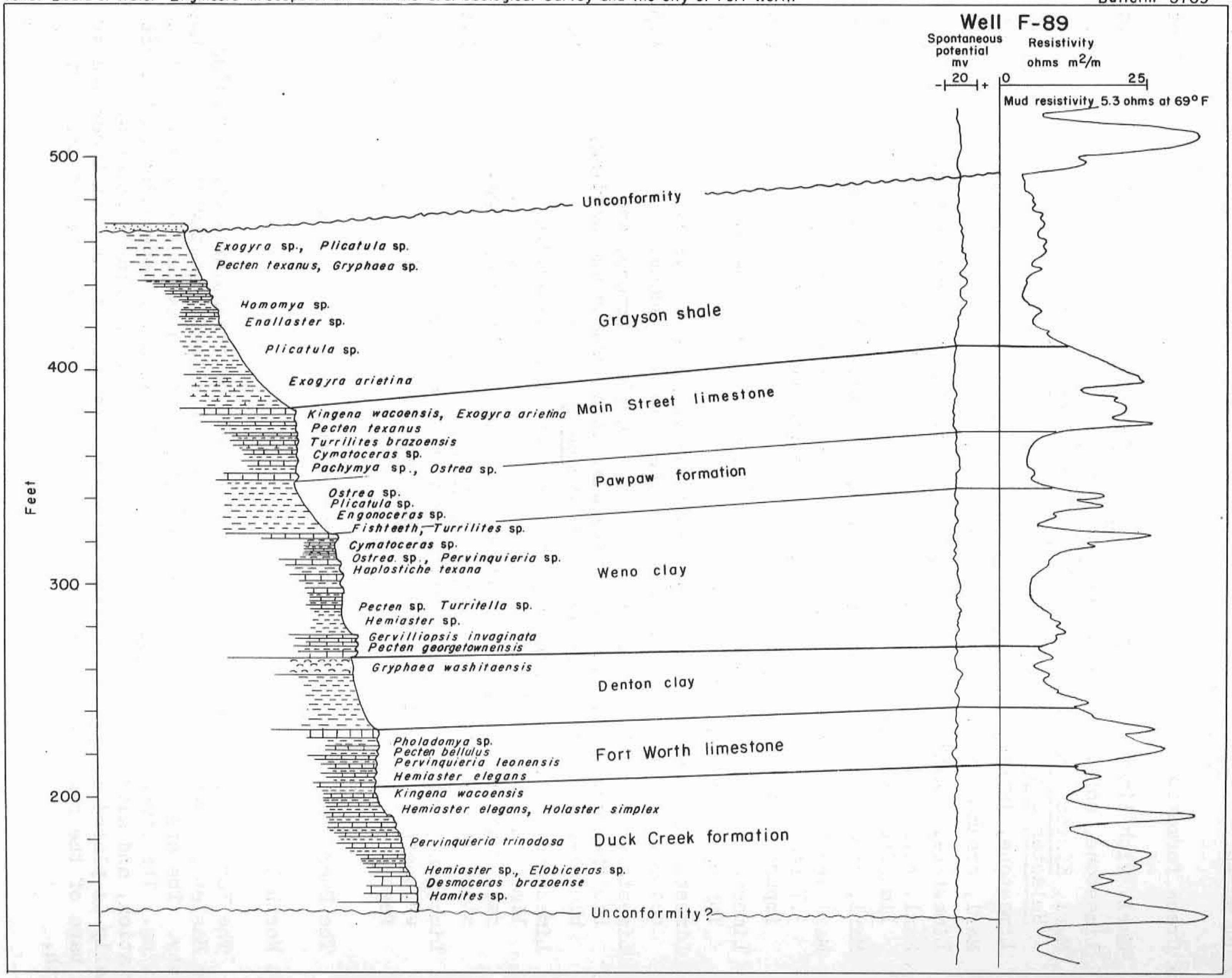

FIGURE 7.-Comparison of lithologic properties and resistivity of the Washita group, Tarrant County, Tex.

The following composite section was measured in the quarry of the Trinity Portland Cement Co. and at an exposure on Inwood Drive in the Westcliff Addition of Fort Worth.

Duck Creek formation	Feet
Marl, with limestone fragments, Kingena wacoensis, Pecten, sp.	1.6
Limestone, soft, impure, Kingena wacoensis.	0.7
Marl, Kingena wacoensis, Turritella, sp., Hemiaster sp., Holaster simplex.	1.5
Limestone, impure, sandy.	0.5
Marl, cream colored.	7.1
Limestone, heavily iron-stained, platy appearance on weathering.	2.0
Marl, straw colored, and limestone, evenly but thinly bedded; limonite concretions.	5.0
Marl, straw colored, with three limestone seams 0.2 foot thick.	3.0
Marl and bluish impure limestone, becoming more marly in upper 3.7 feet of zone. Top of zone is a weathered, chalky-white impure limestone 0.7 foot thick.	8.4
Limestone, compact, impure weathers to a chalky whitish-gray. Top of lower limestone member.	1.5
Limestone and marl. Limestone, bluish-gray, compact, evenly bedded, and impure, separated by three thin marl seams.	4.5
Limestone and marl. Limestone is ropy, fucoidal, impure, and bluish-gray. Marl seams are irregular in thickness and bedding, bluish-gray on fresh exposure. Gryphaea sp.	6.7
Limestone, impure, bluish-gray, not as compact as underlying limestone, with thin bluish-black marl seams. Limestone and marl weathers to yellowish-white. Maximum thickness of limestone is 1.9 feet. Desmoceros brazoense.	10.6
Limestone, impure, compact, bluish-gray on fresh exposure, weathers to a yellowish-white. Hamites sp. in basal 2 or 3 feet.	3.4

The Duck Creek formation does not yield water to wells in Tarrant County.

Fort Worth limestone

The Fort Worth limestone crops out in a belt of irregular width extending from Haslet southward through Fort Worth and then slightly southwestward to Johnson County. The area of outcrop forms an upland prairie suitable for farming and grazing. The limestone is apparently conformable with the underlying Duck Creek formation, and although the contact is gradational and generally obscure, it usually is placed at the top of the upper marl sequence of the Duck Creek and at the base of the regularly alternating limestone and marl sequence of the Fort Worth.

The Fort Worth limestone is about 25 feet thick at its most complete exposure at Lancaster and Rosedale Streets in Fort Worth. It thins to the south, however, ranging from 35 feet in well C-23 to 25 feet in well J-34. South of Tarrant County the Fort Worth is considered equivalent to part of the Georgetown limestone.

The Fort Worth consists of fairly regularly alternating limestone, bluish on fresh exposure but weathering grayish white, and marl, the contacts between the individual beds being somewhat gradational. The limestone is in layers 6 to 16 inches thick, and the marl beds generally are less than a foot thick. The Fort Worth limestone is characterized by the fossils Hemiaster elegans, Pecten bellula, and Pervinquieria leonensis, and an abundance of fucoids and yellowish-brown iron stains.

The Fort Worth limestone is not a source of ground water in Tarrant County.

Denton clay

The Denton clay has not been mapped separately from the Weno clay because of its relatively small area of outcrop. However, the outcrop may be seen in a narrow band along the western edge of the Denton, Weno, and Pawpaw unit as shown on plate 1. The Denton apparently is conformable with the overlying Weno clay and the underlying Fort Worth limestone. The Denton has a relatively constant thickness in Tarrant County; however, it thins slightly southward from 35 feet in well C-23 to 30 feet in well J-34.

The Denton clay consists of blue-gray marl, laminated in places, with several resistant marl ledges near the base and in the middle. The upper 6 feet of the Denton is almost entirely a shell agglomerate of Gryphaea washitaensis and a few Ostrea sp.

The following complete section was measured in Cobb Park along Sycamore Creek in Fort Worth.

Denton clay	Feet
Marl, blue-gray, shelly, indurated, forms a more or less prominent ledge which breaks off into slabs.	0.2
Marl, shelly, slightly indurated.	3.6
Marl, fossiliferous.	2.7
Marl, brownish-yellow, unfossiliferous.	2.5
Marl, sandy to calcareous, laminated and locally slightly indurated. A slightly indurated light gray marl 1.0 foot in thickness occurs 12.2 feet above base but does not form a prominent ledge.	15
Marl, indurated, weathers to light gray and forms a prominent ledge.	0.4
Marl, blue-gray, laminated, sandy, becoming calcareous and considerably plastic toward the top. Locally the marl is slightly indurated and exhibits a cuboidal jointing.	8.5
Marl, indurated, light-gray on fresh exposure, slightly fossiliferous, Pecten sp., Gryphaea washitaensis.	0.4
Marl, laminated, blue-gray, somewhat sandy, Pecten sp., Lima sp., Enallaster sp.	1.5
Total thickness of Denton clay	34.8

The Denton clay is not a source of ground water in Tarrant County.

Weno clay

The Weno clay crops out in the middle of Tarrant County in a belt which narrows toward the south. The Weno is apparently conformable with the Denton clay below and the Pawpaw formation above, and the three formations have been shown as a unit on plate 1. The contact between the Weno and the Pawpaw is readily identified in the field by the projecting shelf at the top of the Weno formed by the erosion of the relatively soft shales of the Pawpaw.

The Weno clay is about 60 feet thick at its outcrop at Sycamore Creek, but thickens in the subsurface to about 75 feet in well F-39. It also thickens toward the north, reaching a maximum thickness of about 70 feet in Tarrant County.

The Weno clay, which is composed of bluish-gray marl and several prominent limestone beds, may be divided into three parts. The lowest 11 feet consist of three prominent limestone beds that are 2 feet or less in thickness and are separated by bluish-gray marl. The uppermost limestone is distinctive because of the abundance of the razor clam Gervilliopsis sp. The middle part of the Weno consists of 29 feet of marl and several prominent limestone ledges containing Haplostiche texana in the upper part. The upper part of the Weno, which is 19 feet thick, consists of grayish-white limestone and interbedded marl and contains many of the nautiloid Cymatoceras sp. and the pelecypod Ostrea carinata.

The following section was measured along Sycamore Creek at Seminary Drive in Fort Worth.

Weno clay	Feet
Limestone, chalky white, and marl. Upper part forms a projecting shelf that is 2.3 feet thick. Weathers to yellowish-cream, highly fractured. Pervinquierea sp., Cymatoceras texanum, Ostrea carinata	11.3
Limestone, indurated, grayish-white, weathers to a yellowish-gray, slightly fossiliferous, interbedded with brownish marl. Top limestone forms somewhat prominent bench.	3.8
Marl, yellowish-brown and grayish-white limestone; contains Tapes sp., Kingena sp., and Pecten sp.	4.4
Limestone, weathers to yellowish-white.	0.9
Marl, bluish-gray in fresh exposure, upper part slightly indurated. Haplostiche texana characteristic.	1.5
Limestone, massive, weathers to creamy white, fucoidal. Thin marl beds occur 1.3 feet from base of limestone.	2.6
Marl, containing three prominent limestone or indurated marl layers, each 0.4 foot thick or less.	3.0
Limestone, massive, weathers to chalky, creamy white, fucoidal.	1.8
Marl, bluish-gray, containing some thin indurated marl layers, Tylostoma sp.	3.9
Limestone, hard, dense, crystalline, gray on fresh exposure, flaggy on top.	0.8

(continued on next page)

Weno clay - continued

	Feet
Marl, Hemiaster sp., Turritella ventrivoluta, Pecten sp.	1.9
Limestone, hard, gray, in part highly iron-stained.	1.0
Shale, bluish-gray ("pipe clay"), containing about midway in the unit a partly indurated sandy marl about 0.2 foot thick.	11.8
Limestone, hard, crystalline, dark gray on fresh exposure, weathers brown. Contains abundant Gervilliopsis invaginata.	1.8
Shale, bluish-gray.	4.6
Limestone, chalky, yellowish-white.	1.0
Shale, bluish-gray ("pipe clay").	2.8
Limestone, chalky, yellowish-white, bluish-gray on fresh exposure, contains Pecten georgetownensis.	1.0
Total thickness of Weno clay	59.9

The Weno clay is not a source of ground water in Tarrant County.

Pawpaw formation

The Pawpaw formation crops out in Tarrant County in a narrow belt at the western edge of the upland formed by the overlying Main Street limestone. Because of the small area of outcrop, the Pawpaw is shown on plate 1 with the underlying Weno and Denton clays. The outcrop of the Pawpaw is relatively treeless and generally steeply sloping. In stream cuts the Pawpaw slopes recede markedly from the face of the terrace formed by the upper part of the Weno to form amphitheater-like basins.

The Pawpaw thins southward in the outcrop from 30 feet in the northern part of the county to about 15 feet in the southern part. In the subsurface the thickness ranges from about 40 feet in well C-23 to about 18 feet in well J-34 (pl. 5).

The Pawpaw formation is composed of reddish-brown shale, a few thin flaggy sandstones in the lower third, and ironstone layers. Nodules and pebbles of ironstone and jasper are more abundant on the outcrop north of the Trinity River than south of the river. The most distinguishing characteristic, other than the color, is the occurrence of a dwarfed "pyrite" fauna of ammonites, pelecypods, and gastropods.

The Pawpaw formation is not a source of ground water in Tarrant County.

Main Street limestone

The Main Street limestone crops out in Tarrant County in a belt of irregular width at the western edge of the Eastern Cross Timbers belt. It underlies a conspicuous and extensive upland prairie with a westward-facing escarpment, and is similar in appearance to the upland formed by the Fort Worth limestone. The Main Street is apparently conformable with the underlying Pawpaw formation and the overlying Grayson shale.

Unlike the underlying formations of the Washita group, the Main Street limestone thickens southward, ranging in thickness from about 35 feet in well C-23 to 45 feet in well J-34 (pl. 5). In the Sycamore Creek section at Fort Worth the Main Street is 32 feet thick.

The Main Street consists of hard white limestone beds which are 0.5 foot to 2 feet thick and are separated by thin- to thick-bedded marl. The marl beds are more massive and numerous in the lower part of the formation.

The Main Street limestone has a characteristic zonal sequence of faunas in Tarrant County. The upper part is characterized by the brachiopod Kingena wacoensis; the pelecypod Exogyra arietina is abundant in the upper 10 feet and ranges upward into the Grayson shale; the large spiral ammonite Turrilites brazoensis occurs abundantly in the middle part; Ostrea sp. and Pachymya sp. characterize the basal part. The nautiloid Cymatoceras sp., the echinoid Holectypus sp., and the pelecypod Pholadomya sp. are found sparingly throughout the formation.

The Main Street limestone is not a source of ground water in Tarrant County.

Grayson shale

The Grayson shale crops out in a gentle slope separating the outcrops of the Woodbine formation and the Main Street limestone. The slope generally is overwashed and in many places obscured by the sand and vegetation of the Woodbine formation. The Grayson is overlain unconformably by the Woodbine.

The Grayson shale, like the underlying Main Street limestone thickens toward the south, reaching a maximum thickness of 85 feet in Tarrant County. In Johnson County it has an estimated thickness of 100 feet (Winton and Scott, 1922, p. 28).

The Grayson shale consists of yellowish-brown and grayish-blue fossiliferous marl, clay, and thin limestone layers. The basal part is very fossiliferous, containing an abundance of the "rams-horn" fossil Exogyra arietina. An upper marl member exposed in a cut west of Village Creek on the Crowley-Rendon Road has several thin marly limestone layers and contains in relative abundance the large ribbed Pecten texanus, Plicatula sp., Gryphaea sp., Holectypus sp., and Enallaster sp.

The Grayson shale is not a source of ground water in Tarrant County.

Gulf Series

The Gulf series was named by Hill (1887, p. 298) and is represented in Tarrant County by the Woodbine formation and Eagle Ford shale. The rocks of the series, which have a maximum thickness of 510 feet, form the surface of the Eastern Cross Timbers and the Black Prairie belts.

Woodbine formation

The Woodbine formation, which was named by Hill (1901, p. 292), crops out in the eastern third of Tarrant County in a heavily timbered sandy area called the Eastern Cross Timbers belt. West of this belt, remnants of the Woodbine cap isolated low hills or knobs. The Woodbine has been subdivided (Hill, 1901, p. 297) into the Dexter member below and the Lewisville member above. Bergquist (1949) further subdivided the Woodbine in ascending order into the Dexter member, overlain by a bed called the rainbow clay, the Red Branch member, the Lewisville member, and the Templeton member from exposures in Cooke, Grayson, and Fannin Counties. However, because of the difficulty in correlating the Woodbine in Tarrant County with the Woodbine farther north, the Lewisville member in this report includes all the strata above the Dexter member. The Woodbine formation has a maximum thickness of 310 feet in Tarrant County, decreasing in thickness southward.

Dexter member.- The Dexter member of the Woodbine formation consists of 80 to 100 feet of extensively crossbedded, massive to thin-bedded fine-grained ferruginous sandstone and laminated and sandy clay. In the subsurface the sands are generally white and friable and contain iron and manganese minerals. These minerals oxidize when exposed, giving a buff to reddish-brown color to the more or less consolidated sandstone. The sands generally are more massive in the lower part of the member but, because the beds are lenticular, the lithology is not constant over a wide area. Two prominent sand beds each about 25 feet thick encountered near the base of the Dexter in well F-39 thin considerably toward the outcrop, and in well F-35 are replaced in part by clay and sandy clay beds (pl. 2). The top of the Dexter member cannot be differentiated accurately from the overlying Lewisville member.

Lewisville member.- The Lewisville member of the Woodbine formation consists of at least 200 feet (Adkins, 1932, p. 415) of laminated lignitic and ferruginous sandstone, vari-colored clay, and sandy clay interbedded with seams of lignite and gypsum. The sand and clay strata are considerably thinner than those in the underlying Dexter member. The seams of lignite have a maximum thickness of 3 feet. In places the upper part of the Lewisville is fossiliferous and contains an abundance of Ostrea sp. Alunite nodules are common in the Woodbine and according to Stevenson (1946, p. 177), they are conspicuous at the contact between the Lewisville member and the overlying Eagle Ford shale.

The Woodbine formation is an important source of ground water for domestic use in the eastern part of Tarrant County. Most wells are drilled to the sands of the Dexter member, although small quantities of water are obtained also from the shallower sands of the Lewisville member. Water from the Lewisville generally is more highly mineralized and, where lignite has been encountered in wells, the water generally is unfit for most uses. The Woodbine formation supplies small quantities of water for municipal use in Mansfield and eastward in Dallas County.

Eagle Ford shale

The Eagle Ford shale crops out along the eastern edge of Tarrant County in two areas separated by the Trinity River. The shale forms the surface of the gently rolling generally treeless Black Prairie belt.

The maximum thickness of the Eagle Ford in Tarrant County is probably about 200 feet. According to Lozo (1948, p. 1337) the shaly facies of the Eagle Ford increases in thickness southward at the expense of the sandy facies of the Woodbine formation.

The Eagle Ford shale consists of bluish-black shale interspersed with thin beds of sandstone and limestone. The shales are soft and weather rapidly to a black waxy soil.

The Eagle Ford shale is not a source of ground water in Tarrant County.

Quaternary System

Alluvium

Detrital alluvial deposits veneer the Cretaceous rocks in Tarrant County, particularly along the incised stream valleys and on the uplands. The alluvium is probably Pleistocene and Recent in age but is undifferentiated on the geologic map. The oldest alluvial deposits, known as upland gravels, are scattered patches of unconsolidated sand and gravel capping interstream divides. Because of their small areal extent and relative thinness, most of these deposits were not mapped. Younger deposits, known as bottom-land gravels, form terraces or benches closer to the stream valleys. These terraces become more distinct toward the present stream channel. The lowermost terrace is the present flood plain, which includes the stream bed.

The alluvial deposits consist of material derived from formations that crop out within the drainage basin. The upland gravels are composed of angular gravel, sand, red clay, and silt. The sand and gravel is composed mostly of poorly sorted fragments of platy limestone. The lower terraces and flood-plain deposits consist of rounded gravel, sand, and clay. The sorting generally is good, and the deposits are not well cemented. The thickness of the alluvial deposits ranges from a featheredge to approximately 45 feet.

Flood-plain deposits are extensive along the West Fork and Clear Fork of the Trinity River, and range in width from a few feet in the upper reaches of the stream course to more than 2 miles. The most extensively developed terrace is in the Haltom City-northeast Fort Worth area, where the deposits extend a distance of more than 4 miles from the present river channel and as much as 110 feet above it. This extensive deposit probably consists of several terraces formed by the gradual shift southward of the ancestral channel of the West Fork of Trinity River, but the typical terrace or bench topography has been obscured by erosion and slumping.

The alluvial deposits in Tarrant County furnish small to moderate quantities of ground water, the larger yields coming from wells on the lower terraces and flood plains. The water generally is polluted and is used only for irrigation of lawns and crops, but, where treatment is economical, the water from the alluvium may be used for public supply. The primary importance of the alluvial deposits, however, is as a source of sand and gravel for building and road construction.

STRUCTURE

The oldest structural feature in Tarrant County is the Fort Worth geosyncline (Adkins, 1918, p. 13), which was formed in middle Paleozoic time. It trends northwestward through the northeastern part of the county. Cross sections based on electric logs and drillers' logs (pls. 2 and 5) show a general thickening of Cretaceous sedimentary rocks toward the middle of the basin.

The Cretaceous rocks dip toward the coast at a low but uniform rate. The alternation of permeable and relatively impermeable strata within this homoclinal structure is favorable to the occurrence of water under artesian pressure. Identification of key beds within the homoclinal structure permits the accurate determination of the depth to the various aquifers at any place in the county.

Hawley and Smith (1932, p. 103) reported a departure from the homoclinal structure in the Walnut clay at the Eagle Mountain dam site, in the form of flexures described as gentle and of low relief, the sharpest one being an anticlinal nose at the east end of Eagle Mountain dam.

Small-scale faulting and vertical jointing were reported by Winton and Adkins (1919, p. 81) in the Woodbine formation near Tarrant in the eastern part of the county. In a roadcut 3.8 miles north of Arlington on Farm Road 157, sharp reversals of dip and deceptive dome-like structures due to extensive crossbedding, lenticularity of the beds, and differential compaction were observed in the Woodbine (pl. 8). In the Arlington area, Dodge (1952, p. 67), reported a vertical fault trending N30°W, its southern side being downthrown about 10 feet.

Slickensides were noted at several widely separated localities in the Desmoceras brazoense zone of the Duck Creek formation. No displacement of the strata was found, however, and inasmuch as the slickensides were observed in the outcrops only, it is probably that they are secondary in origin and resulted from unloading. The removal of all or part of the over-burden by erosion is thought to have resulted in readjustment which was concentrated particularly in the relatively incompetent Demosceras zone.

GROUND WATER

HISTORY OF DEVELOPMENT OF GROUND WATER

The early settlers in Tarrant County obtained their water supplies from shallow wells in the alluvium, and also from springs, cisterns, and streams. When Fort Worth was settled in 1849 the water supply for the settlement was obtained from Cold Springs, a cluster of little springs along the West Fork of the Trinity River below the bluff on which the present courthouse stands.

According to Hill (1901, p. 437):

> The first successful wells in the Black and Grand Prairie region were drilled in the river valley...on the western edge of the city at Fort Worth, and struck moderate flows of water at 263 feet.... Many of these shallow wells were bored, and they constituted the chief artesian supply of Fort Worth for many years before the deeper and more abundant supply of the Trinity system was developed.

In 1882 the city of Fort Worth obtained water from the Clear Fork of the Trinity River, but by 1892 this supply was inadequate. In 1890, after the city of Waco had obtained large yields from flowing wells in the Travis Peak formation, Fort Worth had an experimental well drilled at Tucker's Hill to test the deeper strata below the Paluxy sand. The test was successful and in 1892 the city had 13 closely spaced wells drilled to the Travis Peak. All the wells flowed.

Soon thereafter several wells were drilled in the city to obtain water for industrial purposes. By 1897 Hill (1901, p. 573) reported that 150 to 160 wells were in use in Fort Worth and it is probable that there were as many more elsewhere in Tarrant County. In 1905 the city developed a second field of 16 flowing wells at what is now University Drive. The many wells drawing from the

PLATE 8. - Structure in Woodbine formation on Farm Road 157, 3.8 miles north of Arlington, Tex.

Travis Peak formation caused a reduction in the artesian head, and the wells in the city soon stopped flowing. The city abandoned the use of all wells by 1914 and obtained its water supply from artificial lakes.

During the period 1900-41, most of the ground-water development outside the Fort Worth area was in the Paluxy sand and Woodbine formation. In the Fort Worth area, according to George and Rose (1942, p. 4):

> ---the demand for ground water probably rose most rapidly in the decade between 1920 and 1930 when new industries using large quantities of ground water were developed and when most of the large office buildings and hotels were built. A large number of wells have been drilled since 1930 and the pumpage is probably greater now than it ever has been.

Since 1941 the use of ground water has increased considerably. During the period 1941-54 the number of wells drawing from the Travis Peak formation increased from 31 to 90.

OCCURRENCE AND MOVEMENT OF GROUND WATER

The principles of the occurrence and movement of ground water in all types of rocks have been described by Meinzer (1923a, p. 2-192; 1923b; 1942, p. 385-497) and Wenzel (1942), among others. The occurrence and movement of ground water in Tarrant County are discussed briefly here.

Ground water occurs under water-table or artesian conditions. Under water-table conditions the water is unconfined and does not rise in wells above the level at which the water is first encountered. Under artesian conditions the water is confined under hydrostatic pressure in the sands between relatively impermeable beds, and when the elevation of the land surface is considerably below the general level of the area of outcrop the pressure may be sufficient to cause the water to rise a considerable distance in the well. The homoclinal structure of the strata underlying Tarrant County and the interbedding of shale, limestone, and sand favor the occurrence of artesian conditions.

In Tarrant County water-table conditions exist in the outcrop area of the Paluxy sand and Woodbine formation and in the scattered Quaternary deposits. Artesian conditions prevail in the Travis Peak formation and Glen Rose limestone throughout the county and in the Paluxy and Woodbine where they are overlain by relatively impervious material southeast of their areas of outcrop.

Ground water moves steadily from areas of intake to areas of discharge under the influence of gravity. The rate of movement is slow owing to friction, and where the coefficient of transmissibility and hydraulic gradient are low the time required for the water to move, for example, from the outcrop of the Travis Peak formation to Fort Worth would be measured in centuries rather than years.

The general direction of movement and the hydraulic gradient of the water in the Paluxy sand are shown by a contour map (fig. 8) of the piezometric surface, which is the imaginary surface to which the artesian water will rise in tightly cased wells that penetrate the aquifer. The movement, which is at right angles to the contours, generally is toward the east or southeast; however, because of

Trinity Sand Formation [illegible]
the [illegible]
and detailed [illegible]

[illegible]

[illegible] period [illegible]

[illegible]

[illegible] of the occurrence and [illegible] described by McIntyre [illegible] and [illegible], among others. The occurrence and movement [illegible] Tarrant [illegible] are discussed briefly here.

[illegible] water occurs under water-table or artesian conditions. Under water-table conditions the water is unconfined and does not rise in wells above the level at which the water is first encountered. Under artesian conditions the water is [illegible] under hydrostatic pressure in the sands between relatively impermeable beds, and when the elevation of the land surface is considerably [illegible] the area of [illegible] the [illegible] considerable distance [illegible] Tarrant County [illegible] of artesian [illegible]

In Tarrant [illegible]

[illegible]

[illegible]

the heavy withdrawals of ground water from the Paluxy sand between Fort Worth and Dallas, the contours do not conform to this general direction but swing sharply toward Arlington.

Figure 9 shows the direction of movement of the water and the slope of the piezometric surface in the Travis Peak formation. The contours show that water moves toward the center of areas of large or concentrated withdrawal. Sufficient data are not available to show the direction of movement of water in the Woodbine formation; however, the direction of movement probably conforms to the southeastward dip of the sand. The movement of ground water in the alluvial deposits is toward the streams, as is shown by the contour map of the water table (fig. 10) in the River Oaks area.

RECHARGE OF GROUND WATER

The ground water in Tarrant County is derived from precipitation that falls on the outcrop area of the water-bearing formations. Part of the precipitation runs off directly into streams, part is evaporated or is transpired by plants, and part percolates to the water table and then moves down the dip of the water-bearing beds into the artesian sections of the aquifers. In addition to recharge from precipitation, water enters the formations by seepage from lakes and by seepage from streams that rise north and west of the county and flow southward across the areas of outcrop.

Recharge from Precipitation

The sandy outcrops of the Travis Peak, Paluxy, and Woodbine formations present excellent opportunities for recharge from precipitation whenever water is available in excess of soil-moisture requirements. The average annual runoff in the areas of outcrop is about 2.5 to 4 inches (Langbein, 1949, pl. 1), or only about a tenth of the annual precipitation. Recharge by direct infiltration on the outcrop area generally occurs only during periods of heavy rainfall. About two-thirds of the annual precipitation falls during the growing season, mostly as showers of less than an inch, and most of this is discharged by evapotranspiration. Therefore, the bulk of the precipitation during the average year is not available for ground-water recharge. Records of water-level fluctuations in wells in the outcrop area of the Paluxy sand in Parker County indicate that considerable recharge occurred from the above normal rainfall in 1949-50.

Most of the ground water in the Quaternary flood-plain and terrace deposits near Haltom City, Richland Hills, and River Oaks is derived from precipitation on the surface of these deposits, although part may be from subsurface leakage from cisterns and water distribution lines.

Recharge from Lakes

The lakes in Tarrant County are a source of recharge to the ground-water reservoirs. Lake Worth and Eagle Mountain Lake are on the outcrop of the Paluxy sand and Grapevine Reservoir is on the outcrop of the Woodbine formation.

Figure 11 shows the profile of the piezometric surface of the Paluxy sand along line E-E' through Lake Worth. It shows that the lake is both effluent and influent. Recharge from the lake to the aquifer is induced by the relatively

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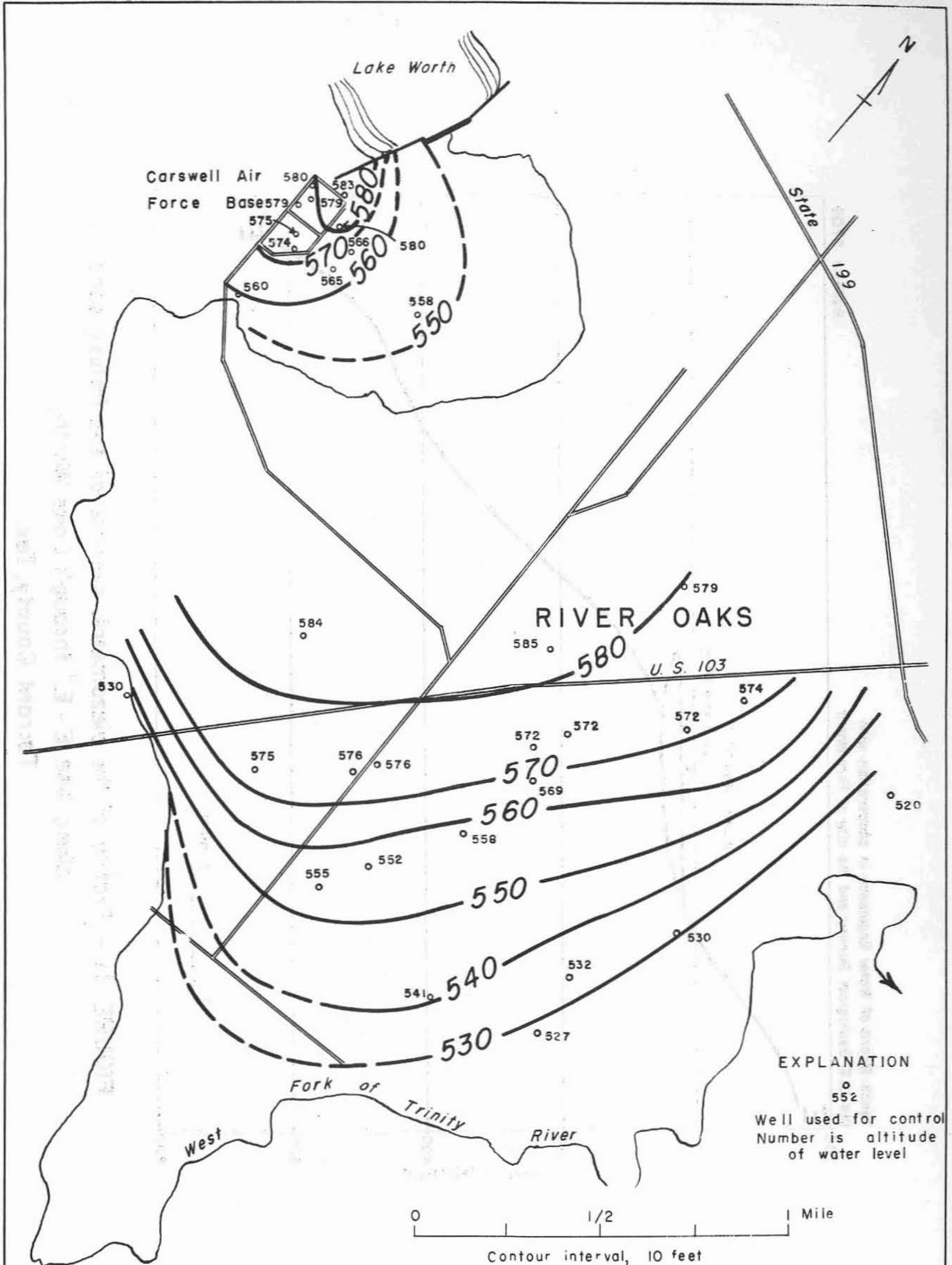

FIGURE 10.- Contour map on water table at River Oaks, Tex., 1954-55.

Texas Board of Water Engineers in cooperation with
the U.S. Geological Survey and the city of Fort Worth

Bulletin 5709

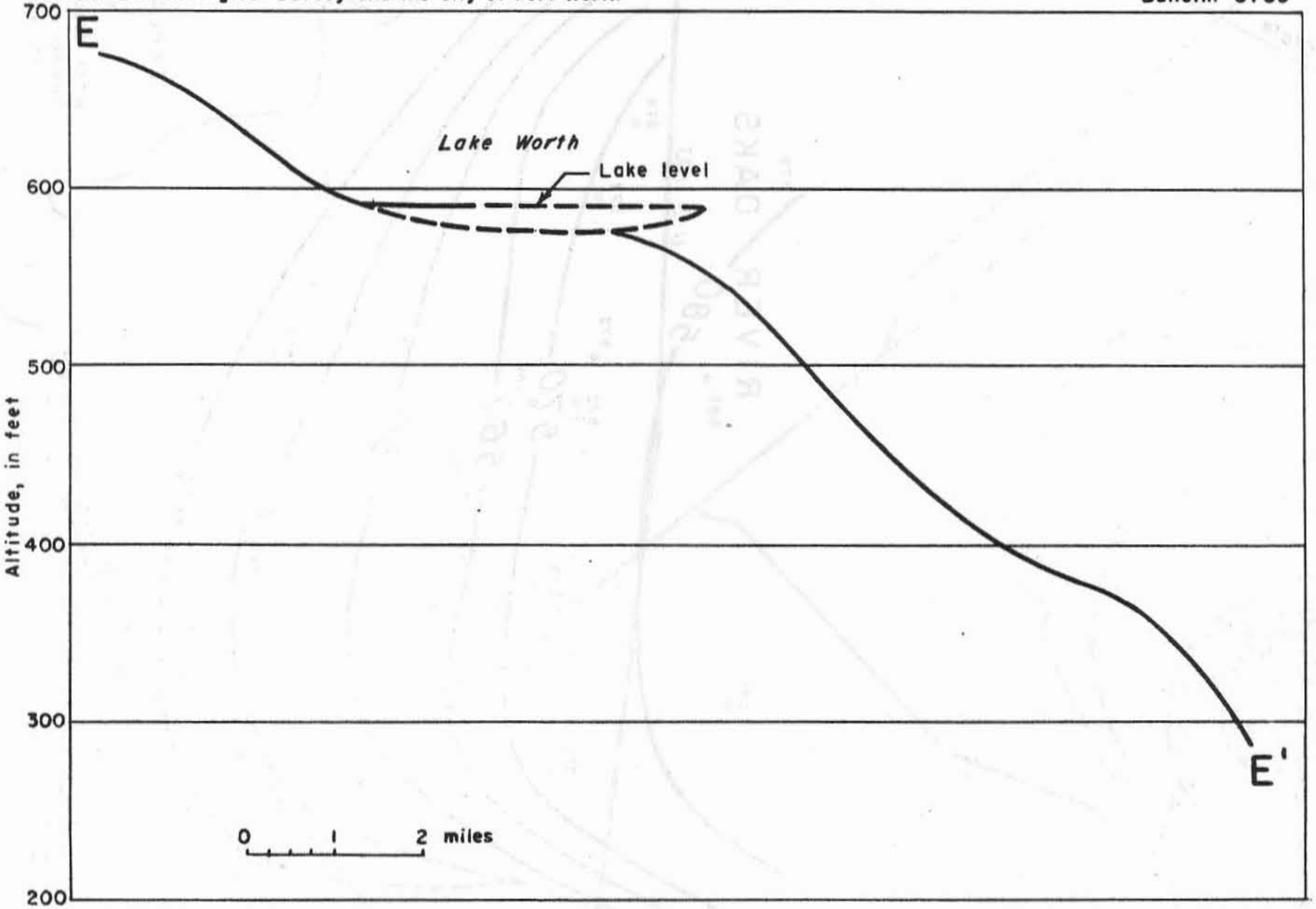

FIGURE 11.- Profile of the piezometric surface of the Paluxy sand along line E-E' through Lake Worth, Tarrant County, Tex.

steep gradient developed by the large withdrawals of water from the Paluxy sand in the Fort Worth area in recent years. Because of the low permeability of the sand and the imperfect hydraulic connection between the lake and the Paluxy sand because of siltation, the amount of recharge from Lake Worth is small. Computations based on the hydrologic properties of the Paluxy sand and the existing hydraulic gradient indicate that recharge from Lake Worth amounts to approximately 600,000 gpd. As pumping continues or is increased, the hydraulic gradient will steepen and the rate of recharge, therefore, will increase. Because geologic conditions at Eagle Mountain Lake are similar to those at Lake Worth, it is probable that Eagle Mountain Lake also is a source of recharge.

The hydrograph of the water level in well C-19 and the water level in Grapevine Reservoir (fig. 12) indicate that recharge from the reservoir is small. The records of the United States Corps of Engineers for August 1953, when rainfall was negligible, indicate that evaporation from the reservoir surface was approximately equal to the decline in water level corrected for inflow. Furthermore, the similarity of the rise in the water level during the period January to March 1952, when the reservoir was empty, and the rise in water level during the same period in 1953, when the reservoir contained several feet of water, indicates that loss from the reservoir to the Woodbine formation is considerably smaller than might be expected.

Recharge from Streamflow

After a controlled release from Lake Bridgeport in Wise County, discharge measurements were made during the period June 28-July 12, 1954, at two sections 15 miles apart on the West Fork of the Trinity River between Bridgeport and Boyd in Wise County. The measurements indicated a loss of 77 acre-feet, or 2.3 percent of the flow past the upper section. This represents a loss of about 5 acre-feet per mile of stream channel. Measurements made at the same stations during the period July 15-31, 1954 indicated a loss of 285 acre-feet, or 5.5 percent of the flow past the upper section. This represents a loss of 19 acre-feet per mile of stream channel. The measured loss during the June 29 release is not representative because thundershowers between the gaging stations caused a relatively high discharge at the lower station. If the loss per mile computed during the July 15-31 release was constant throughout the 22-mile length in which infiltration losses are possible, the total loss would have been about 418 acre-feet. On this basis it is estimated that the annual loss by seepage from the West Fork of the Trinity River would amount to about 9,000 acre-feet, equivalent to about 45 percent of the total pumpage of ground water in Tarrant County during 1954. However, as the controlled releases are periodic rather than continuous, the amount of recharge is considerably less than 9,000 acre-feet. Moreover, the losses computed above may include a considerable amount of water lost by evapotranspiration.

DISCHARGE OF GROUND WATER

Natural Discharge

Ground water is discharged naturally from the underground reservoirs in Tarrant County chiefly through evapotranspiration and springs and artifically through wells. Before pumping began, the average annual discharge of ground water was balanced approximately by the average annual recharge. This state of approximate equilibrium was upset as pumping began from wells.

Discharge by evapotranspiration in Tarrant County is greatest in the areas of outcrop of the Paluxy sand and Woodbine formation and in the lower alluvial deposits of the Trinity River. These areas support a relatively heavy growth of vegetation where the water table is close to the surface. The amount of water discharged by evapotranspiration varies with the season, being greatest during the growing season from April to October when temperatures are highest. For example, discharge records of Denton Creek near Grapevine prior to 1952, when the gates of Grapevine Dam were closed, indicate that during a part of the period the streamflow consisted of rejected recharge from the ground-water reservoir. They indicate also that during the summer months evapotranspiration was sufficient to capture the low flow of the stream. The discharge records for the period October 1950 to September 1951, inclusive, indicate that the base flow ranged from 13 to 20 second-feet from October to April. During a part of August and September the creek was dry.

Discharge of ground water by evapotranspiration from the area of outcrop of the Woodbine formation is suggested also by the fluctuation of water levels in wells C-19 and F-38 (fig. 13). The hydrographs show an annual cycle comprising a high period in spring and a low period about autumn. Soon after the last killing frost in spring the water levels start a steady decline that continues throughout the growing season. The water levels are lowest about the end of October or mid-November, at which time the growth of vegetation is reduced, thereby decreasing evapotranspiration. With the reduction in evapotranspiration, water levels generally start to recover in the latter part of the year, leveling off somewhat during the first quarter of the following year. Although this annual pattern corresponds to the growing season, it also corresponds in part to the seasonal increase in pumping from June to September, inclusive. However, computations based on the hydrologic properties of the Woodbine formation indicate that the decline in water level in well C-19 is too large to have been caused by pumpage and, therefore, a considerable part of the decline may be attributed to the natural discharge of ground water by evapotranspiration in the area of outcrop. Because of the proximity of well F-38 to the city of Irving, which is about the center of large withdrawals from the Woodbine, the percentage of water-level decline due to evapotranspiration is somewhat less and the percentage due to pumping more than in well C-19.

Ground water is discharged through springs from the Paluxy sand and Woodbine formation and from the Quaternary alluvial deposits. A large part of the discharge is from the Paluxy sand west of Lake Worth where the water table is intersected by the land surface. The flow from any one spring is small but the aggregate flow of all the springs may be appreciable. Ground water is discharged also into Lake Worth, which is bottomed in the Paluxy sand. The discharge of ground water into the lake is small; computations based on the hydrologic properties of the Paluxy sand indicate it is probably about half a million gallons a day. It is probable that some ground water is discharged into Eagle Mountain Lake also.

Contact springs occur in the vicinity of Lake Worth Dam where the permeable alluvial deposits are underlain by the relatively impermeable Walnut clay. The water issues along the contact of these beds. Part of the ground water in this area emerges as seeps along the flood plain of the West Fork of the Trinity River from which water is lost directly by evaporation.

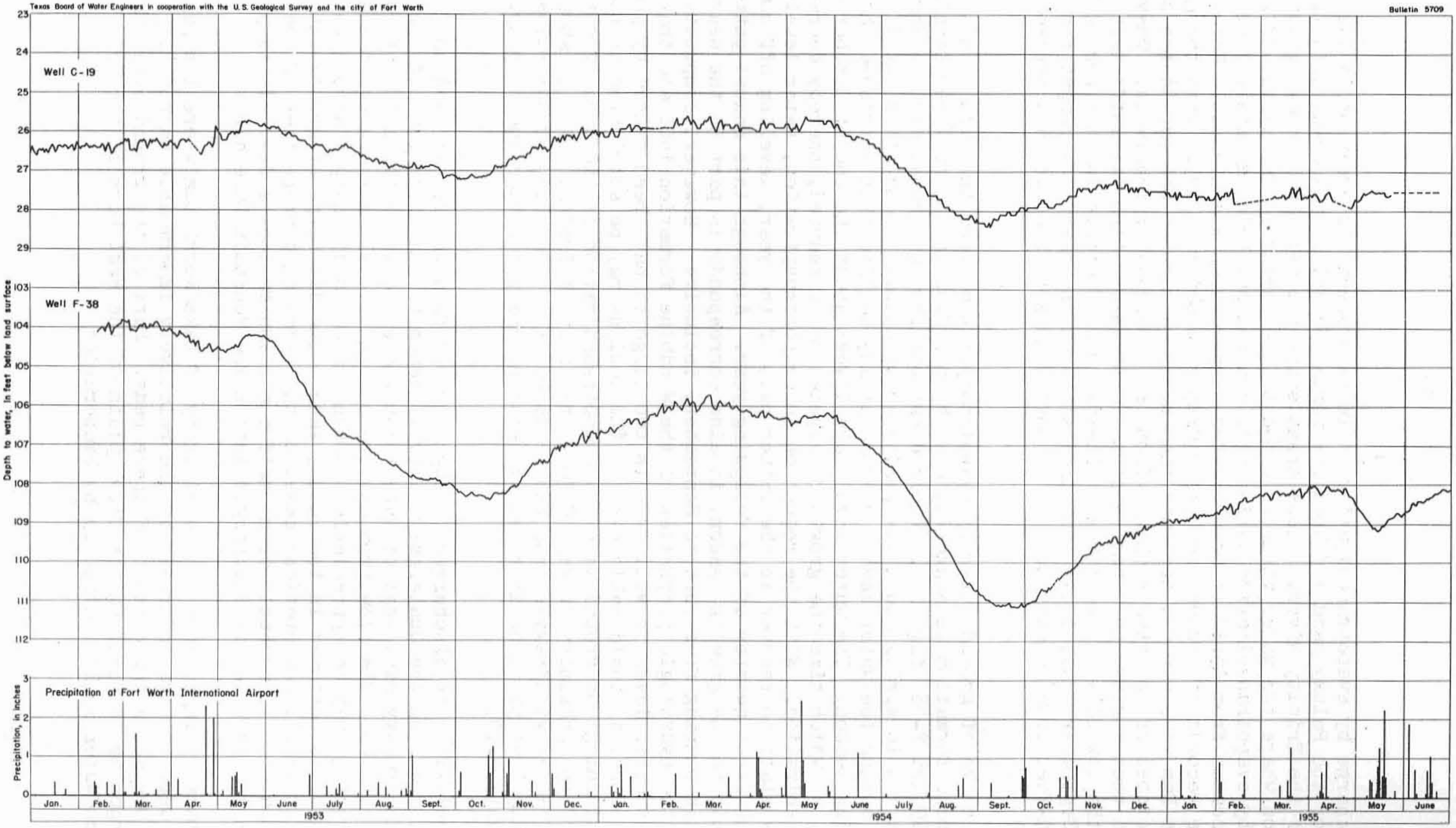

FIGURE 13- Hydrograph of wells C-19 and F-38 screened in the Woodbine formation, and precipitation at Fort Worth International Airport, Tarrant County, Tex.

Artificial Discharge

The artificial discharge of ground water in Tarrant County is through pumped wells. The first reliable estimate of the quantity of ground water pumped from all aquifers was made in 1941 when George and Rose (1942, p.5) estimated that in the Fort Worth area approximately 7.5 mgd was pumped for public and industrial supplies. George states also that about 5 mgd, or 70 percent of the pumping, was from the Travis Peak formation, as compared with 2 mgd and 0.5 mgd estimated to have been pumped from the Paluxy sand and the Glen Rose limestone, respectively. An additional 1.5 mgd was pumped for public and domestic supplies outside the Fort Worth area in Tarrant County. Most of this pumpage was from the Paluxy sand and Woodbine formation.

The withdrawal of ground water in the vicinity of Fort Worth increased at least 20 percent from 1941 to 1944 (Lang, 1944, p. 2).1/ Thus, the total pumpage in the Fort Worth area was approximately 9 mgd, of which 6 mgd was from the Travis Peak formation. A large part of the increase in pumping in the Fort Worth area was in the industrial area in the northern part of the city, where packinghouses, oil refineries, and manufacturing plants were dependent upon ground-water supplies. Pumping was increased substantially from the Paluxy sand and Glen Rose limestone for smaller industrial plants and private water companies.

Since World War II population and industry have expanded outward from Fort Worth with a concomitant increase in the withdrawal of ground water. Approximately 17 mgd was pumped in the county for all purposes during 1954. About 11 mgd, or 65 percent, was pumped from the Travis Peak formation and 5 mgd from the Paluxy sand. No data are available regarding the pumpage from the Woodbine formation, but it is probably about 0.5 mgd. The remaining 0.5 mgd is believed to be from the Glen Rose limestone and the alluvial deposits.

An increase in the use of ground water during 1955 is to be expected, owing to the drilling of additional municipal-supply wells fpr Arlington, Richland Hills, Haltom City, and Hurst. The increased pumping probably will be divided equally between the Travis Peak formation and Paluxy sand.

FLUCTUATIONS OF WATER LEVELS

The water level fluctuates almost continuously in a well tapping an artesian aquifer. The fluctuations, which result from natural and artificial processes, vary considerably in magnitude and pattern. Fluctuations of the water level that are not the result of pumping generally are smaller than those caused by pumping. These include fluctuations caused by changes of atmospheric pressure, loading and unloading the aquifer, earthquakes, or changes in the rates of natural recharge and discharge.

Fluctuations due to changes of atmospheric pressure have a rhythmic pattern and are inverse to the change in pressure; that is, as the barometric pressure rises, the water level in the well declines. The effect of the changes of atmospheric pressure on the water level in the aquifer is due to the ability of

1/ Lang, Joe W., 1944, A few facts regarding the ground-water supply of Fort Worth and vicinity, Tex.: U. S. Geol. Survey unpublished report.

the overlying aquiclude, or less permeable confining bed, to resist the transmission of changes in barometric pressure; thus the aquiclude does not transmit the full effect of the change in pressure. The full effect is transmitted directly down the well, however, and the water level fluctuates accordingly.

The fluctuations of the water level in a well produced by an increase in the load on an aquifer is shown in the hydrographs for Grapevine Reservoir and well C-19. (See fig. 12.) During the period April 20 to May 15, 1953 the water level in Grapevine Lake rose approximately 20 feet. This additional load resulted in compression of the underlying Woodbine formation, thereby causing the water level in well C-19 to rise 0.7 foot. Figure 12 shows also that the changes in lake level are transmitted almost instantaneously to the well, indicating a pressure change rather than recharge. After the aquifer adjusts to this additional load, the water levels begin to decline in response to evapotranspiration and pumping. A decrease in the load on an aquifer causes the aquifer to expand and the water level declines. This is shown during the period December 1, 1954 to January 31, 1955, when the water levels declined in response to a decrease in lake level despite the fact that water levels elsewhere generally rose during this period. (See hydrograph for well F-38 in fig. 13.) The ratio of the rise or fall in lake level to the rise or fall in water level in the well is a measure of the competency of the aquifer and aquiclude to resist deformation.

The water levels in the areas of outcrop of the water-bearing formations of Tarrant County fluctuate in response to changes in the rate of natural recharge. Short-term changes in the rate of natural recharge seldom affect water levels in the artesian part of the aquifers, whereas long-term changes due to the effect of a series of wet or dry years noticeably affect artesian water levels.

The large fluctuations of water levels usually result from withdrawals of ground water, the magnitude of the fluctuations diminishing with distance from the point of discharge. The maximum decline of artesian head takes place during the period from July to September when pumping is greatest; recovery of the artesian head begins in October and generally continues until about April or May, at which time water levels again begin to decline. Thus, the annual net decline of artesian head can best be determined from annual measurements made sometime during the interval January to March which follows the period of recovery.

Travis Peak Formation

According to Hill (1901, p. 576) the water level in the Tucker Hill experimental well in Fort Worth was about 720 feet above sea level in 1890. The water level in a well drilled in about 1890 at the Texas Brewery in downtown Fort Worth rose to a height of 90 feet above land surface, or to an altitude of about 690 feet, and other deep wells in the present packing house area also flowed. Hill did not report water levels for most of these wells but it is reasonable to assume that the artesian head was about 700 feet above sea level.

Hill further reported (p. 578):

> The flow of the artesian wells of Tarrant County has greatly decreased in many localities. The flow of ... deep Trinity wells ceased after the drilling of 15 of 16 wells within a small area. In fact, most of the wells which several years ago yielded large volumes of water at the surface now have to be pumped.

The wells described by Hill have been abandoned, but water levels have been obtained for other wells in the same area. The water levels, or artesian pressures, declined at a rapid rate early in the 20th century, but as development slowed down after World War I, the rate of decline decreased. The draft on the Travis Peak formation underlying Fort Worth was greatly accelerated during World War II, however, owing to the increased demand for water for industrial and public supply. Since 1950 new centers of ground-water withdrawals from the Travis Peak formation have been developed outside the Fort Worth area, and as a result water levels in the Travis Peak have declined markedly.

During the period 1892 to 1942 the decline of water levels in wells tapping the Travis Peak in the Fort Worth area ranged from 460 feet in well E-86 in the packing house area (fig. 14) to 389 feet in the vicinity of well E-183. During the period 1942-54, inclusive, water levels in the Armour-Swift well field declined 360 feet, an average of 30 feet a year. In the industrial refinery area the declines ranged from 268 feet in the well field of the Magnolia Petroleum Co. to approximately 200 feet in well E-41, an average of 22 to 17 feet a year. In downtown Fort Worth, where most of the pumping was by hotels and commercial establishments, the declines were considerably less. At the Fort Worth and Denver Railroad well (E-183) the water level declined 133 feet, an average of 11 feet a year. In the Arlington area, the water level in well F-83 declined 264 feet, an average of 22 feet a year. At Grapevine water levels declined an average of 20 feet a year from 1946 through 1954. Near Handley, where large quantities of ground water were pumped for industrial and municipal supply, the artesian head declined an average of 26 feet a year.

A considerable part of the declines discussed above is due to the marked increase in pumping from the Travis Peak formation since 1952 for the rapidly growing cities and new industries, which are primarily in the eastern half of the county. At the same time, Irving, Grand Prairie, and Dallas in Dallas County also increased withdrawals from the Travis Peak. As a result, artesian heads declined markedly over an extensive area. The hydrographs of wells screened in the Travis Peak (fig. 15) show that the declines decrease in magnitude with distance from the centers of heavy pumping. For example, in 1953 and 1954 the artesian head in the Bell Aircraft-International Airport area declined 110 and 105 feet in wells F-27 and F-39, respectively, or an average of about 50 feet a year (fig. 15). In 1953 water levels in well F-95 at Arlington declined 105 feet. Measurements were not made in well F-95 in 1955 but, by comparison of water levels from nearby wells in Grand Prairie, it is calculated that during 1954 the water level in well F-95 declined about 50 feet or a total decline of 155 feet since 1952. On the west side of Arlington, the water level in well F-83 (fig. 15) declined 34 feet during 1954. Measurements in well F-117 indicate that water levels in the Handley area declined 52 feet from February 1953 to April 1955, or an average of 26 feet a year. This relatively small average decline appears to reflect a reduction in the use of well F-117 caused by a reduction in the electrical output of the Texas Electric Service plant. This is illustrated by the fluctuation of water levels at well F-64 (fig. 16), which is a mile north of F-117 and within the area of influence caused by pumping of well F-117. Figure 16 shows that the water level in well F-64 recovered only about 15 feet during the period September 1953 to February 1954, whereas during the same period in 1954-55 the water level recovered approximately 55 feet.

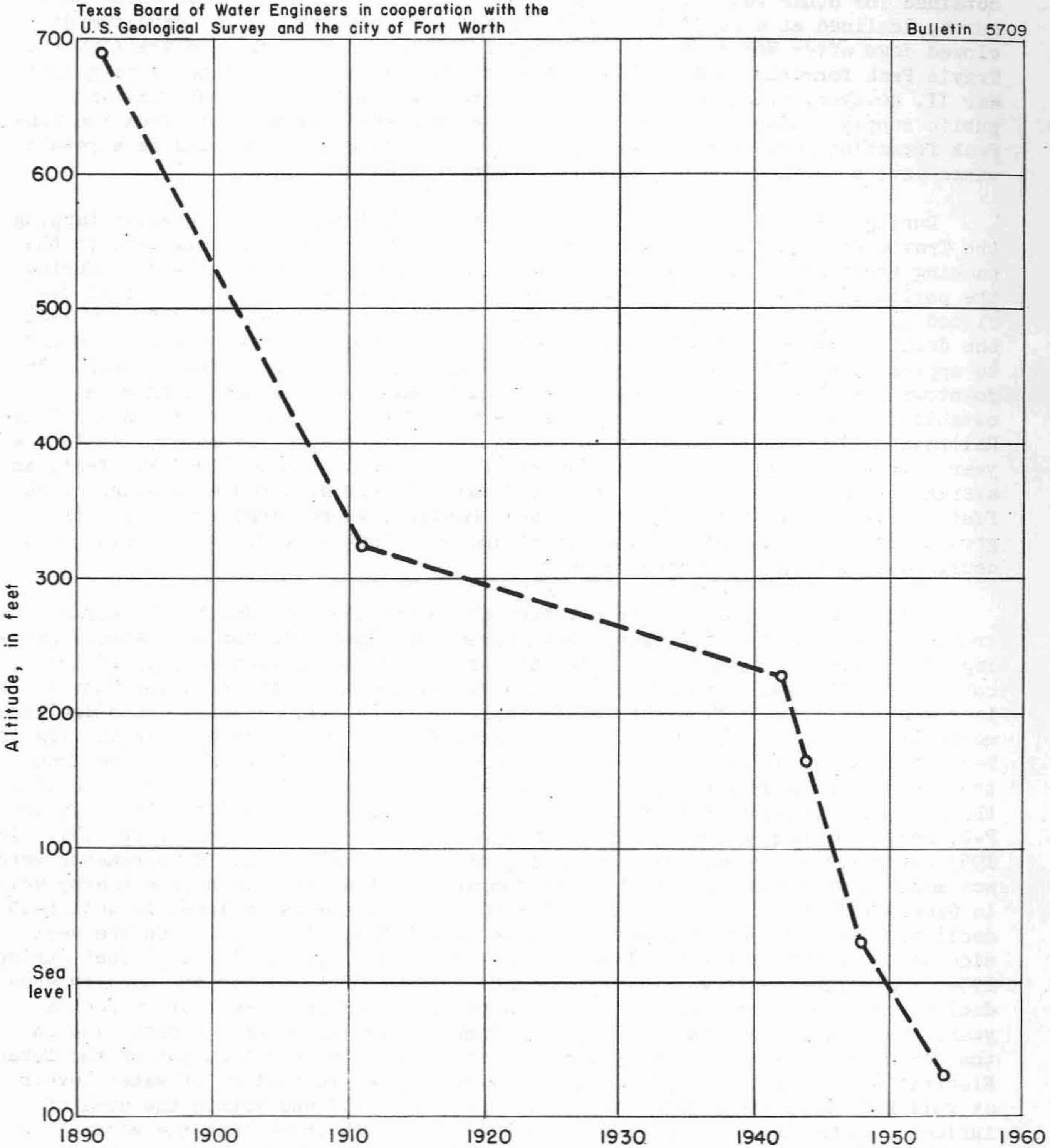

FIGURE 14.- Altitude of water levels in Travis Peak formation in packinghouse area, north Fort Worth, 1892-1954.

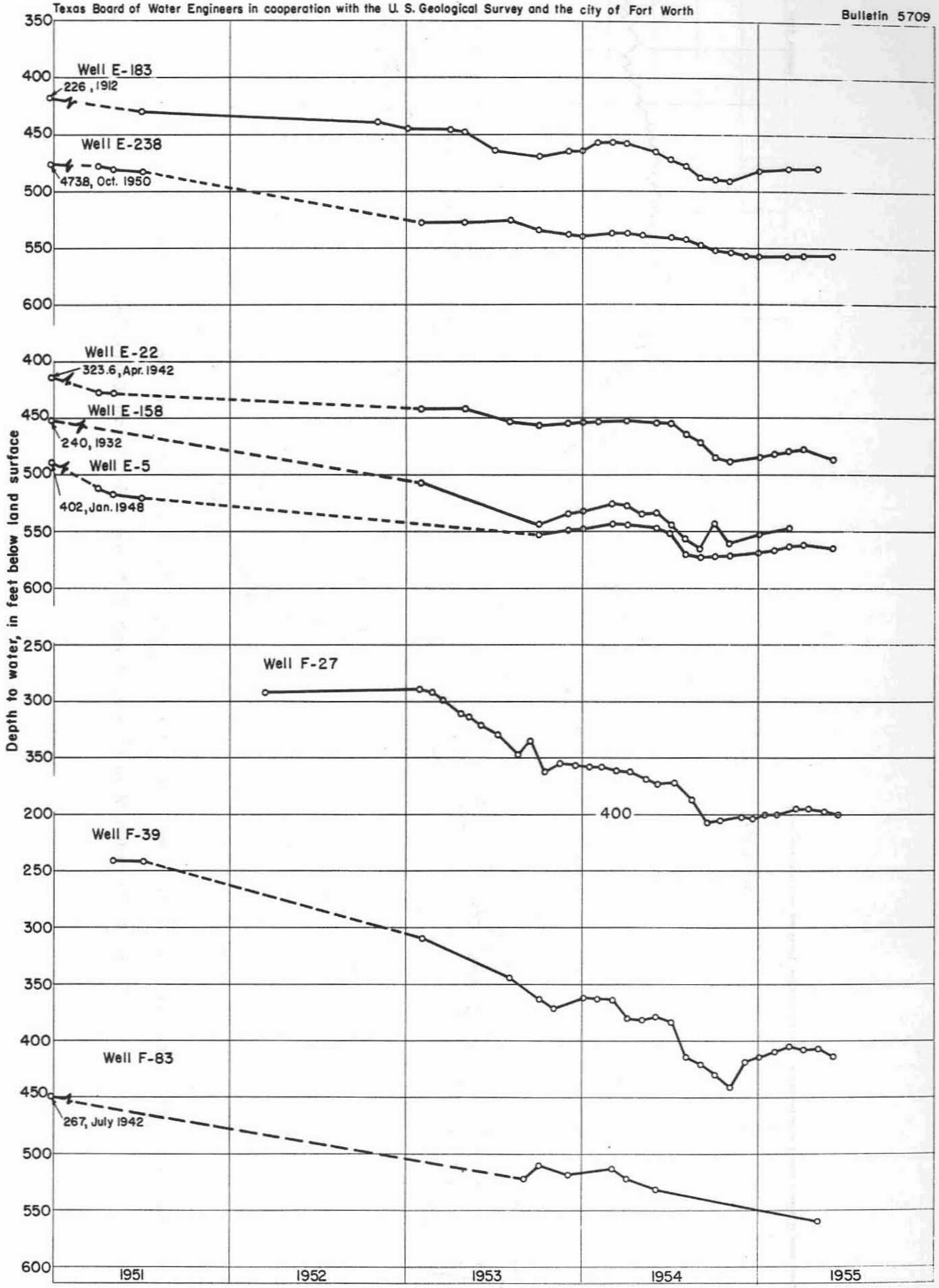

FIGURE 15.- Fluctuation of water levels in wells screened in the Travis Peak formation, Tarrant County, Tex.

FIGURE 16 - Fluctuation of water levels in wells E-157 and F-64, Tarrant County, Tex.

During 1953 water levels in the Fort Worth area declined by amounts ranging from 9 feet in well E-22 to 33 feet in well E-69 at Haltom City. In Fort Worth the decline in 1953 averaged about 12 feet at wells E-22, E-158, E-183, and E-238, whereas in 1954 the rate of decline averaged 22 feet in the same wells. The water levels in 1954 in 5 widely scattered wells declined from 41 feet in well E-77 in east Fort Worth to 15 feet in well E-120 in River Oaks.

The altitude of the piezometric surface in wells in the Travis Peak formation in 1954 is shown by means of contour lines in figure 9. The largest and best defined cone of depression is centered in the packinghouse area of Fort Worth, where the piezometric surface has been lowered to 70 feet below sea level, representing a total decline of about 770 feet since 1892. A less well-defined cone of depression has been developed in the Handley-Arlington area. Profiles of the piezometric surface along the lines of the geologic sections are shown in plates 2, 3, 4, and 5.

Paluxy Sand

During the drilling of the Tucker Hill experimental well in 1890 (Hill, 1890, p. 576) the artesian pressure in the Paluxy sand was sufficient to raise the water to within 70 feet of the surface, or to an altitude of 580 feet. Although this well subsequently was abandoned, measurements made in 1942 reveal that the water level in nearby well E-195 (land surface datum 650 feet) was 277 feet below the land surface, or at an altitude of 373 feet. Therefore, the loss of artesian head in the Paluxy sand in the Fort Worth area was about 210 feet during the period 1890 to 1942. In March 1954 the water level in well E-195 was 285 feet below the surface, for a total net decline of 215 feet since 1890. In well E-28 in the north Fort Worth area the decline in artesian head was about 224 feet from 1897 to 1953. In well F-97 near Arlington the water level declined 171 feet from 1935 to 1954. In contrast to these large declines, the water level in well B-16, which is 2.5 miles southeast of Haslet and remote from any area of concentrated pumping, reportedly declined only 35 feet from 1890 to 1954.

Withdrawals from the Paluxy sand have increased considerably since 1953. Increased pumping at Arlington, Haltom City, and Richland Hills in Tarrant County and Grand Prairie in Dallas County resulted in a general decline of artesian pressure in the Paluxy sand throughout most of Tarrant County. Since 1953 pumps have been lowered in such widely scattered wells as B-16, C-65, F-7, F-97, and H-8, the maximum lowering being 85 feet. Although the decline in artesian pressure has been widespread, the largest declines have been in the Arlington-Grand Prairie area and the Haltom City-Richland Hills area. The declines decrease in magnitude westward and away from centers of heavy pumping. The approximate decline of the artesian head in the Paluxy sand during 1954 and the extent of the cones of depression created by the intensive pumping in Tarrant County are shown in figure 17.

During 1954 pumping from the Paluxy sand in the Arlington-Grand Prairie area was increased from 200,000 gallons a day to about 700,000 gallons a day. The effect of this increase in pumping is reflected in the marked decline of the water levels in observation wells located at various distances from the center of pumping. (See fig. 18 and table 3.)

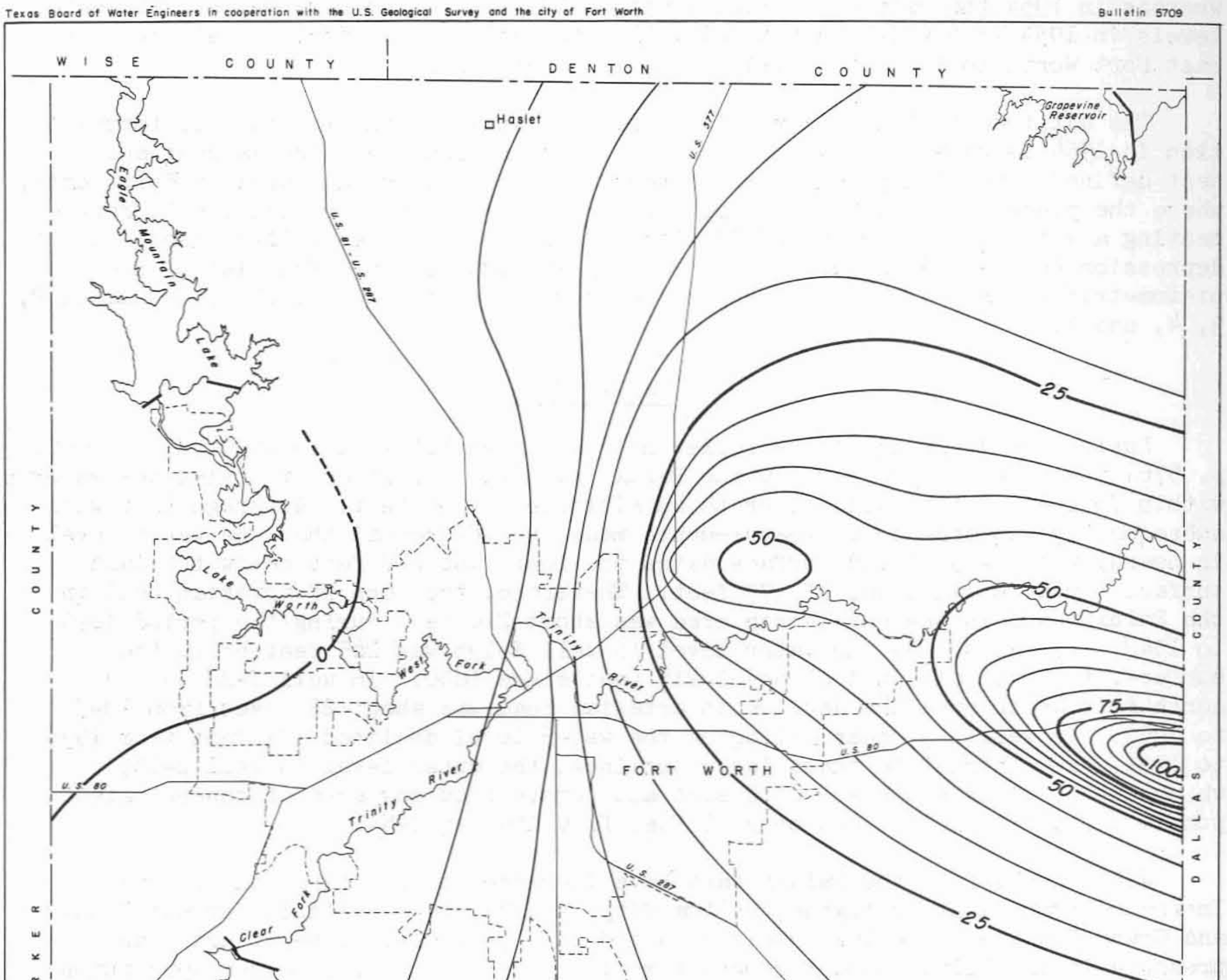

FIGURE 17 - Approximate decline in artesian head in the Paluxy sand, Tarrant County, Tex. 1954-55.

FIGURE 18. - Fluctuation of water levels in wells in the Paluxy sand in the Arlington - Grand Prairie area, Tarrant County, Texas.

Table 3.- Decline of water levels during 1954 in selected observation wells in the Arlington-Grand Prairie area.

Well No.	Distance from center of pumping (miles)	Decline of water level during 1954 (ft)
F-96	0	103
F-97	1.4	92
F-92	2.1	75
F-84	4.1	51
F-81	4.1	49
F-35	6.5	44

In the Haltom City-Richland Hills area the decline of artesian head in the Paluxy was accelerated during 1954. The water level in well F-7 (fig. 19), approximately in the center of the Richland Hills well field, declined 55 feet during 1954, for a total of about 93 feet from January 1950 to January 1955. The water level resumed its downward trend in May 1955 and by June the water level had declined a total of 21 feet since January, as compared with a decline of 13 feet during the same period in 1954. The artesian head declined an average of 46 feet during 1954 in two well fields in Richland Hills. At the Midway station in the Haltom City area, well E-68 showed a decline in water level of about 25 feet during 1954.

In the Fort Worth area the water levels in wells E-24, E-195, and D-72 (fig. 19), which had declined an average of about 2 feet during 1953, declined about 5.5 feet in 1954. The smallest decline was recorded in well D-72, which is in the southwest part of the city, relatively distant from areas of heavy pumping.

Figure 17 shows that the effect of the large withdrawals from the Paluxy sand in 1954 extended over a considerable part of Tarrant County even in areas relatively distant from the centers of heavy pumping. For example, the water levels in wells B-26 and B-27 in the Watauga area declined an average of 22 feet, and south of Grapevine the water level in well C-51 declined 19 feet. Declines were considerably less in the western part of the county; water-level fluctuations in the vicinity of Lake Worth ranged from a decline of less than 0.5 foot in well E-113 to a rise of 1.7 feet in well D-37.

It seems reasonably certain that the recent large increase in pumping from wells in the Paluxy sand in Tarrant and Dallas Counties has caused a decline of the water table in the outcrop area and a reduction in the discharge to the Clear Fork of the Trinity River. On the other hand, a large part of the decline of the water table and decrease in discharge to the river probably resulted from the below-normal precipitation since 1950.

The average fluctuation of the water table in six wells in the area of outcrop of the Paluxy sand in Parker County is compared in figure 20 to the precipitation at Weatherford, Tex., and the minimum flow in the Clear Fork of the Trinity River at Aledo, Tex., during the nongrowing seasons 1951-54, inclusive. The fluctuations of the water table in the observation wells can be correlated directly with the precipitation. The above-normal rainfall during 1949 and 1950 is reflected in the 3-foot rise in the water table from 1950 to 1951. The subnormal rainfall of 1950-54 is reflected in a decline of 2.9 feet in the water

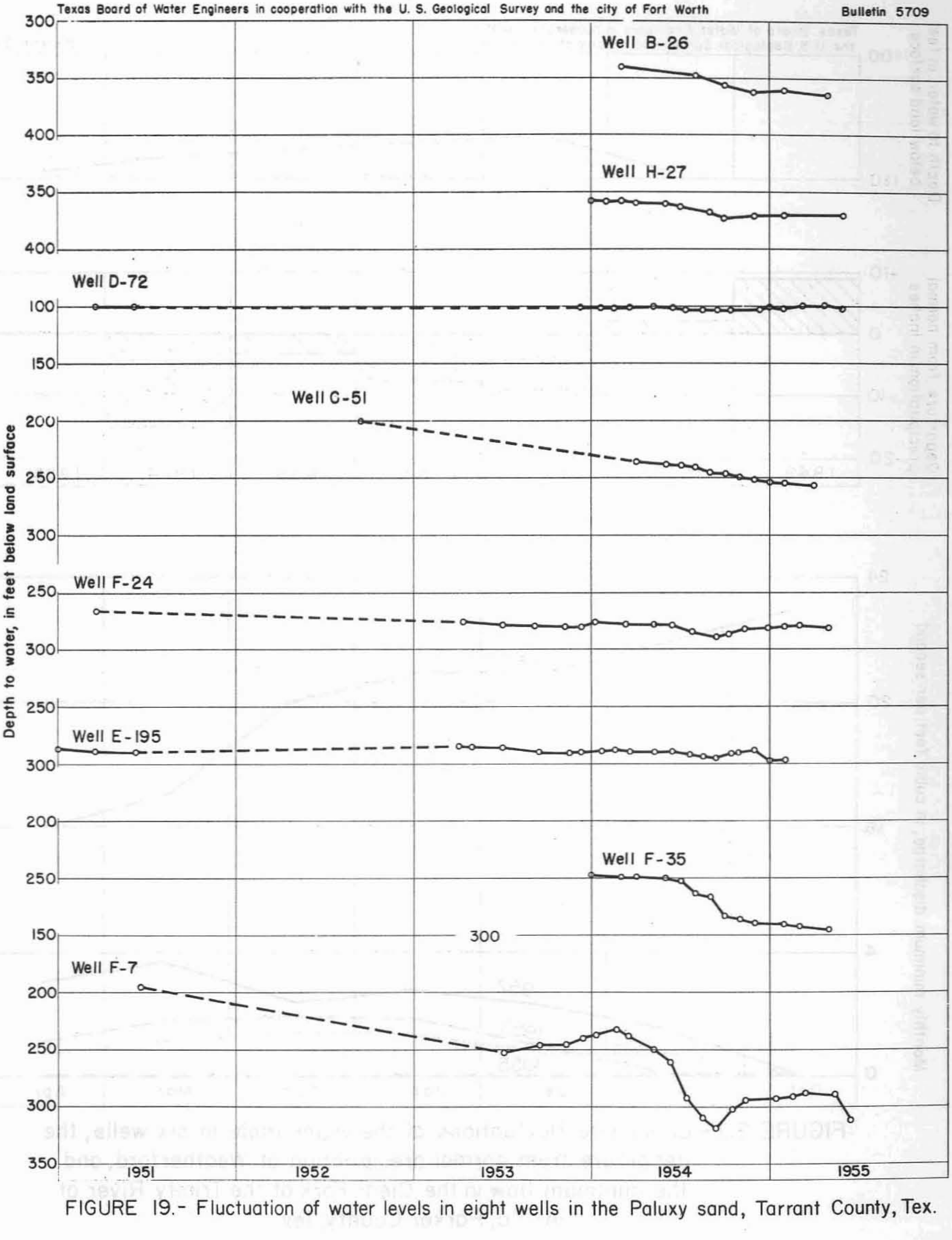

FIGURE 19.- Fluctuation of water levels in eight wells in the Paluxy sand, Tarrant County, Tex.

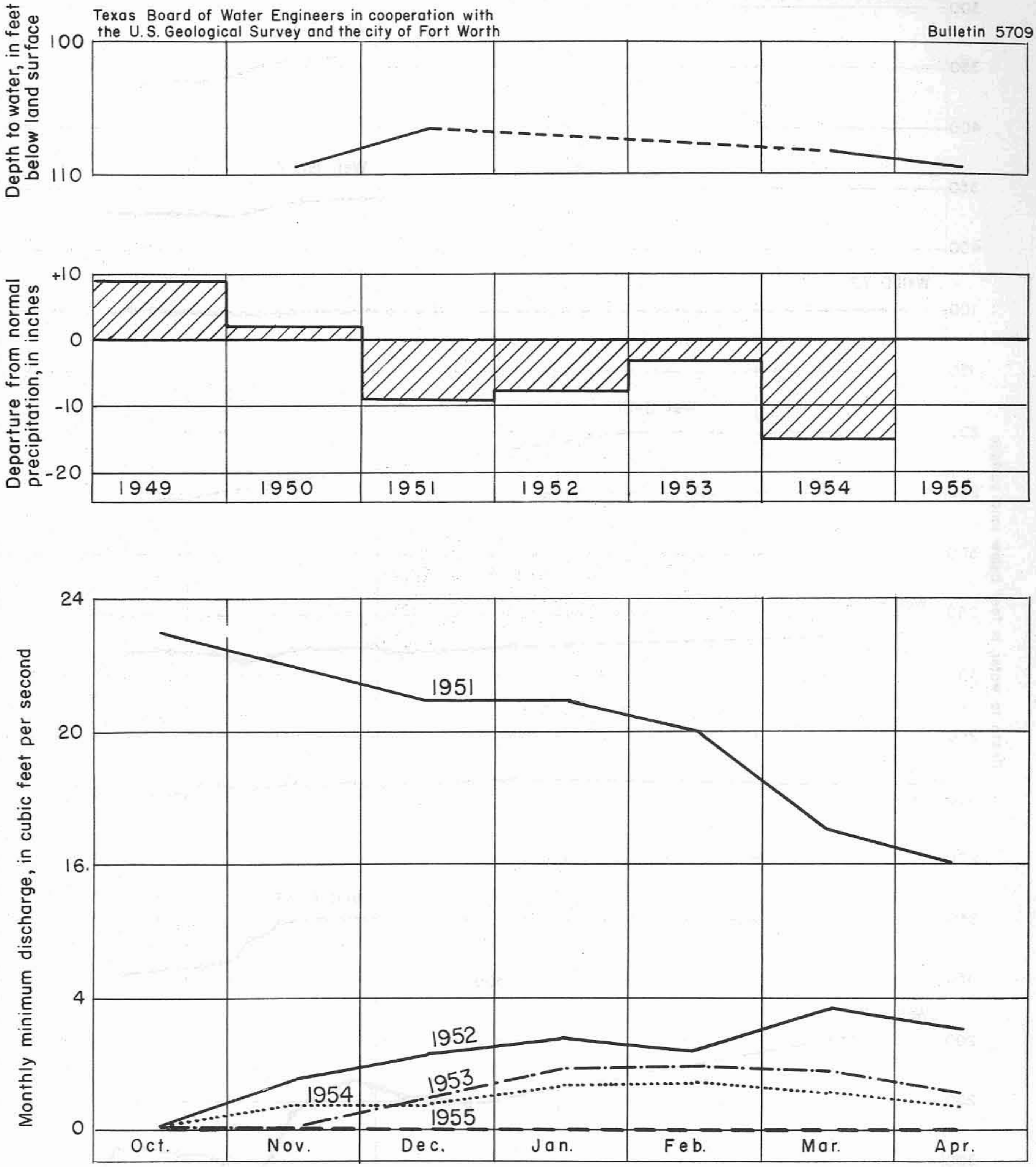

FIGURE 20.- Composite fluctuations of the water table in six wells, the departure from normal precipitation at Weatherford, and the minimum flow in the Clear Fork of the Trinity River at Aledo, Parker County, Tex.

table during the same period. The records of discharge of the Clear Fork of the Trinity River near Aledo reveal that the base flow, or that part of the stream flow sustained by ground water, correlates rather closely with the precipitation and the fluctuations of the water table in the area of outcrop of the Paluxy for the period 1951-54. Records of discharge for the Clear Fork from October 1954 to April 1955 show that no ground water was discharged into the stream.

Woodbine Formation

Few long-term records are available of fluctuations of water levels in the Woodbine formation.

During the period February 1953 to April 1955 water levels declined 1.2 feet in well C-19 and 4.2 feet in well F-38 (fig. 13). According to reports from several owners of dug wells in the area of outcrop of the Woodbine formation, the water table has declined in recent years and in some wells the yields have decreased noticeably.

GROUND-WATER RESERVOIRS

The principal ground-water reservoirs in Tarrant County are in order of importance, the Travis Peak formation, the Paluxy sand, the Woodbine formation, the Glen Rose limestone and the alluvial deposits of Quaternary age. About 65 percent of the ground water used during 1954 was pumped from the Travis Peak.

Travis Peak Formation

Yields of Wells

The yield of a well depends upon the ability of the aquifer to transmit water, the thickness of the material screened, the efficiency of the well, and the allowable drawdown. Few wells in Tarrant County are screened in all the water-bearing material penetrated, thus the yields of most wells are somewhat less than the maximum yields that could be developed.

The yields of 46 wells in the Travis Peak formation range from 65 to 800 gallons per minute (gpm). The largest yields, which more nearly represent the maximum yield of wells in the Travis Peak, are obtained from wells that are constructed with a gravel pack and screen and are fully developed to remove fine-grained material from around the well. The yields of 25 such wells range from 140 to 754 gpm; the yields increase eastward, in which direction the Travis Peak thickens. In the western part of Tarrant County, wells yield less than 200 gpm. In the Fort Worth area the yields range from about 300 gpm near Westover Hills to about 350 gpm in the industrial area of north Fort Worth. In contrast, the old wells having torch-slotted casing of small diameter in the downtown Fort Worth area yield an average of only about 100 gpm, and individual wells yield as little as 65 gpm.

The yields of five wells in the Haltom City-Richland Hills area ranged from 361 to 408 gpm and averaged about 380 gpm. Farther east at Bell Aircraft Plant, well F-27 had a measured yield of 754 gpm, and the wells at the Greater Fort Worth International Airport (F-39 and F-40) had measured yields of 614 and 520 gpm, respectively. In the Handley-Arlington area the yields of 10 wells ranged from 375 to 602 gpm and averaged about 500 gpm.

Specific Capacity of Wells

The specific capacity of a well is generally expressed as the ratio of the yield in gallons per minute to the drawdown in feet. The term might imply that the ratio of yield to drawdown is constant and may be extrapolated over any period of time; however, the specific capacity of a well should be considered only as an approximation because of the effects imposed by the rate of withdrawal and the element of time. Moreover, a comparison of specific capacities as an indication of aquifer productivity is subject to considerable error unless the methods of well construction and the degree of development are taken into account. The specific capacities of many old wells, which were completed with torch-slotted casing of small diameter, are considerably less than the specific capacities of wells of large diameter that are gravel walled and screened. The use of a gravel wall and screen increases the effective diameter of the well by offering a larger open area for the passage of water than is provided by slotted casings. This results in reduced entrance velocities, thereby decreasing the drawdown and increasing the specific capacity. The specific capacities of properly developed wells with gravel walls and screens probably best represent the true capacity of the formation to transmit water.

The specific capacities of 30 wells that obtain water from the Travis Peak formation in Tarrant County are shown in table 4. The specific capacities ranged from 0.9 to 5.8 gpm/ft, increasing eastward in which direction the Travis Peak thickens.

Table 4.- Yield and specific capacity of wells in the Travis Peak formation in Tarrant County, Tex.

Well number	Diameter of screen or casing (in.)	Yield (gpm)	Drawdown (ft.)	Specific capacity (gpm/ft)
A- 3	8	140	132	1.1
E- 32	10*	73	37	2.0
E- 45	-*	411	121	3.4
E- 46	10	316	100	3.0
E- 48	8*	123	132	.9
E- 51	6	361	129	2.8
E- 53	6	407	161	2.5
E- 56	8	380	170	2.2
E- 59	6	553	189	2.9
E- 69	8	340	145	2.3
E- 85	6	360	166	2.2
E-134	7	303	186	1.6
E-155	10*	100	53	1.9
E-233	8	338	138	2.5
F- 12	7	408	142	2.9
F- 27	8	754	164	4.6
F- 39	8	614	117	5.1
F- 40	8	520	90	5.8
F- 79	6	500	133	3.8
F- 83	8	602	135	4.5
F- 88	6	512	112	4.6
F- 89	6	510	98	5.2

(Continued on next page)

Table 4.- Yield and specific capacities of wells in the Travis Peak formation in Tarrant County, Tex.- continued.

Well number	Diameter of screen or casing (in.)	Yield (gpm)	Drawdown (ft.)	Specific capacity (gpm/ft)
F- 95	6	508	94	5.4
F-104	13	508	88	5.8
F-106	6	470	96	4.9
F-115	10	539	217	2.5
F-116	8	215	85	2.5
F-117	10	548	166	3.3
F-118	8	280	110	2.5
J- 34	-	390	146	2.7

* Well is not screened.

Pumping Tests

A total of 20 pumping tests were made in Tarrant County to determine the coefficients of transmissibility and storage, which govern the ability of an aquifer to transmit water and yield water.

The coefficient of transmissibility is defined as the rate of flow of water in gallons per day through a vertical strip of the aquifer that is 1 foot wide and extends the full thickness of the aquifer, under hydraulic gradient of 100 percent and at the prevailing temperature of the water. Therefore, the volume of water that will flow each day through each foot of this water-bearing material is the product of the coefficient of transmissibility and the existing hydraulic gradient. The smaller the coefficient of transmissibility, the greater must be the hydraulic gradient in order for the water to move through the aquifer at a given rate.

The coefficient of storage of an aquifer is defined as the volume of water it 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. Under artesian conditions, the coefficient of storage is a measure of the ability of the formation to yield water from storage by the compression of the formation and expansion of the water. The coefficient of storage in an artesian aquifer is small; consequently after pumping starts, a cone of depression is developed over a wide area in a short time. Under water-table conditions the coefficient of storage reflects gravity drainage of the aquifer and is very much larger.

The coefficients of storage and transmissibility were computed from the results of the pumping tests by means of the formula for nonsteady-state flow developed by Theis (1935, p. 519-524). A discussion of the formula, the assumptions upon which it is based, and its application is given by Wenzel (1942).

Results of tests

The coefficients of transmissibility determined from pumping tests on wells in the Travis Peak formation increase eastward in Tarrant County, ranging from 2,600 to 12,500 gpd per foot in Fort Worth and Arlington, respectively (table 5).

The increase eastward is due in large part to the thickening of the Travis Peak downdip, and in small part to the decrease in viscosity of the water as the temperature of the water increases with the depth of the aquifer. An increase of the coefficient of transmissibility due to an increase of the temperature of the water, of course, does not represent an actual increase in the permeability of the aquifer. The coefficients of storage are relatively uniform, ranging from 0.00013 to 0.000045 (table 5).

The results of a typical pumping test in the Travis Peak formation are shown in figure 21.

Table 5.- Coefficients of transmissibility and storage of the Travis Peak formation in Tarrant County, Tex.

Well number	Owner	Location	Coefficient of transmissibility (gpd/ft)	Coefficient of storage
F- 83	Arlington	Arlington	12,500	
F-104	Arlington	Arlington	12,400	
E-148	Texas Electric Service Co.	Fort Worth	2,600	9.5×10^{-5}
E-149	do	do	2,600	4.5×10^{-5}
F-115	do	Handley	9,700	6.1×10^{-5}
F-116	do	do	7,000	4.8×10^{-5}
F-118	do	do	7,700	5.6×10^{-5}
F-119	do	do	9,200	1.3×10^{-4}
E- 51	Haltom City	Haltom City	6,500	
E- 43	Magnolia Petroleum Co.	Fort Worth	5,500	

Application of results

If geologic and hydrologic conditions are favorable, the coefficients of transmissibility and storage may be used to predict the general order of magnitude of the future drawdown in water levels caused by a nearby pumping well or by a general increase of pumping in the area. Average coefficients obtained from many tests generally are used in such predictions. The theoretical drawdown curves in figure 22 were computed from average coefficients for the Fort Worth area and the Handley-Arlington area. Because the coefficients of transmissibility vary over such a wide range across Tarrant County, however, the application to all of Tarrant County of the average coefficient obtained in the Fort Worth area would probably result in errors of considerable magnitude.

The curves in figure 22 show the computed theoretical drawdown in water levels at the end of 3 months, 1 year, 3 years, and 5 years at various distances from a well pumped continuously at 1,000 gpm. The decline at any point is directly proportional to the rate of pumping; thus, to compute the decline produced by pumping 300 gpm, the indicated decline should be multiplied by 0.3. A storage coefficient of 0.0001 was adopted for the Travis Peak formation. Although this is somewhat higher than the average of the computed coefficients during a long period of time more water probably would be released from storage than is released during the

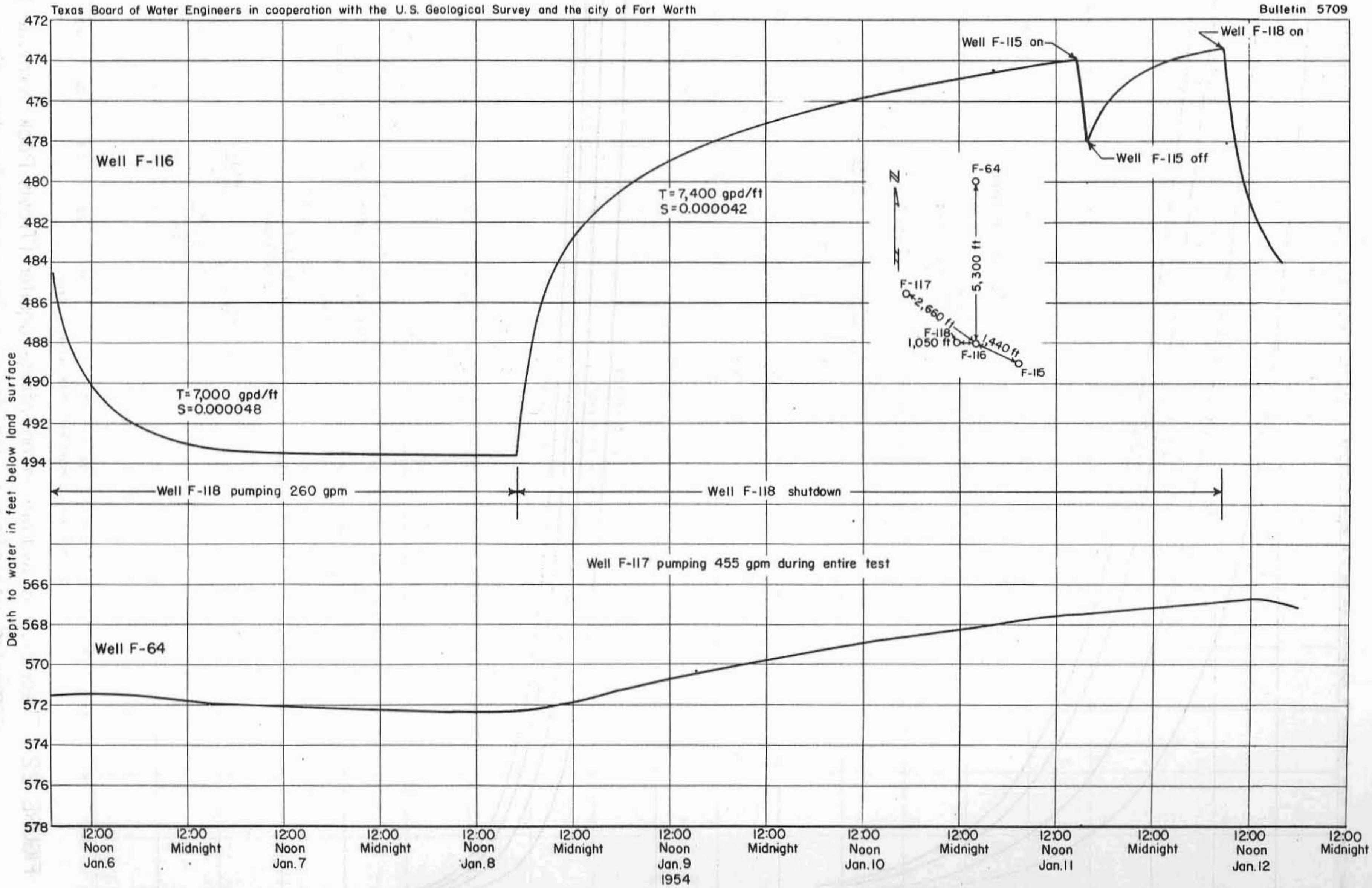

FIGURE 21. - Drawdown and recovery data for wells F-64 and F-116 screened in the Travis Peak formation, Handley, Tex.

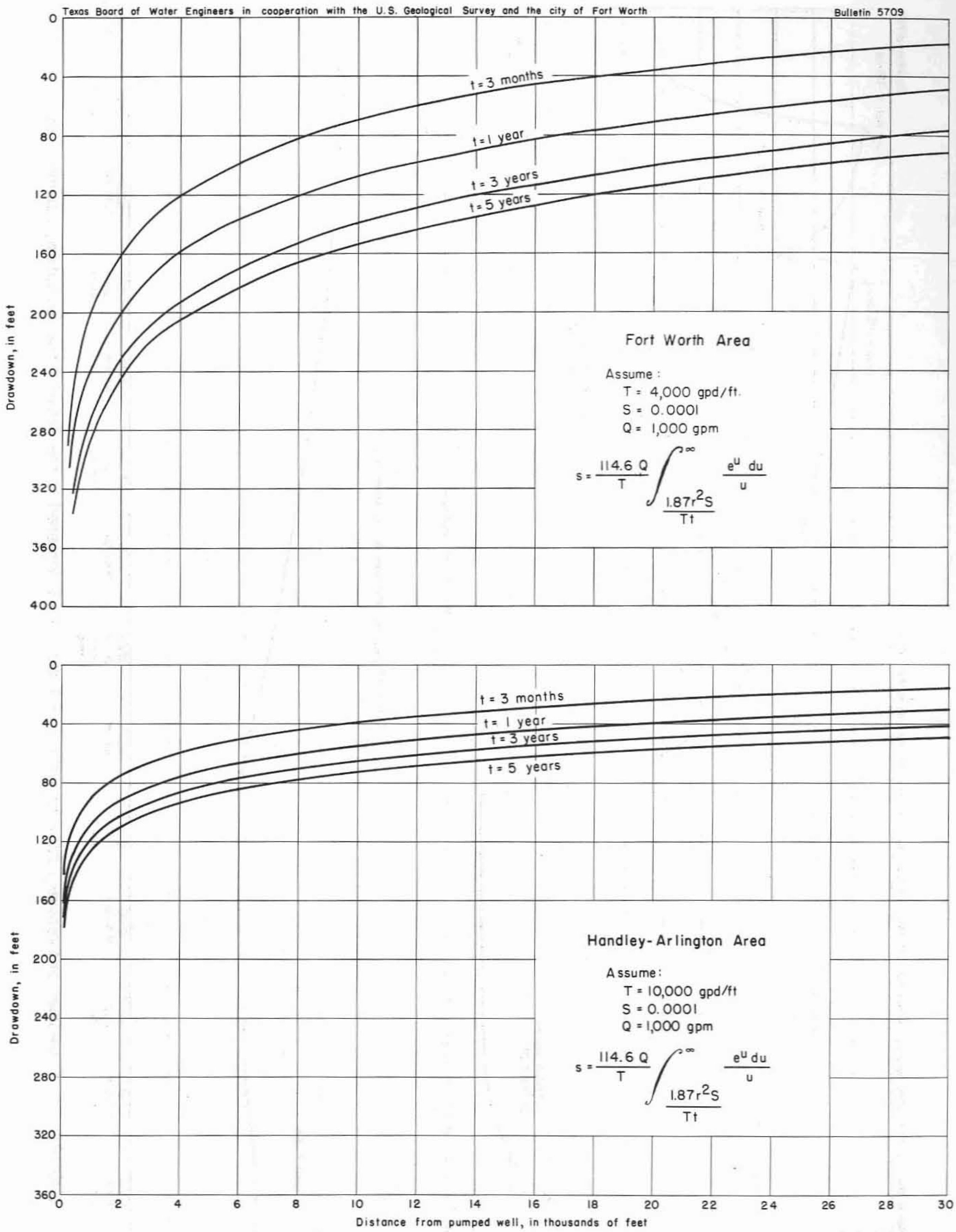

FIGURE 22.- Theoretical drawdown in an infinite aquifer (Travis Peak formation) computed according to the formula for nonsteady-state flow.

short pumping tests. Part of this additional water is squeezed out of storage by the compaction of the fine sediments within the aquifer, and part is from the overlying and underlying confining beds.

The widespread effect that large increases in pumping from the Travis Peak formation might have on artesian pressures is illustrated by a study of the water-level fluctuations in Tarrant County caused by increases in pumping in Dallas County. For example, in 1953 the city of Dallas increased the pumping from the Travis Peak by 2.5 million gallons per day (1,750 gpm). The computed drawdown for the period January 1953 to March 1954 in well F-95 at the eastern edge of Tarrant County was approximately 25 feet, or about 25 percent of the actual net decline measured during the period. Similarly, computations indicate that during 1953 approximately 50 percent of the total net decline of 53 feet in well F-39, which is in the Bell Aircraft-International Airport area, was caused by the increased pumping in Dallas County. The effect of the increased pumping in Dallas County on the artesian head in the Travis Peak in the Fort Worth area was not computed because of the errors inherent in applying an average coefficient of transmissibility across long distances in Tarrant County.

The Theis nonsteady-state formula is useful for predicting the interference effects caused by pumping closely spaced wells. In parts of Tarrant County, wells and well fields are sufficiently close to each other that considerable interference results. For example, in 1956 the Texas Electric Service Co. plans to increase pumping from 4 wells (F-115, F-119, F-121, and F-123) at the Handley plant by a total of 800,000 gallons per day, or by about 140 gpm from each well. The computed effects of the increase in pumping on the artesian head in the 4 wells, in 2 other production wells, and in wells E-91 and F-88 in Fort Worth and Arlington, respectively, are shown in table 6. The drawdowns computed for the 6 wells at Handley are based on coefficients of transmissibility and storage that are low for the area; therefore, the drawdowns in table 6 may be considered as the maximum.

Table 6.- Theoretical drawdown in wells produced by pumping an average of 140 gpm from each of four wells at Handley, Tex.

Well number	Location	Drawdown (ft.)		Computations based on:
		1 year	2 years	
F-115	Handley	103	110	
F-117	do	47	53	
F-119	do	109	115	T = 7,000 gpd/ft: S = 7×10^{-5}
F-121	do	105	112	
F-123	do	106	113	
F-118	do	52	58	
				1 day specific capacity: 2.5
F- 88	Arlington	13	16	T = 10,000: S = 10^{-4}
E- 91	Fort Worth	18	22	T = 5,000: S = 10^{-4}

Future Development

The development of large amounts of additional ground water from the Travis Peak formation does not appear practicable in the Fort Worth area unless the heavy pumping can be dispersed over large areas. The marked increase in the withdrawals of ground water in Tarrant and Dallas Counties during 1953 and 1954 has resulted in a substantial lowering of the artesian head in Tarrant County and has substantially depleted the available supplies of ground water in the Fort Worth area where wells and pumping are heavily concentrated. The pumping level in the Swift and Co. well E-91 in December 1954 was at 812 feet, which is 70 feet above the screen but more than 140 feet below the top of the formation. The pumping level in well E-134 at Westover Hills in March 1954 was at 736 feet, which is 23 feet below the top of the screen and about 70 feet below the top of the formation.

As long as pumping level remains above the top of the aquifer from which the well draws water, the aquifer is still full of water and the decline in level represents a decline in pressure. However, when the pumping level is lowered below the top of the aquifer, the aquifer is partly dewatered and the coefficient of transmissibility is decreased. Thus, dewatering of the aquifer indicates that more water is being pumped than is moving toward the areas of heavy pumping. One favorable condition develops, however: The coefficient of storage increases greatly when the aquifer is unwatered, and the growth of the cone of depression at a given rate of pumping becomes slower.

It is apparent, therefore, that the total withdrawal of ground water from the Travis Peak could be greatly increased if large scale pumping from concentrated areas were reduced and if the wells were spaced at greater intervals. Additional supplies of ground water may be obtained in the eastern part of the county or in the relatively undeveloped areas without causing dewatering of the aquifer because of the relatively high artesian head in those areas. However, an increase in pumping would result in further expansion of the zone of dewatering as well as a serious decline in the yields of most of the wells in the Fort Worth area.

Paluxy Sand

Yield of Wells

The yields of 62 wells that obtain water from the Paluxy sand in Tarrant County range from 15 to 408 gpm. Many domestic wells were reported to yield considerably less than 15 gpm but the yield was limited mostly by the capacity of the pump rather than by the aquifer.

The yields of 21 wells that were constructed with a gravel pack or screen or both ranged from 47 to 408 gpm and averaged 162 gpm. In only 6 of the wells was the yield less than 100 gpm. In general, the yields increased eastward, owing mainly to the larger available heads in wells which become progressively deeper as the Paluxy sand dips toward the east.

The specific capacities of 21 wells screened in the Paluxy sand ranged from 0.5 in well F-74 to 4.0 in well F-103 and averaged 1.9 (table 7).

Table 7.- Yield and specific capacities of wells screened in the Paluxy sand in Tarrant County, Tex.

Well number	Owner	Yield (gpm)	Drawdown (ft.)	Specific capacity (gpm/ft)
D- 16	Lake Worth Village	110	134	0.8
F- 50	Haltom City	100	40	2.5
F- 54	do	78	65	1.2
F- 57	do	115	45	2.6
F- 60	do	139	37	3.8
F- 74	do	47	89	.5
F-135	Westover Hills	55	76	.7
F-194	Parker Browne	55	76	.7
F-200	Curran Laundry	112	84	1.3
F- 2	Richland Hills	98	83	1.2
F- 5	do	174	83	2.1
F- 13	do	202	57	3.7
F- 22	Municipal Service Co.	199	53	3.3
F- 80	Arlington	408	133	3.1
F- 90	do	280	221	1.3
F- 94	do	200	155	1.3
F-103	do	400	101	4.0
F-107	do	300	209	1.4
F-110	do	155	134	1.2
H- 12	Everman	65	50	1.3
J- 5	Kennedale	111	72	1.6

The specific capacities increase toward the east, although varying substantially even in closely spaced wells of similar construction. The wide range in specific capacities is due primarily to changes in lithology and secondarily by variations in well construction. The thickness of the Paluxy in Tarrant County is fairly uniform and therefore has little effect on the variation in specific capacity.

Pumping Tests

The coefficients of transmissibility and storage determined from pumping tests at wells in the Paluxy sand are fairly uniform in Tarrant County (table 8). The coefficients are low, indicating that when closely spaced wells are pumped, steep hydraulic gradients are developed over a wide area in a relatively short time and there is considerable interference.

Table 8.- Coefficients of transmissibility and storage of the Paluxy sand.

Well number	Coefficient of transmissibility (gpd/ft)	Coefficient of storage
D- 32	4,300	3.4×10^{-4}
E-226	5,700	1.8×10^{-4}
E-113	3,300	8.7×10^{-5}
F- 1	3,300	1.0×10^{-4}
F- 96	5,600	
F-129	3,900	
H- 5	4,800	
J- 5	4,500	
	Average = 4,400	Geometric mean = 1.5×10^{-4}

Analysis of data obtained from a pumping test at well E-113 indicates that the drawdown rate decreases with time more than would be expected under the Theis formula. Thus, additional water was obtained either (1) by the vertical seepage of water through the less permeable confining beds, or (2) from a finite line source (Lake Worth ?) which intersects the sand. In most places the lower part of the Paluxy sand is separated from the upper part by a clay or shale bed of variable thickness, and the vertical movement of water through these less permeable materials is increased as the head in the lower sand is reduced by pumping. Because the distance from the well to a possible line source, which was computed to be about 1,600 feet, is much less than the actual distance from the well to the outcrop of the sands in the lake, it follows that the additional water indicated by the data was due to leakage through the shale bed and not recharge from the lake.

The theoretical drawdown in the Paluxy sand at various distances from a well pumping continuously is shown in figure 23. The coefficients of transmissibility and storage used in constructing the curves in figure 23 are within the range of coefficients determined from the pumping tests (table 8). Although the curves were computed on the assumption that the Paluxy is an infinite aquifer, the outcrop of the Paluxy is within finite distance and its effect will eventually tend to reduce the rate of decline because of the existence of water-table conditions and a larger coefficient of storage in the outcrop area. Nevertheless, the drawdown curve may be used to estimate the magnitude of the decline in artesian head caused by an increase in withdrawals or the interference from closely spaced wells.

Future Development

The development of additional large amounts of ground water from the Paluxy sand in Tarrant County is not practicable in the heavily pumped Fort Worth area. The Paluxy is now overdrawn in a large part of the area between White Settlement and the eastern part of Fort Worth. The artesian head has been lowered below the top of the Paluxy in many wells; consequently the aquifer is partly dewatered and the coefficient of transmissibility decreased. The artesian head is below the top of the screened part of the lower sand in several wells; thus, additional large withdrawals in this area would result only in the further expansion of the zone of dewatering, a decrease in the coefficient of transmissibility of the sand, and a serious decrease in the yields of most wells.

A moderate increase in withdrawals of ground water from the Paluxy sand may be possible in the relatively undeveloped areas in Tarrant County without appreciably lowering the artesian head in the heavily pumped Fort Worth area. It should be expected, however, that large withdrawals even from these areas of relatively light pumping will have a measurable effect on the artesian head in a large part of Tarrant County. On the other hand, overall pumping from the Paluxy could be increased materially if the pumping in the Fort Worth area were dispersed and the wells spaced over a wider area.

Woodbine Formation

Yield of Wells

Very few wells of large capacity obtain water from the Woodbine formation in Tarrant County. The city of Mansfield has four wells each of which were reported to have an average yield of about 70 gpm from the Woodbine. Yields of wells in the city of Dallas range from about 70 to 200 gpm, indicating that yields from the Woodbine increase eastward. On the whole, in Tarrant County

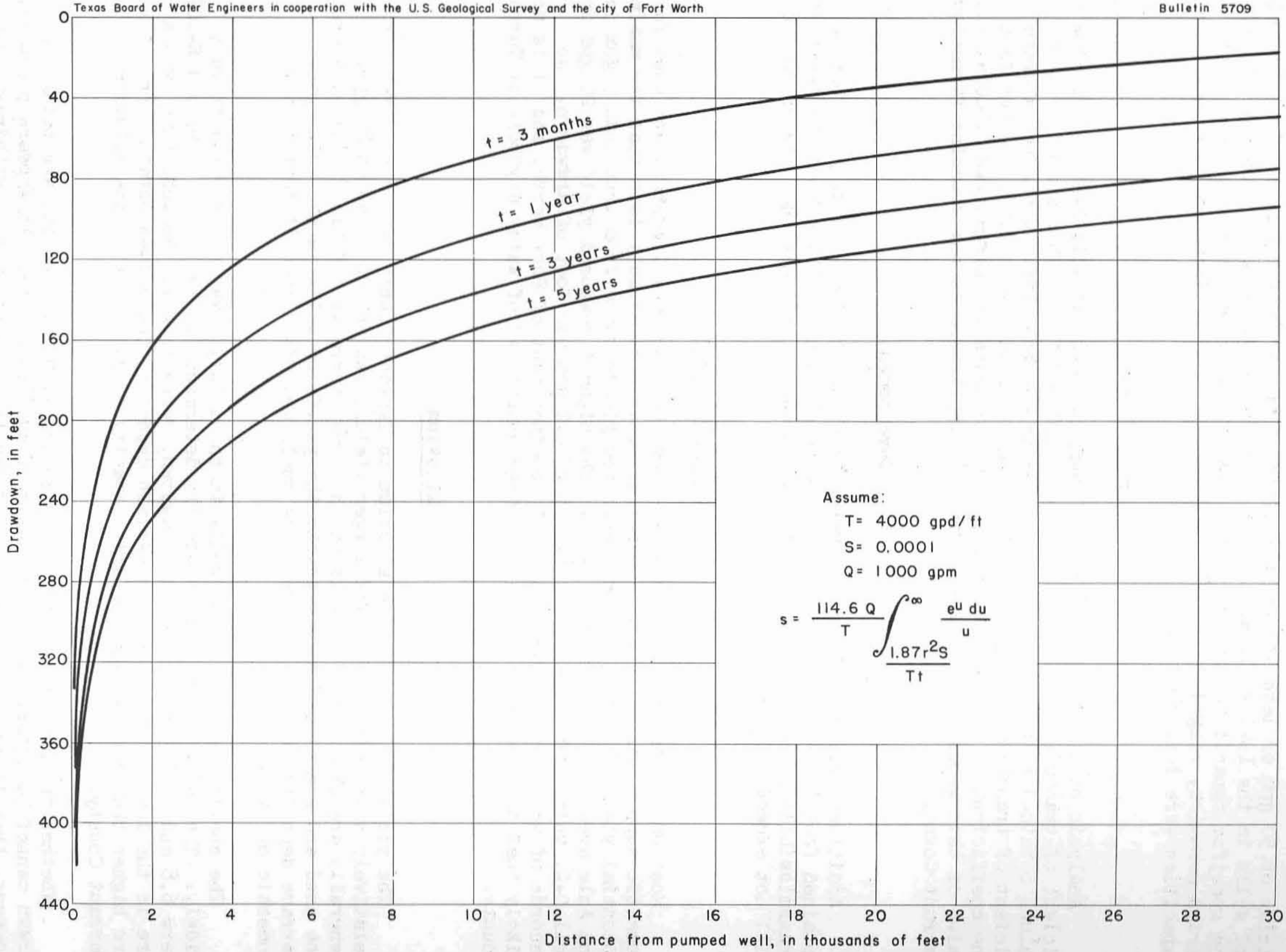

FIGURE 23. - Theoretical drawdown in an infinite aquifer (Paluxy sand) computed according to the formula for nonsteady-state flow.

yields of 50 gpm or less are to be expected from the Dexter member of the Woodbine and wells in the Lewisville member may be expected to yield even smaller quantities. The specific capacity of seven wells in the Woodbine, as determined from tests of varied duration, ranged from 0.3 to 3.9 gpm per foot of drawdown; most specific capacities were less than 0.5.

Pumping Tests

Analysis of the results of a short pumping tests at well F-28 indicates a coefficient of transmissibility of about 2,700 gpd per foot. This agrees with the values obtained by Livingston (1945, p. 5) in Sherman, Tex., where the average coefficient of transmissibility for two pumping tests was about 2,400 gpd per foot. The coefficient of storage determined from the tests at Sherman was 0.00014, and a value of this general magnitude probably is applicable to the Woodbine formation in Tarrant County.

Future Development

Additional supplies of ground water adequate for domestic purposes may be obtained from the Woodbine formation in Tarrant County. The low coefficients of transmissibility and the lenticularity of the sands indicate that yields probably will not exceed 100 gpm.

Glen Rose Limestone

Most of the wells that draw water from the Glen Rose limestone are used for domestic supply and usually are pumped at rates considerably less than the maximum potential yield of the formation. Reported yields range from less than 5 gpm in the Azle area to 45 gpm in well E-172. The highest measured yield was 20 gpm in well D-2, which had a specific capacity of 0.2 gpm per foot of drawdown. No records of wells in the Glen Rose were obtained east of Fort Worth, and it is unlikely that the Glen Rose will yield large quantities of water anywhere in Tarrant County.

Alluvium

The yields of wells in the alluvium in Tarrant County vary considerably over relatively short distances. The larger yields, ranging up to about 80 gpm, generally are obtained from wells on the lower terraces and flood plains, where the sand and gravel are fairly thick; the yields of wells in the thin upper terrace deposits or upland gravels are small and often insufficient even for domestic or stock purposes.

The specific capacities of wells in the alluvium may be expected to vary widely. The values of specific capacity determined in two wells, E-95 and E-109, were 6.8 and 10.6 gpm per foot of drawdown, respectively. Because these wells are in the lower terrace and flood-plain deposits, the values obtained probably are higher than the average specific capacity of all wells in the alluvium in Tarrant County.

Whether the ground-water supplies in the alluvial deposits are being overdrawn cannot be determined on the basis of available data. It appears probable, however, that in most of the lower terraces the present rate of withdrawal can be maintained without serious depletion.

USE OF GROUND WATER

During the course of the investigation in Tarrant County, data were obtained for 729 wells (table 10). About 170 of the wells were used for public supply, 102 were used for industrial purposes, 35 for irrigation, and the remainder for domestic or stock supplies, or both. Although the wells that were inventoried are only a fraction of the wells in Tarrant County, most of the large public-supply and industrial wells are included.

Public Supplies

The municipal water supplies for all but three cities and towns in Tarrant County are obtained from wells. The wells of River Oaks and Westover Hills were abandoned in 1953 and 1954, respectively. Fort Worth has a surface-water supply, but several localities within the corporate limits of Fort Worth are supplied from wells of private water companies.

The average daily pumpage of ground water for public supplies in Tarrant County increased about seven fold from 1941 to 1954, inclusive. In 1941 the municipal use of ground water was estimated at about 1 mgd, or about a tenth of the total withdrawal of ground water in the county. In 1954 public supplies accounted for 7.5 mgd, or about 45 percent of the total ground water pumped. About two-thirds of the wells used for public supply obtain water from the Paluxy sand. Although less than a quarter of the wells used for public supply obtained water from the Travis Peak formation, these wells supplied 4.5 mgd, or about three-fifths, of the water pumped for municipal use. The remaining wells, about a tenth of the total, draw from the Glen Rose and Woodbine formations.

The city of Arlington is the largest single user of ground water in Tarrant County. In 1940 the population of Arlington was 4,240, according to the United States Bureau of the Census, and the public-water supply came from five wells in the Paluxy sand ranging from 800 to 900 feet in depth. The average daily withdrawal was about 400,000 gallons, or approximately 100 gallons per capita. By 1946 the average daily rate had increased to 800,000 gallons. The entire supply was obtained from two wells, one of which was completed in the Travis Peak formation in 1946. This well is 1,775 feet deep and produced 448 gpm.

Between 1950 and 1954 the population of Arlington increased from 7,692 to an estimated 25,000. To keep up with the constantly growing demand for water (see table 9), five new wells were completed in the Travis Peak formation and three new ones in the Paluxy sand. The yields of the wells in the Travis Peak ranged from 369 to 508 gpm, and the yields of the wells in the Paluxy ranged from 160 to 408 gpm. The new development of the Paluxy sand was necessitated by the fear of local over-pumping of the Travis Peak formation. The average daily pumpage during the period 1951-54, inclusive, is given in the following table.

Table 9.- Average daily pumpage of ground water for municipal supply at Arlington, Tex., 1951-54.

Year	Gallons
1951	990,000
1952	1,290,000
1953	1,650,000
1954	2,500,000

In order to meet the expected increase in water needs for 1955, the city drilled four more wells to the Paluxy sand and one to the Travis Peak formation. Thus, in 1955, Arlington had a total of 14 wells which were evenly divided between the Travis Peak and the Paluxy.

Because of the anticipated additional increase in the use of water and the rapid decline in artesian head due to the concentration of pumping, the city plans to obtain a surface-water supply from Village Creek. The reservoir is expected to impound 45,700 acre-feet, and 23,000 acre-feet per year, or 20 mgd, will be available to the city of Arlington.

Prior to 1955 the city of Mansfield obtained its entire water supply from the Woodbine formation. Pumping was from four wells which were about 200 feet deep and had a reported average yield of 70 gpm each. The average daily consumption was reported to be 80,000 gallons. Early in 1955 the city had a well drilled to the Travis Peak formation. The well was 921 feet deep and was test pumped at 391 gpm.

In 1954 the water supply for Haltom City was obtained from 10 wells, 4 of which were drilled to the Travis Peak formation. Wells that drew from the Travis Peak range in depth from 1,140 to 1,280 feet and had yields ranging from 340 to 407 gpm. The other 6 wells in the Paluxy sand range in depth from 385 to 480 feet and had yields ranging from 50 to 115 gpm. The average pumpage in 1954 was estimated at 900,000 gpd. During the latter part of 1954 and in 1955 four new wells were drilled, two to the Travis Peak and two to the Paluxy.

In 1954 the water supply for Richland Hills was obtained from seven wells, two of which were drilled to the Travis Peak formation. The yields ranged from 147 to 400 gpm in the wells in the Travis Peak, and from 70 to 202 gpm in wells in the Paluxy sand. The average daily consumption increased from 75,000 gallons in 1949 to approximately 450,000 gallons in 1954. During 1955 the city had two wells drilled to the Travis Peak formation, one of which was abandoned because of an insufficient thickness of sand.

In 1954 the public-water supply for White Settlement was obtained from 14 wells, 12 of which obtained water from the Paluxy sand. The yields of the wells in the Paluxy are not known but are believed to be less than 100 gpm. The other two wells draw from the Travis Peak formation and the yield of well D-39 was reported to be 265 gpm. The average daily consumption in 1954 was approximately 400,000 gallons, of which less than 25 percent was reported to be from the Travis Peak. A new well drilled to the Paluxy sand in 1955 had a reported yield of 180 gpm.

Industrial Supplies

Until recently, most of the ground water pumped in Tarrant County was for industrial supply. In 1941 the industrial use of ground water in the Fort Worth area was about 6.2 mgd, or about 85 percent of the total pumpage. Most of the pumping was in the heavily industrialized area of north Fort Worth, where packing houses, petroleum refineries, and stockyards used more than 4.0 mgd. Most of the railroads, hotels, steel plants, laundries, and other industrial plants obtained their water supply from wells. The use of ground water by industry increased during World War II, but no records are available for the quantity of ground water pumped.

In 1954 the industrial use of ground water totaled about 6.5 mgd, or about 40 percent of the ground water pumped in Tarrant County. The largest individual consumer was the plant of the Texas Electric Service Co. at Handley, which used an average of 2.5 mgd from 6 wells in the Travis Peak formation. Swift and Company, which is the second largest consumer of ground water, is estimated to have pumped 1.4 mgd from 5 wells in the Travis Peak. Thus, pumping at the Swift plant and Texas Electric Service Co. plant at Handley amounted to 60 percent of the ground water pumped by industry in Tarrant County.

The increase in the use of ground water by industry has not kept pace with the increase in use for other purposes in Tarrant County. This is due in part to the closing, or reduction in output, of the Sinclair and Gulf refineries which used a reported 1.4 mgd in 1941; in part to the complete dieselization of the railroads; and in part to the fact that many of the industrial wells were too small in diameter to permit the lowering of large pumps as water levels declined. Many industries and business establishments have found it more economical to obtain water from the municipal supply of Fort Worth.

Agricultural Supplies

Ground water is not used extensively for agriculture in Tarrant County. Irrigation of truck crops and grasses is practiced to a small extent on the flood plains of the West Fork of the Trinity River in the southwestern part of the county, and on the uplands in the area of outcrop of the Woodbine formation.

Irrigation on the flood plains is from shallow wells that yield small to moderate quantities of water. The largest yield is 80 gpm from well F-4, which obtains water from the alluvial deposits and irrigates 35 to 40 acres. Irrigation on the uplands is limited to isolated plots on the outcrop of the Woodbine. Well C-55, which was drilled to a depth of 209 feet and had a yield of 60 gpm, was used to irrigate 20 acres in 1954. Water from the Trinity group is generally considered unsuitable for irrigation because of the high percentage of soluble sodium, commonly known as the percent sodium. In late 1954 and early 1955, however, 11 wells, of which C-9 to C-13 are representative, were drilled in the Wheatland area to the Travis Peak, Glen Rose, and Paluxy formations to obtain water for irrigation. Irrigation was suspended in 1955 pending determination of the suitability of the chemical quality of the water.

Nearly all the stock supplies in the upland farming and ranching areas are obtained from wells drilled to the Paluxy and Woodbine formations.

QUALITY OF GROUND WATER

Chemical analyses of water from 169 wells and springs in Tarrant County are given in table 13. In addition, analyses of water collected from Lake Worth, Eagle Mountain Lake, and the Trinity River are listed to show any possible relationship between surface water and the ground water in adjacent areas. Representative analyses of water from the major aquifers underlying Tarrant County are shown graphically in figure 24. The heights of the sections in each block correspond to the quantities in equivalents per million of the cations magnesium, calcium, and sodium and potassium and the anions bicarbonate, sulfate, and chloride (the latter including fluoride and nitrate).

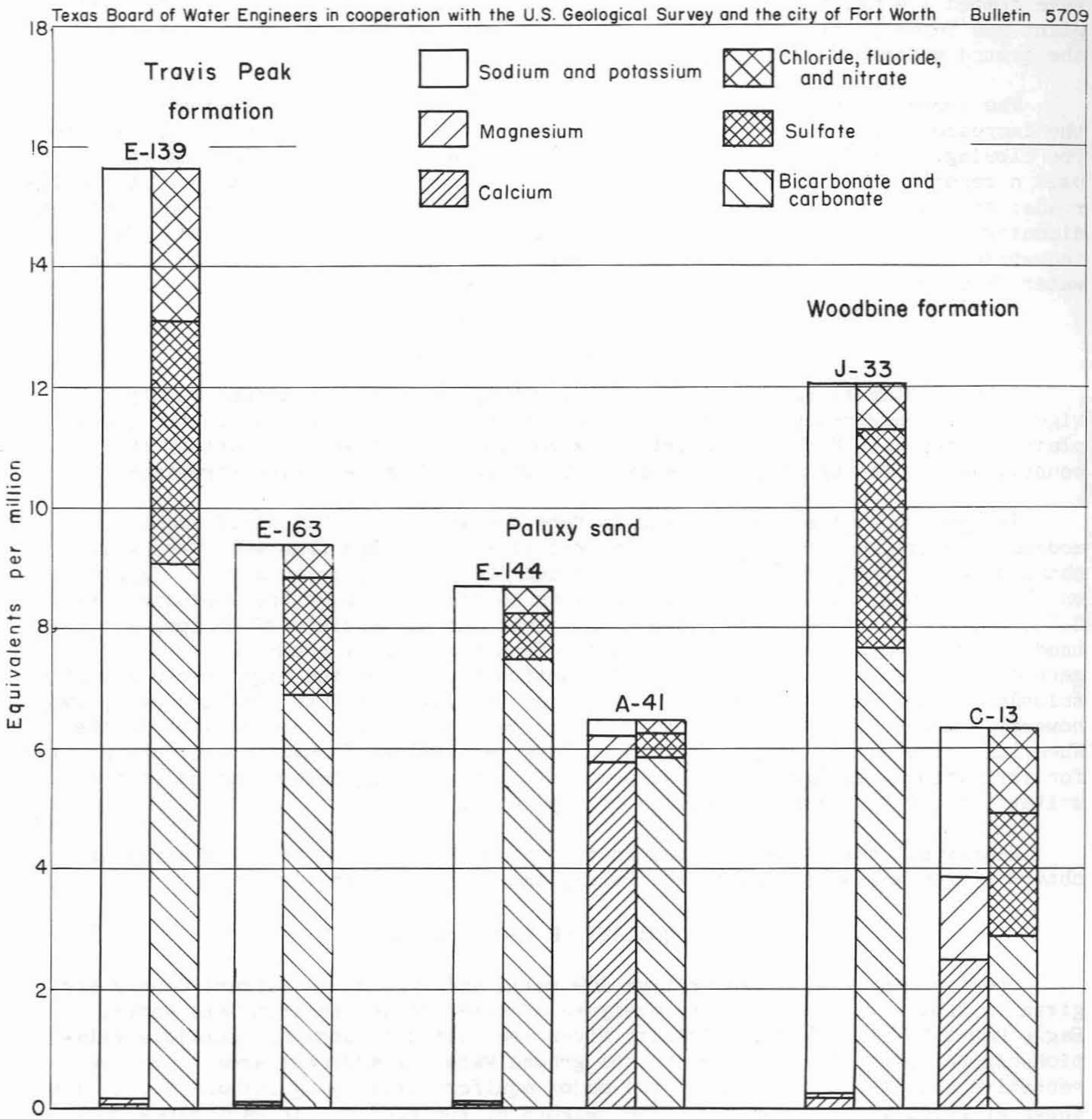

FIGURE 24.- Quality of water from typical wells in the water-bearing formations of Tarrant County, Tex.

It is not possible to define exact limits of mineralization beyond which ground water cannot be used for particular purposes. Wherever possible, however, water used for municipal and domestic supplies should conform to the standards promulgated by the United States Public Health Service (1946) for drinking water for use on interstate carriers. These standards place the following limits on some of the minerals most commonly found in solution:

Iron (Fe) and manganese (Mn) together should not exceed 0.3 part per million (ppm).
Magnesium (Mg) should not exceed 125 ppm.
Chloride (Cl) should not exceed 250 ppm.
Sulfate (SO_4) should not exceed 250 ppm.
Dissolved solids should not exceed 500 ppm for a water of good chemical quality. However, if such water is not available, a dissolved-solids content of 1,000 ppm may be permitted.

A fluoride content in excess of 1.5 ppm in drinking water may cause a dental defect known as mottled enamel (Dean, Dixon, and Cohen, 1935, p. 424-442). On the other hand, the presence of fluoride in quantities less than 1.5 ppm may have a beneficial effect in decreasing the incidence of tooth decay (Dean, Arnold, and Elvove, 1942). The Texas State Department of Health now recommends as desirable a fluoride concentration of 1.0 to 1.5 ppm.

Hardness is caused almost entirely by compounds of calcium and magnesium. Water that has a hardness of less than 60 ppm usually is rated as soft and is suitable for many purposes without further softening. Water having hardness ranging from 61 to 120 ppm may be considered moderately hard. Water having hardness ranging from 121 to 200 ppm is considered hard, and laundries and industries may profitably soften such supplies. Water having hardness of more than 200 ppm usually requires some softening before being satisfactory for most purposes.

Dissolved solids, percent sodium, residual sodium carbonate (equivalents per million of carbonate and bicarbonate in excess of calcium and magnesium), and boron are important factors when considering the use of ground water for irrigation. Water having a percent sodium of more than 80, more than 2.5 epm of residual sodium carbonate, or a boron content greater than 1.25 ppm for sensitive crops and 3.75 ppm for tolerant crops is generally considered unsuitable for irrigation (U. S. Salinity Laboratory Staff, 1954, p. 81). Other factors, however, including climatic conditions, soil type, crop, and quantity of water used may be equally significant and under optimum conditions may permit the satisfactory use of a water with a high percent sodium or a high boron content.

Travis Peak Formation

The Travis Peak formation in Tarrant County generally yields water that conforms in most respects to the drinking-water standards of the Public Health Service. The water is high in sodium bicarbonate and soft. In 43 samples the hardness ranged from 4 to 42 ppm and averaged 15 ppm. The dissolved solids, which ranged from 527 to 1,510 ppm in 38 samples and averaged 864, exceeded 1,000 ppm in 6 samples. In 26 samples the fluoride content ranged from 1.4 to 7.0 ppm and averaged 2.4 ppm. In 21 of these samples the fluoride exceeded the maximum limit of 1.5 ppm. The percent sodium averaged 98 in 38 analyses and exceeded 90 in all samples. Thus, the water from the Travis Peak formation is unsuitable for irrigation of crops.

Paluxy Sand

The water from the Paluxy sand generally is suitable for domestic, public, stock, and some industrial supplies. On the whole it is superior to the waters from the underlying Travis Peak formation and Glen Rose limestone, being softer and considerably less mineralized. The analyses of 75 water samples from the Paluxy indicate that the hardness ranged from 2 to 310 ppm. The hardness varied considerably where the Paluxy crops out in grids A and D, ranging from 5 ppm in well D-13 to 310 ppm in well A-41. Downdip the water becomes softer; in 44 samples the hardness was less than 10 ppm. The dissolved solids in 75 samples ranged from 272 to 762 ppm and averaged 518 ppm. The percent sodium in 74 samples of water ranged from 4 to 99. In the outcrop area in grids A and D the percent sodium varied widely, ranging from a low of 4 in well A-41 to 99 in well D-25. Downdip the percent sodium averaged 97 in 52 water samples, and in only 4 of these was the percent sodium less than 97. The fluoride content of 46 water samples averaged 0.6 ppm, and in only two samples exceeded the maximum limit of 1.5 ppm.

Woodbine Formation

Water from the Woodbine formation is used for domestic, public, and stock supplies in Tarrant County. Analyses of 32 samples of water from the Woodbine show that the water is more highly mineralized than water from the deeper Paluxy sand, but, because of its relatively shallow depth, the Woodbine is the source of water for many wells in the eastern part of the county.

The chemical quality of the water from the Woodbine formation varies considerably, both laterally and vertically. In 32 water samples the hardness ranged from 2 to 2,630 ppm, and the dissolved solids ranged from 58 to 3,510 ppm. The water from the deeper sands generally is less mineralized than the water from the shallow sands, but water from the deeper sands may be satisfactory in one area and unsatisfactory in another area. For example, the water from wells F-38 and F-108, which obtain water from the Dexter member, had hardnesses of 53 and 338 ppm, respectively.

The water from the Woodbine is typically high in iron, which generally is in the form of ferrous bicarbonate. The iron content ranged from 0.08 to 35 ppm and averaged 3.8 ppm in 25 water samples. In only 6 of the samples was the iron content less than 0.3 ppm.

Shallow wells in the outcrop of the Woodbine formation or wells that are drilled to the Lewisville member in places obtain highly mineralized water from beds of gypsum or lignite. The water, referred to by Hill (1901, p. 566) as "copperas," may be acid and high in sulfate. The analysis of water from well F-76, drilled to the Lewisville member, indicated a hardness of 2,280 ppm and dissolved solids of 3,510 ppm, including 1,960 ppm of sulfate. Waters from two shallow wells (H-36 and C-64) in the area of outcrop of the Woodbine had acidities as H_2SO_4 of 5 and 6 ppm and pH values of 4.0 and 3.9, respectively. These acid waters are in sharp contrast to the generally alkaline waters from the Woodbine (table 13). The principal constituent of the water from well H-36 is aluminum sulfate (alum), which may result from the reaction of sulfuric acid on the alumina of clay. The sulfuric acid may be due to the action of ground water on sulfides in the associated lignite beds.

Alluvium

Wells in the alluvial deposits of Tarrant County yield water that is very hard and high in bicarbonate. The water is satisfactory for irrigation, but because of the shallow depth the water is readily contaminated, and unless disinfected it is unsafe for domestic and public supplies. The hardness of 14 water samples ranged from 138 to 1,410 ppm. Because of the low percent sodium, which was less than 35 in 10 of the 14 water samples, the water is satisfactory for irrigation of lawns and crops. Analyses of 11 samples of water from the alluvium indicated that the nitrate content ranged from 0.5 to 64 ppm. According to Maxcy (1950), water that has a nitrate concentration between 20 and 40 ppm might be unsafe for infant feeding, and water that has more than 44 ppm probably is unsafe. Maxcy points out that boiling of water does not lessen the nitrate concentration.

TEMPERATURE OF GROUND WATER

The temperature of ground water at a given locality and depth is relatively uniform throughout the year. In this respect, ground water is superior to surface water for cooling purposes. The temperature of water from the Clear Fork and West Fork of the Trinity River ranged from 32° to 98°F, reflecting daily and seasonal atmospheric variations.

The temperature of ground water from 23 wells screened in the Travis Peak formation in Tarrant County ranged from 69.5° to 91°F, and the temperature of water from 16 wells screened in the Paluxy sand ranged from 64° to 81°F. Figure 25 shows the relationship of ground-water temperature with depth. The thermal gradient determined from the Travis Peak and Paluxy formations averaged roughly 1°F in 50 feet.

The temperature of water from three wells screened in the Woodbine formation ranged from 67° to 69°F. Because of the meager data available, the thermal gradient for water in the Woodbine in Tarrant County could not be determined. According to Plummer and Sargent (1931, p. 90) the gradient at Dallas is about 1°F in 65 feet.

The temperature of water in shallow wells in the alluvial deposits approaches the mean annual air temperature of the area. In five wells averaging 28 feet in depth the temperature ranged from 63° to 69°F and averaged 67°F. The mean annual temperature at Fort Worth is 66°F.

CONCLUSIONS

The principal aquifers in Tarrant County are the Travis Peak formation and the Paluxy sand. Small quantities of ground water are obtained from the Woodbine formation, the alluvial deposits, and, west of Fort Worth, the Glen Rose limestone.

The ground water in Tarrant County is derived chiefly from penetration of rainfall on the outcrop area of the aquifers either in the county or in areas north and west of the county. A part of the ground water is derived from streamflow and seepage from lakes.

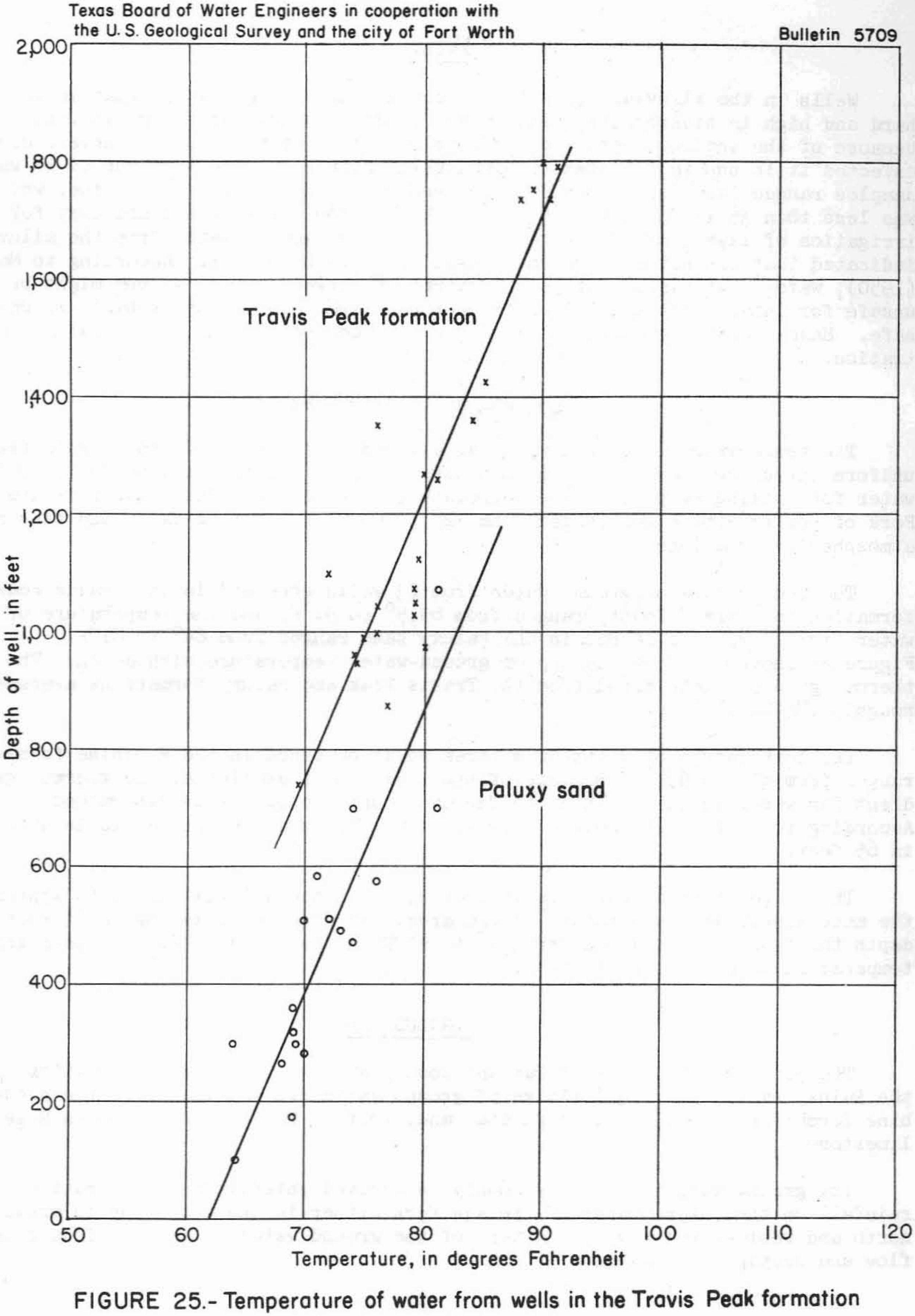

FIGURE 25.- Temperature of water from wells in the Travis Peak formation and Paluxy sand, Tarrant County, Tex.

The marked increase in the withdrawals of ground water from the Travis Peak formation and Paluxy sand in Tarrant and Dallas Counties during 1953 and 1954 resulted in a substantial lowering of the artesian head in Tarrant County and seriously depleted the available supplies of ground water in the older and more heavily pumped part of the Fort Worth area. Concentrated pumping rather than overdraft of the regional supply has caused some dewatering of the aquifers in the Fort Worth area. Consequently, continued pumping of large quantities of water or an increase in the withdrawal of water from the Fort Worth area will result in further expansion of the zone of dewatering as well as a large decrease in the yields of most existing wells and the abandonment of many wells. In addition, because of the low coefficients of transmissibility of the aquifers, the development of large amounts of ground water from presently undeveloped areas is not practicable without serious effect on the ground-water supply in the heavily pumped Fort Worth area. It is possible that use of the ground-water resources of Tarrant County can be increased by wider spacing of wells or redistribution of pumping from the Travis Peak formation and the Paluxy sand in the overdeveloped areas. A moderate increase in withdrawals of water may be possible from the Travis Peak and Paluxy outside the areas of concentrated pumping, and small additional amounts of water may be developed from the Woodbine formation in the eastern part of the county.

It is apparent, therefore, that the larger cities and industries will not be able to depend indefinitely upon the dwindling ground-water resources for water supplies, and that there will have to be increased development of surface-water sources in Tarrant County and nearby counties. A part of the decrease in the withdrawal enabled by the development of additional surface-water sources would thus become available for the water supplies of the smaller communities and industries that are relatively distant from sources of surface water. In any future development, however, wider spacing of wells should be considered and withdrawals of large quantities of ground water from small areas should be discouraged.

The observation of water levels and the inventory of pumpage should be continued on a regular basis to enable the evaluation of the status of declining artesian head and dewatering of aquifers.

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Table 10.- Records of wells in Tarrant County, Tex.

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 : C, cylinder; E, electric; G, gasoline; H, hand; J, jet; T, turbine; W, windmill. 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.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*A-1	C. Brister	C. Brister	1946	26	24	Paluxy sand	24.2 27.8	Nov. 1, 1950 Dec. 13, 1954	C, W	D	Dug. Temp. 68°F.
A-2	Texas National Guard	Layne-Texas Co. Ltd.	1943	542	16, 13, 4	Travis Peak formation	144	1943	T, E, 15	P	Drawdown reported 194 ft after 24 hours pumping 76 gpm, Feb. 4, 1943. Pump set at 370 ft.
*A-3	do	do	1942	573	13, 8	do	211	Nov. 1942	T, E, 30	P	Casing: 13-in. to 465 ft; 8-in. liner to 545 ft; screen from 482 to 539 ft. Drawdown reported 132 ft after 2[illegible]-hours pumping 140 gpm, Nov. 17, 1942. Pumps set at 350 ft, lowered 40 ft, September 1954. 1/
A-4	R. E. Ellis	E. S. Allen	1945	336	8, 4	Paluxy sand	266.0	Sept. 16, 1954	C, W, E	D, S	Pump set at 292 ft.
*A-5	I. A. Warren	Ft. Worth Drilling Co.	1948	152	8, 4	Glen Rose limestone	12	Nov. 2, 1950	J, E, ¾	D	Reported odor of hydrogen sulfide from bottom sand. 1/
A-6	Tim Carter	F. W. Watts	1953	365	7, 5	do	130	Aug. 1953	C, E, 1	D	Paluxy sand to 30 ft. Sand in Glen Rose limestone 175 to 185 ft cased off. Pump set at 210 ft.
A-7	L. E. Adler	Joe Teague	1948	306	8, 6, 4	Paluxy sand and Glen Rose limestone	12	Mar. 1949	C, E	D	Casing perforated from 119 to 123 ft, and 278 to 299 ft.
A-8	F. E. Paschall	do	1947	123	6, 4	Paluxy sand	12	July 1947	J, E, ½	D	
A-9	Bob Thomas	B. H. Whitfield	1953	470	7, 5, 4	Travis Peak formation	180	Jan. 1953	T, E, 1½	D	Casing: 4-in. liner perforated from 342 to 470 ft. Pump set at 315 ft.
*A-10	H. E. Boyd	Milner Supply Co.	1950	340	4	Glen Rose formation	60	Sept. 1950	C, E, ¾	D	1/
*A-11	H. A. Farrell	B. H. Whitfield	1949	260	7, 4	do	--	--	C, E, ½	D	
A-12	-- Tuttle	do	1952	104	6, 4	Paluxy sand	--	--	J, E, ¾	D	
*A-13	Texas Electric Service Co.	--	1953	Spring	--	do	+	--	Flows	N	Spring flow.
*A-14	do	B. H. Whitfield	1952	196	7,	Glen Rose limestone	--	--	T, E	P, Ind	Pump set at 147 ft. Temp. 68°F.

See footnotes at end of table.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
A-15	Texas Electric Service Co.	--	--	123	6, 4	Paluxy sand	116.3	Aug. 3, 1953	N	N	Abandoned.
A-16	Lakeview Baptist Church	Dan McKee	1953	250	4	do	130	Jan. 1953	T,E, 1	D,P	Reported water hard.
*A-17	Eagle Mountain Lake School	J. C. Hall & Son	1948	254	8, 6	do	80	Apr. 1950	C,E, 2	--	
A-18	P. R. Bond well 7	Milner Supply Co.	1948	225	4	do	153	Sept. 1948	C,W	-S	
A-19	W. C. Hart	do	1950	233	4	Glen Rose limestone	--	--	C,E	D,P	1/
A-20	H. V. Woodall	B. H. Whitfield	1953	242	7, 4	do	70	Aug. 1953	C,E, ¾	D	Casing perforated from 215 to 242 ft.
A-21	Ray Polley	do	1953	270	7, 4	do	65	July 1953	T,E, 1	D	Casing: 4-in. perforated from 230 to 270 ft.
A-22	Houston Hill	J. Teague	1952	539	4	Travis Peak formation	220	Sept. 1952	C,E	D	Pump set at 265 ft. 1/
*A-23	J. W. Lancaster	H. E. Turberville	1948	349	7, 6	Glen Rose limestone	--	--	J,E, ¾	D	
A-24	L. L. Rector	Dan McKee	1953	251	4	do	110	June 1953	T,E, 1	D	
A-25	Bill Pierce	Bill Pierce	1950	25	4	Paluxy sand	--	--	--	--	Casing: 1½-in. pipe to 19 ft, 3-in. pipe from 19 to 25 ft. Reported water hard and high in iron.
*A-26	Pierce Water Co.	Milner Supply Co.	1948	450	4	Glen Rose limestone	--	--	C,E	P	Yield reported 1 gpm in 1952. Well deepened to 450 ft; pump lowered from 211 to 340 ft in 1952. 1/
*A-27	George Dunaway	B. H. Whitfield	1949	393	5, 4	do	25	1949	C,E, ¾	D	
A-28	F. R. Harrison	Ft.Worth Drilling Co.	1944	320	4	do	--	--	C,E, ¾	D	
A-29	Pierce Water Co.	Dan McKee	1953	295	4	do	60	Mar. 1953	T,E	P	Well in Parker County.
A-30	B. H. Whitfield	C. Baker	1943	140	4	Paluxy sand	60	Mar. 1953	J,E, ¾	D	Reported weak supply. Water from sand below shellrock.
A-31	Wm. Porter	-- Gross	1920	325	5	Glen Rose limestone	58.3	Sept.28, 1953	C,W	D,S	Pump set at 180 ft.
*A-32	S. J. Gilbreth	W. Lindsey	--	153	4	Paluxy sand	--	--	C,E	D	Water at 40 ft reported hard, cased off.
A-33	C. T. Trammel	R. P. Dillbeck	1947	138	6	do	--	--	C,E, ¾	D	Pump set at 105 ft.
A-34	-- Conway	B. F. Whitfield	1952	187	4	do	80	Dec. 1952	C,E, 1	D	Water in top sand reported high in iron content, cased off.
A-35	P. W. Simonds	R. P. Dillbeck	1953	190	5	do	84.7	Oct. 2, 1953	C,E, ½	D	

See footnotes at end of table.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
A-36	J. H. Morris	B. F. Whitfield	1951	50	--	Paluxy sand	15.5	Sept.24, 1953	C,E, 1/3	D,S, Irr	Reported weak supply. Pump set at 21 ft.
A-37	M. R. Young	do	1953	374	7, 4	Glen Rose limestone	15	Mar. 1953	T,E, 1½	D	Pumping level reported 200 ft while pumping 20 gpm. Pump set at 252 ft.
A-38	W. H. Slay	--	1935	330	6, 4	do	15 48.5 45	Nov. 1948 Nov. 2, 1950 Apr. 1955	J,E, 1½	P	Pumping level measured 110 ft Nov. 2, 1950. Pumping level reported 175 ft while pumping 6 gpm, April 1955.
A-39	E. H. Robinson	H. E. Turberville	1949	151	7, 5, 4	Paluxy sand	54.0	Jan. 11, 1950	C,E, ½	D,Ind	
A-40	D. E. Bowser	F. W. Watts	1953	130	4	do	60.0	Sept.24, 1953	J,E, ¾	D	Pump set at 110 ft.
*A-41	L. M. Easley	P. Dillbeck	1947	135	4	do	40 41.8	1947 Feb. 9, 1955	N	N	Abandoned.
*A-42	Duel Ince	F. W. Watts	1948	136	4	do	46	Feb. 1955	T,E, 2	D	Water reported hard at 60 ft, cased off. Owner reported 300 ft well drilled in area flowed. Temp. 68½°F.
A-43	Seth Barwise	B. F. Whitfield	1950	370	4	do	280	Apr. 1950	C,E, 1½	D	Pump set at 312 ft. Reported weak supply.
*B-1	F. E. Wolf	W. Plunkett	1950	317	10, 4	do	217	Mar. 1950	C,E, 1½	D	Casing: 10-in. to 17 ft; 4-in. to 317 ft. Pump set at 253 ft.
B-2	J. J. Wilson	Milner Supply Co.	1950	340	6, 4	do	213	July 1950	C,E, ¾	D	Casing: 6-in. to 21½ ft; 4-in. to 330 ft. 1/
B-3	Clarence Shirley	E. S. Allen	1949	352	4	do	--	--	C,W	D,S	
B-4	Dick Boaz	--	--	275	4	do	213.6	Sept.16, 1954	C,W,E	D,S	Well deepened to 325 ft in 1954. Pump set at 325 ft.
B-5	J. A. Nelson	D. C. McKee	1952	422	4	do	270	May 1952	C,E	D,S	Casing: 4-in. to 398 ft.
*B-6	Haslet Public School	--	--	320	4	do	--	--	C,E, 1-1/6	P	Temp. 69°F.
*B-7	P. Haley	--	1924	280	4	do	125	1950	C,E, 1	P	Pump set at 200 ft. Temp. 69°F.
B-8	Jesse Brown	W. Plunkett	1950	330	4	do	146.8	Nov. 6, 1950	--	--	Pump to be installed.
B-9	-- Powell	C. S. Allen	1949	470	4	do	--	--	C,W	D,S	Casing perforated from 428 to 470 ft. Pump set at 333 ft.
*B-10	W. C. McPherson	--	--	520	4	do	--	--	C,E, 1½	D,S	Pump set at 260 ft, lowered to 300 ft in 1953.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
B-11	T. R. Hinton	R. P. Dilbeck & Son	1949	533	4	Paluxy sand	290	Dec. 1953	C,W	D,S	Casing: 4-in. to 474 ft.
*B-12	Charlie Johnson	J. L. Myers & Sons	--	447	6	do	175	1948	C,E	P	Pump set at 320 ft. Temp. 69°F. 1/
B-13	do	-- Cambill	--	610	6	do	--	--	T,E	P	Pump set at 320 ft. Temp. 69°F.
*B-14	Frank Ripple	--	1946	515	6	do	261.4	Aug. 20, 1953	C,W	D,S	Pump set at 278 ft, lowered to 300 ft in 1952. Temp. 70°F.
*B-15	J. C. Rupe	C. S. Allen	1953	512	4	do	306	Aug. 1953	C,E	D	Pump set at 356 ft. Casing perforated from 470 to 512 ft.
B-16	C. S. Allen	W. V. S. Allen	1890	480	4	do	313	1953	C,W	D,S	Pump set at 250 ft, lowered to 270 ft in 1938, lowered to 313 ft in 1949, and lowered to 350 ft in 1953.
B-17	A. L. Simms	D. C. McKee	1952	385	4	do	245	Mar. 1952	C,E	D	Casing: 4-in. to 368 ft. Pump set at 280 ft.
B-18	P. R. Bonds	--	--	350	4	do	257.4	Sept.16, 1954	C,W	D,S	Pump set at 340 ft.
B-19	do	Milner Supply Co.	1948	315	4	do	237	Sept. 1948	C,W	S	Casing: 4-in. to 295 ft.
B-20	Hicks Field	--	1918	342	--	do	245	Sept. 1940	C,E	P,S, Ind	
B-21	do	--	1942	350	--	do	--	--	C,E	P,S, Ind	
B-22	L. P. Tannhill	H. Millican	1953	403	6	do	224 232.8	Nov. 2, 1953 Mar. 11, 1954	C,E	D,S	Casing: 6-in. perforated from 311 to 341 ft, and 347 to 384 ft.
B-23	H. M. Stallings	--	--	--	6	do	226.0 231.3	Feb. 3, 1954 Sept.15, 1954	C,W,E	S	
B-24	Northwood Farms	J. C. Hall	1948	354	6	do	--	--	C,E	D,S	Casing: 6-in. to 328 ft. Pump set at 290 ft.
B-25	--	--	1900	540	6, 4	do	280	- 1953	C,W,E	D,S	Pump set at 300 ft.
B-26	Ray White	--	1897	503	6	do	2/ 340.0 365.0	Feb. 15, 1954 Apr. 6, 1955	C,W,E	D,S	Pump lowered 30 ft, August 1953.
B-27	P. L. Coupland	Milner Supply Co.	1951	500	4	do	2/ 247. 309.7	Mar. 1951 Apr. 6, 1955	C,E	D	Pump set at 296 ft, lowered to 359 ft in July 1954. 1/
B-28	J. L. Henry	C. S. Allen	1949	472	4	do	205	1949	C,E	P	Casing perforated from 430 to 472 ft. Pump set at 250 ft.
*B-29	D. West	--	1923	20	30	Alluvium	14.3	Aug. 19, 1953	C,E	D,S	Dug. Temp. 68°F.
*B-30	do	Dan McKee	1953	390	7, 4	Paluxy sand	219.0	Aug. 12, 1953	--	D,S	Casing: 7-in. to 26 ft, 4-in. to 365 ft. Pump to be installed. Temp. 71°F.

See footnotes at end of table.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
B-31	Walter Graves, Jr.	Brien Drilling Co.	1953	375	6, 4	Paluxy sand	260	--	T,E	D,S	Casing: 6-in. to 20 ft, 4-in.to 358 ft. Pump set at 315 ft.
B-32	Saginaw Park	J. L. Myers & Sons	1954	--	--	do	263.8	July 22, 1954	T,E, 15	P	Drawdown measured 60 ft after 24-hours pumping 90 gpm, July 13, 1954. Pump set at 360 ft.
B-33	Bell Aircraft	--	1942	1,135	--	Travis Peak formation	--	--	T,E, 50	Ind	Discharge measured 140 gpm, April 1952; 187 gpm, June 9, 1954. Pump set at 450 ft, lowered to 500 ft between 1942 to 1952; lowered to 680 ft, September 1953.
B-34	M. D. Walls & P. D. Henry	Q. D. Lewis	--	400±	4	Paluxy sand	231.2 234.0	Mar. 1, 1954 Dec. 17, 1954	C,W	D	Pump set at 250 ft.
B-35	H. F. Holland	--	--	276	4	do	184.3	Sept.29, 1953	C,E	D,S	Casing: 4-in. to 256 ft. Pump set at 232 ft. Broke suction September 1953, lowered to 253 ft, Sept. 29, 1953.
B-36	Mrs. -- Taylor	J. C. Hall & Son	1948	333	4	do	--	--	C,W	D,S	
B-37	-- Moore	H. Millican	1953	--	8	do	277.4	Oct. 7, 1953	C,E, 1	D,S	Pump set at 305 ft.
B-38	do	--	1909	350	4	do	277.9	Oct. 5, 1953	C,W	D	Abandoned.
B-39	Dick Boaz	-- Gross	1917	320	4	do	291.1 282.9	Mar. 2, 1954 June 22, 1954	C,W,E	D,S	Pump set at 296 ft, broke suction in 1953, lowered to 307 ft.
B-40	Southwest Development Co.	B. H. Whitfield	1949	373	7, 5	do	200	1949	C,E, 1-7/8	D,S,P	Casing: 7-in. to 320 ft, 5-in. liner 320 to 373 ft, perforated from 370 to 373 ft. Discharge reported 75 gpm on test. Pump set at 310 ft.
B-41	Red Oliver	--	--	--	4	do	281.8 283.4	Mar. 2, 1954 Dec. 15, 1954	C,W	D,S	
B-42	Rube Roberts	Ft.Worth Drilling Co.	--	423	5	do	270	Sept. 1945	C,E, 2	D,S	Casing: 5-in. to 347 ft. Pump set at 315 ft.
*B-43	City of Saginaw	D. C. McKee	1949	370	8	do	260 261.8 265	June 1949 Feb. 18, 1954 Aug. 1954	T,E, 15	P	Pump set at 330 ft. Temp. 69°F. 1/
B-44	Burris Mills	J. L. Myers & Sons	1945	1,030	10	Travis Peak formation	411.5 461 498.0	June 14, 1949 Nov. 1952 July 23, 1954	T,E, 75	Ind	Discharge measured 250 gpm, Nov. 8, 1952. Pump set at 700 ft.
*B-45	do	Layne-Texas Co. Ltd.	1935	1,049	12, 10	do	313	Sept. 1935	T,E, 60	Ind	Pump set at 625 ft, lowered to 650 ft, 1952. Used as standby well.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
C-1	-- Carpenter	--	1930	14	--	Woodbine formation	12.3	Oct. 6, 1953	C,E	D	
C-2	J. N. Fisher	J. L. Myers & Sons	1937	639	5	Paluxy sand	235.4	Aug. 23, 1954	C,E, 1	D	Pump set at 273 ft, lowered to 315 ft on Aug. 24, 1954, broke suction; lowered to 415 ft, Aug. 25, 1954, reportedly broke suction.
C-3	T. M. Leland	--	1948	22	30	Woodbine formation	11.0	Oct. 6, 1953	C,E, ¼	D	Dug. Water reported high iron content, filtered before use. Weak well.
C-4	L. R. Ragsdale	-- Smith	1952	275	4	do	17.2	Oct. 7, 1953	C,E	D	Contains iron, discolors fixtures.
C-5	P. C. Depew	E. S. Allen	1948	667	8, 6, 4	Paluxy sand	240	1948	C,E, 1½	D,S	Casing: 8-in. to 56 ft; 6-in. to 140 ft; and 4-in. to 667 ft. Pump set at 315 ft.
C-6	-- Long	--	1943	23	30	Woodbine formation	19	Oct. 1953	C,E	--	
C-7	R. F. Myers	J. L. Myers & Sons	1951	784	4	Paluxy sand	198.9	Sept. 13, 1954	N	N	To be used later.
C-8	E. D. Reed	do	--	141	--	Woodbine formation	73.0	Feb. 25, 1954	N	N	Abandoned.
C-9	do	do	1953	797	4	Paluxy sand	158	Mar. 1953	T,E, 1	D,S	Pump set at 250 ft.
C-10	Briggs-Weaver Machinery Co.	do	1952	796	4	do	180	Dec. 1952	T,E, 5	D	Pump set at 300 ft.
C-11	do	-- Arnold	--	160	4	Woodbine formation	68.5	Feb. 25, 1954	N	N	Abandoned.
C-12	D. Lewton	J. L. Myers & Sons	1944	136	7, 4, 2	do	75	1944	C,E, ¾	D	Casing: 7-in. to 65 ft, 4-in. to 129 ft. Pump set at 120 ft.
*C-13	B. R. Neal	do	1944	170	7, 4	do	95	1944	C,E, ¾	D,S	Casing: 7-in. to 43 ft, 4-in. to 144 ft. Pumping level 137 ft while pumping 3 gpm. Pump set at 137 ft. 1/
C-14	J. P. Perry	--	1945	900±	--	Paluxy sand	--	--	C,E, 1	D	
C-15	T. G. Beckett	--	1937	350	--	Woodbine formation	--	--	C,W,E, 1½	D	Water reported high in iron content.
C-16	T. R. James	J. C. Hall	1938	900	7, 5	Paluxy sand	100	1949	C,W,E, 3	D	
C-17	do	do	1948	300	7, 4	Woodbine formation	198	1948	C,E, 1	S	Water reported high in iron content. Pump set at 180 ft. 1/
C-18	do	Waldeen & Plunkett	1946	286	7, 5	do	110	1946	C,E, 1½	S	Pump set at 120 ft.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
C-19	U. S. Geological Survey	Corps of Engineers	1951	268	7	Woodbine formation	--	--	N	--	Casing: 7-in. to 145 ft. Well in Dallas County. Observation well.
*C-20	C. Sanders	Waldeen & Plunkett	1946	315	4	do	60	1949	C,E, 1/3	P	
C-21	R. E. Crews	--	--	214	--	do	105.4	Mar. 9, 1954	C,W	D,S	Water reported high in iron content.
C-22	J. W. Berry	J. L. Myers & Sons	1944	837	4	Paluxy sand	--	--	C,E, ¾	P	Pump lowered 40 ft in 1950. Supplies 7 houses.
C-23	City of Grapevine	do	1949	1,810	16, 10, 7	Travis Peak formation	251	July 1949	T,E, 50	P	Casing: 230 ft of 16-in., 714 ft of 10-in., 955 ft of 7-in., 141 ft of 5-in. liner. Pumping level reported 400 ft in August 1953, while pumping 305 gpm. Pump set at 450 ft.
*C-24	do	Q. D. Lewis	1925	700	12, 10, 8	Paluxy sand	--	--	T,E, 25	P	Discharge measured 90 gpm, August 1953. Pump set at 410 ft. Temp. 81°F.
*C-25	do	J. L. Myers & Sons	1938	1,790	12, 10, 8	Travis Peak formation	150 229 398.4	1938 1946 Dec. 3, 1954	T,E, 25	P	Discharge measured 145 gpm, August 1953. Pumping level measured 410 ft after 5 minutes pumping 50 gpm, Dec. 3, 1954. Pump set at 410 ft. Temp. 91°F.
C-26	Grapevine Ice. Co.	-- Gardner	--	227	4	Woodbine formation	--	--	C,E, 1	Ind	
C-27	R. G. Lyford	J. L. Myers & Sons	1954	852	4	Paluxy sand	290	July 15, 1954	C,E, 1	D,S	Casing: 4-in. to 852 ft, perforated from 822 to 852 ft. Pump set at 399 ft.
*C-28	W. E. Mayfield	T. Millican	1945	229	4	Woodbine formation	75	1945	C,E, 1	D	Water reported high in iron content; water filtered before used.
C-29	E. E. McCain	B. & H. Drilling Co.	1953	227	--	do	129.5	Sept.23, 1953	C,E, 1¼	D,S	Driller reports 7.3 ft drawdown after ½-hour pumping 10 gpm, Sept. 23, 1953.
C-30	B. R. Lee	do	1953	175	4	do	82.8	Oct. 2, 1953	N	N	Casing perforated from 155 to 175 ft.
C-31	C. D. Lancaster	do	1953	120	4	do	85.2	do	N	N	Well blew air for several weeks. To be used later. 1/
C-32	A. I. Cope	do	1953	115	4	do	71	Aug. 24, 1953	C,E, ½	D,S	Casing perforated from 75 to 115 ft. Pump set at 78 ft.
*C-33	R. O. Bozeman	Milner Supply Co.	1951	93	4	do	38.9	Aug. 12, 1953	N	N	Casing: 4-in. to 80 ft. Water reported unfit for modestic use. 1/
C-34	W. F. Schulze	-- Smith	1953	54	4	do	43.1	Oct. 6, 1953	J,E	D	Water reported high in iron content. Reported weak supply.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
C-35	J. F. Chandler	C. S. Allen	1954	568	4	Paluxy sand	240	Jan. 1954	C,E	D	
C-36	G. G. Renegar	do	1913	575	4	do	292.2	Aug. 13, 1953	C,E, ¾	D,S	Pump set at 294 ft, lowered to 315 ft, Aug. 13, 1953.
C-37	Conrad Stegall	Ft.Worth Drilling Co.	1946	537	7, 4	do	280	Dec. 1946	C,E, ¾	D	Well deepened to 600 ft in 1949. Casing: 7-in. to 24 ft, 4-in. to 522 ft. Pump set at 315 ft. 1/
*C-38	L. L. Burton	--	1943	17	30	Woodbine formation	14.3	Aug. 12, 1953	J,E	D,S	
C-39	-- Buchanan	Wallen Bros.	1953	600	4	Paluxy sand	300	Oct. 1953	C,E, 1	D,P	Casing perforated from 545 to 600 ft. Pump set at 400 ft.
C-40	W. P. Henry	C. S. Allen	1946	589	7, 5	do	280	Mar. 1946	C,E	--	Casing: 7-in. to 50 ft, 5-in. to 590 ft. Pumping level reported 336 ft while pumping 30 gpm.
C-41	A. A. Marlar	--	1933	30	30	Woodbine formation	25.6	Oct. 7, 1953	J,E	D	Dug. Water reported unfit for drinking, high in iron content.
C-42	Earl Andrews	--	1949	14	--	do	13.8	do	J,E	D,S	Dug. Water reported high in iron content; weak supply.
C-43	Mart Hare	--	--	42	--	do	40.4	do	C,E, 1	D	Dug. Weak supply.
C-44	-- Hare	Bill Busman	1953	601	6, 4	Paluxy sand	277.1	Oct. 16, 1953	C,E	D,P	Casing: 6-in. to 60 ft, 4-in. to 601 ft.
C-45	Paul C. Hoffner	-- Smith	1951	105	4	Woodbine formation	20	Feb. 1951	J,E	D	Iron removed before used.
C-46	do	--	1950	23	--	do	19.3	Oct. 8, 1953	N	N	Weak supply.
C-47	S. D. Crabtree	J. L. Myers & Sons	1940	826	--	Paluxy sand	185	1940	C,E	D	Reported drawdown 25 ft after 12-hours pumping 40 gpm, 1940. Pump lowered from 250 ft to 290 ft, July 12, 1954.
C-48	A. C. Stone	do	1951	294	4	Woodbine formation	59.4	Feb. 25, 1954	T,E, 5	S	Pump set at 189 ft.
C-49	do	do	1949	897	--	Paluxy sand	--	--	C,E, 1	D	Pumping level measured 238.3 ft while pumping 3 to 4 gpm, Mar. 8, 1954.
C-50	E. Rowley, Jr.	do	1953	914	7, 4	do	180	July 1953	T,E, 1	D,P	Casing: 68 ft of 7-in., 834 ft of 4-in., perforated from 884 to 914 ft. 1/
C-51	Roy Sims	do	1950	814	4	do	2/200 257.4	Oct. 1950 Mar. 8, 1955	C,E	D,S	Pump set at 273 ft. Used as observation well.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
C-52	Mrs. Clara Watson	--	--	12	36	Woodbine formation	8.6	Oct. 7, 1953	C,H	N	
C-53	W. R. Thomasson	J. L. Myers	1941	165	6, 4	do	30	July 1941	C,E, ¾	D	Casing: 6-in. to 24 ft, 4-in. to 160 ft. Pump set at 134 ft.
C-54	B. E. Dill	J. W. Ball	1953	125	4	do	39.4	Aug. 24, 1953	N	N	To be used later.
C-55	Leonard Hall	B. & B. Drilling Co.	1954	209	6	do	26.9	Dec. 12, 1954	T,E, 3	Irr	Pumping level 58.2 ft after 5 days pumping 35 gpm, Dec. 22, 1954. Reported strong supply. Pump set at 160 ft. Irrigated 20 acres in 1954.
C-56	W. V. Fox	Dan McKee	1951	85	4	do	60	1951	C,E, ½	--	Pump set at 63 ft. Water level measured in well 12 ft north.
C-57	Mrs. Charles Cope	--	1940	32	30	do	26.2	Oct. 9, 1953	C,G	Irr	Irrigates 2 to 3 acres. Reported weak supply.
C-58	A. B. Smith	Ft. Worth Drilling Co.	1948	106	6	do	60	Aug. 1948	C,E, ¾	D,S	Pump set at 90 ft.
*C-59	Pleasant Run School	Milner Supply Co.	1950	640	6, 4	Paluxy sand	245	Oct. 1950	C,E, 2	P	Casing: 6-in. to 115 ft, 4-in. to 622 ft. Specific capacity reported 1.09 gpm per ft of drawdown. Pump set at 294 ft. 1/
C-60	Price G. Roberts	Wm. Bushman	1953	65	6, 4	Woodbine formation	13.5	June 23, 1953	C,E, ½	D,S	Casing: 6-in. to 42 ft, 4-in. to 65 ft. Water reported high in iron content.
C-61	-- Shaw	Brien Drilling Co.	1954	640	6, 4	Paluxy sand	281.0	Nov. 18, 1954	C,E, 1	D	Casing: 6-in. to 68 ft, 4-in. to 640 ft. Walnut clays from 525 to 550 ft.
C-62	Mrs. G. M. Reagan	--	--	26	30	Woodbine formation	15	Sept. 1953	J,E, 1	D,S	Dug. Casing: Brick lined to 12 ft. Reports no iron stain.
C-63	L. Slate	C. M. Stoner	1949	654	7, 4	Paluxy sand	100	1949	C,E, 3	D,S	Pump set at 400 ft.
*C-64	do	--	--	22	6	Woodbine formation	14.4	June 23, 1953	B,H	N	Reported unfit for domestic and stock use.
C-65	-- McFadden	--	--	600	4	Paluxy sand	285.2	Oct. 7, 1953	C,W	D,S	Pump set at 264 ft, lowered to 349 ft, Oct. 7, 1953.
C-66	-- Dennis	--	1946	596	4	do	246 280.9	1946 Mar. 8, 1954	C,E, 1	D	Pump lowered 30 ft in 1951.
C-67	M. T. Cluck	--	1948	40	--	Woodbine formation	15.8	Oct. 7, 1953	J,E	Irr	Irrigates yard. Weak supply.
*C-68	Smithfield Water Works	--	1935	600	--	Paluxy sand	--	--	C,E, 1½	P	Supplies school and 35 families.
*C-69	W. B. Townsend	T. J. Millican	1947	507	--	do	--	--	C,E, 1	D,S	
C-70	Lloyd McWhorter	Dan McKee	1953	535	4	do	285.9	Jan. 26, 1953	C,E, 1½	D	

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
C-71	Smithfield Water Works	H. Millican	1953	562	10, 8, 7	Paluxy sand	250 284.0	Mar. 1953 Aug. 12, 1953	T, E, 20	P	Casing: 10-in. to 23 ft, 8-in. to 487 ft. Screen: 7-in. from 487 to 512, and 517 to 562 ft.
C-72	do	Jones Drilling Co.	1952	572	10, 8, 6	do	280	July 1952	T, E, 20	P	Plugged back to 460 ft. Pump set at 400 ft.
*C-73	do	do	1952	580	10, 8, 6	do	--	--	T, E, 20	P	Temp. 76°F.
C-74	Frank Averett	F. W. Watts	1953	580	7, 4	do	261.4 258.2 304.2	Aug. 13, 1953 Dec. 29, 1953 Nov. 22, 1954	T, E, 1	D, S	
*C-75	Variety Ranch	J. L. Myers & Sons	--	1,657	8, 7	Travis Peak formation	479.5	Sept. 17, 1954	T, E, 15	P, S	Pump set at 400 ft, Sept. 10, 1949, lowered to 600 ft, Sept. 17, 1954. Discharge reported 70 gpm, Sept. 19, 1949; 30 gpm, Sept. 14, 1954.
*C-76	C. G. Arnold	Milner Supply Co.	1950	760	8, 6, 4	Paluxy sand	285 286.3	Jan. 1950 Aug. 5, 1953	C, E, 3	D, S	Casing: 8-in. to 65 ft, 6-in. to 173 ft, 4-in. to 749 ft. Pump lowered from 294 ft to 336 ft on Aug. 5, 1953.
C-77	Jack Courtney	--	1950	22	30	Woodbine formation	9.3	Oct. 6, 1953	J, E, ¼	D	Weak supply.
C-78	A. T. Sellers	F. W. Watts	1953	180	6	do	58.7	Aug. 24, 1953	T, E, 3	D	Water reported high in iron content. Pump set at 14 ft.
*C-79	F. O. Genske	J. L. Myers & Sons	1949	887	4	Paluxy sand	291.7	Sept. 13, 1954	C, E, ¾	D	Pump set at 271 ft, August 1949, lowered to 292 ft, July 1954, lowered to 355 ft, Sept. 13, 1954
C-80	R. W. Fuller	C. M. Stoner	1944	725	--	do	298.2	Mar. 3, 1954	C, E, 10	--	Pump set at 400 ft, lowered to 440 ft, Mar. 3, 1954.
C-81	Ray Woods	J. L. Myers & Sons	1946	750	7, 5	do	--	--	C, E, 2	D	Unfit for human consumption.
C-82	do	do	1946	290	5	Woodbine formation	125	1946	C, W	S	Casing: 123 ft of 7-in., 233 ft of 5-in., 70 ft of 4-in. Drawdown reported 55 ft while pumping 12 gpm in 1946.
C-83	Hal Murray	--	--	--	--	do	78.9	Mar. 8, 1954	J, E	D	
C-84	J. M. Moroney	Brien Drilling Co.	1949	150	6, 4	do	65	Aug. 1, 1949	J, E, ½	D	Casing: 6-in. to 92 ft, 4-in. to 136 ft. 1/
D-1	J. H. Fewell	Jones Drilling Co.	1954	157	7	Paluxy sand	91.7	June 11, 1954	J, E, 1½	D	Discharge measured 12 gpm, June 10, 1954. Temp. 69°F.

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*D-2	Van Zandt Estate	P. Dillbeck	1952	440	7, 5	Glen Rose limestone	239.6 289	Sept.28, 1953 June 3, 1954	T,E, 3	P	Drawdown measured 117 ft after 5-hours pumping 20 gpm, June 3, 1954. Pump set at 375 ft, 1952; lowered to 406 ft, May 1954. Well deepened to 490 ft, August 1954. 1/
D-3	D. C. Hall	Ft.Worth Drilling Co.	1945	150	8	Paluxy sand	72	July 1953	C,E, ¾	D	
D-4	R. V. Whiting	P. Baker	1954	120	6, 4	do	13.6	June 1, 1954	J,E, 1	D	
D-5	R. E. Page	D. C. McKee	1953	90	4	do	16	Mar. 1953	C,E, 5	D	
D-6	Azle Water Co.	H. Millican	1953	826	10	Travis Peak formation	319.7	Nov. 30, 1954	T,E	P	Plugged back to 660 ft.
D-7	J. L. Hall	J. C. Hall	1949	131	4	Paluxy sand	--	--	C,W	D	Water reported hard. 1/
D-8	J. D. Powell	G. P. Brien	1953	160	4	do	19.2	Oct. 2, 1953	J,E, 1	D	Pump set at 60 ft.
*D-9	Mrs. -- Griffin	--	--	200	4	do	--	--	C,E, ½	P	Supplies 25 families.
D-10	E. C. Schooler	M. Gross	1935	204	5	do	45	Oct. 1949	J,E, ¾	D	Reports water reacts on galvanized tank. Temp. 70°F.
D-11	J. A. Fadell	D. C. McKee	1953	198	4	do	50	Mar. 1953	C,E, 1½	D	
D-12	E. O. Smith	--	1936	269	--	do	67.2	Oct. 12, 1949	J,E, ½	D	
*D-13	Nina Hodgekins	--	1948	200	6	do	119.6	do	C,E, ¾	P	Water reported to have trace of sulfur.
*D-14	O. M. Jones	--	--	205	6	do	--	--	T,E, 1	P	
*D-15	Lake Worth Village	J. L. Myers & Sons	1952	934	10, 8	Travis Peak formation	406	Feb. 1952	T,E, 60	P	Casing: 10-in. to 760 ft, 8-in. screen from 760 to 810 ft. Plugged back to 820 ft. Pump set at 731 ft. 1/
*D-16	do	do	1954	275	8	Paluxy sand	49.3	June 10, 1954	T,E	P	Screen set from 170 to 195 ft, and 215 to 260 ft. Drawdown measured 134 ft after 24-hours pumping 110 gpm, June 15, 1954.
*D-17	E. I. Beardon	J. C. Hall	1937	200	--	do	--	--	C,E, 1	Irr	Water reported high in iron content.
D-18	W. A. Cox	F. Watts	1941	210	4	do	44.0	Oct. 13, 1949	T,E, 1	D	
*D-19	W. C. Morrow	--	--	40	4	do	--	--	T,E, 1/3	D	Reported water has strong sulfur odor.
D-20	May Eckel	V. Stanley	1930	175	5	do	62.8	Oct. 20, 1949	C,E, ¾	D	

Table 10.- Records of wells in Tarrant County--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water-bearing formation	Water level: Below land-surface datum (ft.)	Water level: Date of measurement	Method of lift	Use of water	Remarks
*D-21	G. E. Moore	Sam Gross	1936	160	4	Paluxy sand	90	1942	J, E, 3/4	D	
D-22	D. B. Baugh	-- Spears	1937	150	6	do	74.0	Oct. 20, 1949	C, E, 3/4	D	
D-23	M. G. Fuller	J. C. Hall & Son	1949	200	4	do	--	--	C, E, 3/4	D	
*D-24	W. O. Teague	--	1944	94	4	do	62	Oct. 1949	C, E, 1/3	D	Pump set at 84 ft.
*D-25	Grover Lautz	Sam Gross	1944	174	4	do	63	1952	J, E, 1/2	D	
*D-26	Moorehead Henley	Ft. Worth Drilling Co.	1946	193	4, 3	do	--	--	N	N	Abandoned, 1953. 1/
D-27	Guy Stratton	Watson Bros.	1951	30	30	do	15	Apr. 1954	N	N	Reported water hard and high in iron content. Abandoned.
D-28	Bill Huffman	--	1900	165	6, 4	do	28	Nov. 1954	J, E	P	Reported water soft with trace of iron.
D-29	Carswell Air Force Base	Milner Supply Co.	1951	235	6	do	77	Sept. 1951	T, E, 3	Ind	
*D-30	Consolidated-Vultee Aircraft	Layne-Texas Co. Ltd.	1943	810	12, 6	Travis Peak formation	264 420 380.2	Sept. 1943 Sept. 1952 Feb. 15, 1954	T, E, 75	Ind	Screen: 6-in. set from 561 to 619 ft, 679 to 699 ft, 714 to 741 ft, 749 to 794 ft. Drawdown reported 163 ft after 24-hours pumping 572 gpm, Sept. 2, 1943. Emergency use. Temp. 72°F. 1/
D-31	White Settlement	--	---	250	4	Paluxy sand	118.7	Jan. 3, 1950	N	N	Abandoned.
D-32	do	F. W. Watts	1946	210	10, 8	do	112.3	Feb. 9, 1954	N	N	Hole crooked, unused.
*D-33	do	T. J. Millican	1945	254	10, 8, 7	do	123.1	do	T, E, 15	P	Temp. 64°F. 1/
D-34	O. F. Rowland	--	1929	308	4	Paluxy sand & alluvium	29	1929	C, W	D	Water reported hard and high in iron content, becoming soft and iron-free after 2 or 3 days pumping. Pump set at 190 ft, 1929; lowered 21 ft, 1947, 21 ft, 1949, 8 ft, 1951, and 8 ft, 1953.
D-35	White Settlement	F. W. Watts	1951	205	10, 8	Paluxy sand	175 105	Aug. 1951 June 1953	T, E, 15	P	Deepened to 311 ft, May 1953.