TEXAS STATE BOARD OF WATER ENGINEERS
C. S. Clark, Chairman
A. H. Dunlap, Member
J. W. Pritchett, Member

PROGRESS REPORT ON GROUND WATER IN THE HIGH PLAINS IN TEXAS

By

W. H. Alexander, Jr., W. L. Broadhurst and W. N. White

Prepared in cooperation with the United States
Department of the Interior, Geological Survey

April 1943

PROGRESS REPORT ON GROUND WATER IN THE HIGH PLAINS IN TEXAS

By

W. H. Alexander, Jr., W. L. Broadhurst and W. N. White

April 1943

INTRODUCTION

Extent of irrigation from wells

Irrigation from wells in the High Plains in Texas has grown during the last eight years at a rate which is believed to be unprecedented anywhere. In 1934 there were only about 300 irrigation wells in the entire region. By 1937 the number had increased to 1,150. Now the total number of wells has reached about 2,700 and more than 300,000 acres can be irrigated from them.

In 1934 most of the well irrigation was confined to the vicinities of Plainview in Hale and Floyd Counties, Hereford in Deaf Smith County and Muleshoe in Bailey and Lamb Counties. The development has spread in nearly all directions from these centers and has reached large proportions in 14 counties.

Investigations and reports

Since 1936 a considerable part of the program of State-wide investigations of ground water in Texas, conducted by the State Board of Water Engineers in cooperation with the Geological Survey, United States Department of the Interior, has been devoted to the High Plains. An office has been maintained at Plainview since the spring of 1937 and from one to six ground-water geologists and engineers have been employed in the region. Surveys of the water wells have been made and the results have been published for 26 counties. The geology, the source and extent of the ground-water resources, and the use of ground water for irrigation

have been studied. Three mimeogrphed reports have been published, the first in July 1938, the second in April 1939 and the last in December 1940. The results of water-level measurements in wells in the region to December 1940 are given in Geological Survey Water-Supply Papers 840, 845, 886 and 909.

The rainfall in the High Plains was exceptionally heavy in 1941 and about average but unusually well distributed during the growing season in 1942. As a result not much water was needed for irrigation and the yearly pumpage during the period was much less than it had been during each of the years 1937 to 1940. The report that follows is concerned mainly with the pumpage in 1941 and 1942 and water levels in wells in 1941, 1942 and 1943 and a comparison of these records with those obtained in former years. It contains considerable information, given in former reports, regarding the source and method of occurrence of the ground water, which has been repeated for the benefit of those who have not had access to these reports. It has been reviewed and approved by O. E. Meinzer, Geologist in Charge of the Division of Ground Water of the Geological Survey.

The following is copied from page 6 of the text and page 31 of the summary of the 1940 report:

> Ground water is contained in interstices between particles of gravel and grains of sand that lie below the surface of the High Plains. Although the ground water is moving, generally in a southeasterly direction, the movement is very slow -- perhaps at an average rate of 200 to 300 feet a year. The movement, therefore, is scarcely comparable to that of a river. Inasmuch as the water-bearing beds are cut off in all directions from outside sources of water except through underlying rocks containing poor water, it follows that the source of the fresh water must be entirely within the High Plains themselves, and must be the rain and snow that fall on the surface of the Plains.

A very large quantity of water, that has accumulated over a long period of time is stored in the underground reservoirs formed by these water-bearing beds. A small part of this water is discharged each year by the flow of springs or by evaporation and the growth of plants in the localities where the water table is near the surface. This natural discharge is approximately balanced through a long term of years by water derived from that part of the rainfall upon the area which penetrates to the water table. The average annual replenishment is only a small part of the average annual rainfall.

In the last 30 years water has been pumped from wells in this region in large quantities, chiefly for irrigation. The annual pumpage has been increased greatly in the last six years. In 1937 it amounted to about 130,000 acre-feet; in 1938 t about 145,000 acre-feet; and in 1939 to about 165,000 acre-feet.

Location and extent of the area

The High Plains in Texas occupy an area of about 35,000 miles, extending from the northern boundary of the Panhandle southward about 300 miles into Glasscock, Ector and Midland Counties, and from the New Mexico line eastward an average distance of about 120 miles to a boundary which in most places is sharply defined by a bold escarpment several hundred feet in height (see fig. 1, p. 23). The surface of the Plains slopes toward the southeast at the rate of approximately 10 feet to the mile. Elevations range from approximately 4,600 feet above sea level in western Dallam County to about 2,800 feet along the southeastern border of the area. The gorge of the Canadian River divides the region into two segments: the Panhandle, or North Plains area; and the Llano Estacado, or South Plains.

The High Plains in Texas are noted for their abundant supply of ground water. All the water for public and industrial supplies and nearly all the water used on the farms and ranches comes from wells, and in parts of the region irrigation on a very large scale is accomplished with water from wells. For convenience in compiling the data and discussing the results, the irrigated areas have been divided into six districts as follows:

Plainview district, in Hale, Floyd, Swisher, and Briscoe Counties.

Hereford district, in Deaf Smith County and northern part of Castro County.

Muleshoe district, in Bailey and northwestern part of Lamb County.

Lubbock-Littlefield district, in Lubbock, Crosby and Hockley Counties and southern part of Lamb County.

Spring Lake district, in northeastern part of Lamb County and southern part of Castro County.

Texline district, in northwestern part of Dallam County.

CLIMATE

The following is from the 1931 Climatic Summary of the United States Weather Bureau:

Section 30, Northwest Texas

While the section is traversed by perhaps twice as many storms as southern Texas, these disturbances are far less frequent than in the more northern and, especially, northeastern states. Storms enter this section from the northwest, west, and southwest, advancing from the Northern Plains, the Rockies, and Southern Plateau district. The region is subject to rapid and marked temperature changes, especially during the winter months, in connection with steep southerly pressure gradients of approaching high pressure areas and the resultant strong northerly winds.

The coolest part of the state is embraced in this section, the mean annual temperature being 58.8 degrees. The mean of the warmest month (July) is 79.2 degrees, and of the coldest (January) 38.1 degrees, with a mean range for the section of 41.1 degrees between the warmest and coldest months.

The average growing season for the area is 198 days. The last killing frosts in spring usually occur in the first or second decade of April. The first autumn killing frosts usually occur in the last two decades of October or in early November. There is a difference of about 45 days between the growing seasons of the extreme northwestern and southeastern portions of the area.

While the average annual precipitation of the section is 20.54 inches, the departures from the average of individual years and stations are wide. As a whole, the section is highly favored in its distribution of precipitation throughout the year. About two-thirds of the moisture is normally recorded during the six months from April to September, inclusive, accruing to the general benefit of agriculture.

The more southerly trend of the continental high pressure areas is responsible for distinctly northerly and, consequently, dry winds over the area during December, January, and February. The remaining cool months have more or less transitional winds, while the six warmer months, having winds from a prevailingly southerly quarter, bring more abundant moisture from the Gulf of Mexico to the Plains.

Sunshine is abundant over the Plains area, the annual mean value at Amarillo being 78 percent of the possible ranging from 72 percent in December to 84 percent in June. Free evaporation from an open pan at Spur, Dickens County, for a full 7-year period, shows a mean annual value of 63.944 inches.

In the High Plains of Texas both dry-land and irrigation methods of farming are practiced, and the problem of water supply is different in some respects from those of more arid areas where most crops cannot be matured at any time without irrigation. In the High Plains water is used only when the precipitation is insufficient for normal plant growth and, consequently, during years of adequate or nearly adequate precipitation the wells are not heavily pumped. However, erratic distribution of the rainfall greatly complicates the problems of both the dry-land farmer and the operator of irrigation wells.

The following table, taken from the records of the U. S Weather Bureau, gives the average annual precipitation, and deviation from the average precipitation in 1940 and 1941, for six representative stations on the High Plains.

Average annaul precipitation and deviation from the average in inches, in Amarillo, Dalhart, Lubbock, Muleshce, Plainview and Tulia.

Station	Length of record (years)	Average annual precipitation	Precipitation in 1940	Deviation from average in 1940	Precipitation in 1941	Deviation from average in 1941
Amarillo	50	20.99	13.62	- 7.37	37.21	+ 16.22
Dalhart	36	18.03	12.74	- 5.29	40.91	+ 22.88
Lubbock	30	19.22	13.76	- 5.46	40.55	+ 21.33
Muleshoe	20	18.99	13.97	- 5.02	43.52	+ 24.53
Plainview	48	21.59	15.43	- 6.16	34.35	+ 12.76
Tulia	36	21.97	14.69	- 7.37	34.01	+ 12.04
Average	37	20.13	14.02	- 6.11	38.43	+ 18.29

These stations were selected because of their proximity to the important irrigation districts and the length of the records. In 1940 the average precipitation at these six stations was 6.11 inches below the long time mean average, but in 1941 it was 18.29 inches above the mean average. The monthly precipitation in 1940 and 1941 and the average monthly precipitation for 48 years at the Plainview station are shown graphically in figure 2, page 24 . In 1942 the precipitation at Plainview was 23.72 inches or about 2 inches above the long-time average.

INTAKE AND NATURAL DISCHARGE OF GROUND WATER

Ground-water intake or recharge, the addition of water to that already in storage in the underground reservoir, is accomplished by the infiltration of a small portion of the precipitation downward to the water table. The principal areas of ground-water recharge are: depressions or sinks, occupied by intermittent ponds; sandy stream beds and adjacent sandy flood plains; and sand dune areas.

A small portion of the ground-water supply is discharged each year by the flow of springs, and by evaporation and growth of plants in localities where the water table is near the surface. This natural discharge is

approximately balanced through a long term of years by the addition of water from recharge. In 1938 and 1939 studies of ground-water discharge were made along a 75-mile stretch of the eastern escarpment of the High Plains extending southward from Quitaque Creek to Double Mountain Fork of the Brazos River, across parts of Briscoe, Floyd, Motley, Dickens, and Crosby Counties. It was estimated that the total natural discharge of ground water along this stretch of the escarpment investigated and in the segment of 9,000 square miles of the High Plains back of it is at the rate of 25,000 to 30,000 acre-feet a year.

DEPTH TO GROUND WATER

The depth to the ground water level, or water table, in the High Plains ranges from a few feet to several hundred feet. The approximate depths, in feet, in the principal irrigation districts and adjacent territory are shown in the sketch map on page 25 (fig. 3). This map is based on the records of several thousand wells and as a whole is approximately accurate. The depth to ground water in general is controlled by several conditions, including the elevation of the land surface, the proximity of the land to areas of heavy recharge or natural discharge, and the relationship of the water-bearing sands and gravels to the underlying bed rock. The last is largely responsible for several of the shallow-ground water districts. If in its slow movement southeastward down the general slope of the High Plains the ground water encounters a buried ridge of impermeable material, the ridge will act as a submerged dam and tend to cause the water to accumulate to the northwestward of the obstruction, resulting in a shallow water table in that locality. For example buried ridges of impermeable materials, chiefly shales, are found along the southeastern borders of the Plainview and Hereford districts and are the principal cause of shallow water in those districts. Because the buried ridges are impermeable and yield little water,

land underlain by them can not be supplied with sufficient ground water for irrigation.

It is estimated that the depth to ground water is less than 60 feet beneath about 1,100,000 acres and less than 80 feet beneath about 2,500,000 acres in Bailey, Castro, Crosby, Deaf Smith, Floyd, Hale, Hockley, Lamb, Lubbock, and Swisher Counties.

USE OF GROUND WATER FOR IRRIGATION

Irrigation from wells in the High Plains in Texas was started near Plainview, Hereford, and Muleshoe about 35 years ago. It was moderately successful for a few years and by 1914 about 140 irrigation wells had been completed. During the next 20 years there was comparatively little development. In 1934 the total number had reached about 300, many of which had been unused for years. Since then the development has spread rapidly and by the end of 1942 the total number of irrigation wells had reached about 2700.

Estimates of the total number of wells pumped and the total amount of land irrigated from them during the three years 1937 to 1939 are given in the 1940 report.

The approximate number of irrigation wells completed during 1940, 1941 and 1942 is given by counties in the following table. These figures were obtained largely through the generous cooperation of the pump dealers of the High Plains.

Approximate number of irrigation wells completed in 1940, 1941 and 1942

County	1940	1941	1942
Bailey	18	11	3
Briscoe	4	3	0
Castro	68	37	2
Crosby	15	6	3
Dallam	6	5	1
Deaf Smith	66	30	6
Floyd	39	16	1
Hale	101	94	34
Hockley	4	11	3
Lamb	49	33	12
Lubbock	45	97	37
Parmer	8	10	0
Randall	7	4	1
Swisher	48	22	10
Others	3	3	3
	481	382	116

In 1940 the rainfall was much below the average, the need for irrigation was greater than usual and the pumpage, it is roughly estimated, reached about 190,000 acre-feet. This is the largest amount of water thus far pumped in the region in one year.

In 1941 the rainfall was exceptionally heavy, being the highest on record in parts of the region, and irrigation was light except in the early spring. According to the best estimate that can be made, only about 1,500 wells were pumped at any time during the year and the total pumpage was only about 50,000 acre-feet. In 1942 the number of wells pumped and the amount of water used for irrigation were about the same as they were in 1941. The rainfall during 1942 was much less than it was in 1941, being only a little above average, but it was exceptionally well distributed during the growing season, and soil moisture conditions in the early spring were exceptionally good because of the heavy rainfall of 1941.

Estimates of the total number of wells equipped for irrigation and the total area irrigated from wells from 1937 to 1942 and the total amount of water pumped for irrigation from 1937 to 1940 are given below.

Estimated number of wells equipped for irrigation, area irrigated and amount pumped in High Plains of Texas

	1937	1938	1939	1940	1941	1942
Total number of wells	1,150	1,500	1,700	2,180	2,560	2,680
Area irrigated (acres)	160,000	200,000	230,000	250,000	-	-
Irrigation pumpage (acre-feet)	130,000	145,000	165,000	190,000	50,000	50,000

FLUCTUATIONS OF WATER LEVELS IN WELLS

The results of water level measurements in wells in 25 counties of the High Plains in Texas to December 1940 have been published in Geological Survey Water-Supply Papers 840, 845, 886 and 909. The results in 180 wells in the Plainview, Hereford and Muleshoe districts are given in the progress report of 1940. In the paragraphs that follow the subject is discussed under three headings; fluctuation of water levels in pumping districts, fluctuation of water levels near areas of recharge or intake and fluctuation of water levels in areas that are more or less remote both from areas of pumping and areas of intake.

Fluctuation of water levels in pumping districts

In general in the pumping districts it has been found that the most dependable information regarding the stage of the underground reservoirs is obtained by comparing measurements made in successive years in the early spring just before the start of heavy pumping. The statements given below regarding the decline or rise in water levels from 1938 to 1943 are based mostly on a

comparison of measurements made in March. In some cases January and February measurements were used.

There was a general decline of the water table in all the pumping districts of the High Plains from 1938 to 1941. This was followed by a general rise during the summer and fall of 1941 and the spring of 1942 as a result of the exceptionally high rainfall and light pumping in 1941. (See hydrographs in figs. 5, 6, 9 and 12). Except in localities of large recharge the greatest rise occurred in the areas where the pumping had been heaviest and in such areas a part of this rise, doubtless, was due to the fact that the pumping in 1941 was light and ground water moved in from outlying unpumped areas. However a considerable part of the rise can be attributed to recharge, which probably was greater than it has been in any year since 1915 and several times the recharge in most years. In 1942 the pumping again was light and there was comparatively little net change in water levels.

Plainview District

Decline of water levels from 1938 to 1941:-- The records of water levels in 56 representative observation wells in the Plainview district have been selected as a basis for computing the rise and fall and net change in water levels in the district from 1938 to 1943. These wells are fairly well distributed over about 1,000 square miles comprising areas of both heavy and light pumping. Partial records of 40 representative wells showing the trend throughout the greater part of the district are given in the tables on pages 19 and 20 , and the location of the wells is shown on the map comprising figure 4. None of the wells are near known areas of important recharge. The records show a decline of water levels in the wells of the district ranging from a fraction of a foot to 6 feet and averaging 2.7 feet. The greatest decline, averaging about 4 feet, occurred in the heavily pumped areas in the

central and east-central parts of the district. In areas of moderate and light pumping the average decline was about two feet.

Rise of water levels from 1941 to 1943:-- The records show an average rise of 2.0 feet in the district from March 1941 to February 1943.

Net change in water levels from 1938 to 1943:-- The records show an average net decline of 1.1 feet in the district from March 1938 to February 1943. In areas of heaviest pumping the average decline was 2.1 feet, and in areas of moderate pumping was 1.1 feet. In a few wells in areas of very light pumping the water levels were as high in 1943 as they were in 1938, or slightly higher.

Net change in water levels from 1934 to 1943:-- All 7 wells that were measured in the Plainview district in 1934 are in areas of rather heavy pumping. These wells showed a decline from April 1934 to March 1941 ranging from 3 feet to 9.9 feet and averaging 5.7 feet; a rise from March 1941 to February 1943 ranging from .2 foot to 3.1 feet and averaging 1.8 feet and a net decline between 1934 and February 1943 averaging 3.9 feet. The records in 3 of the wells are shown graphically in figures 5 and 6.

Net change in water levels from 1914 to 1943:-- Of the 11 wells that were measured in 1914 six are located in areas of heavy pumping. These wells showed a net decline from 1914 to February 1943 ranging from 7.9 feet to 14.4 feet and averaging 10.1 feet. Three of the wells are in areas of moderate pumping but are less than a mile from White River which flows through Plainview and in wet years contributes substantially to the subterranean reservoir. One of the wells showed a net rise of 6.9 feet, another a net decline of 2.0 feet and the third a net decline of 2.5 feet from 1914 to February 1943. Two wells are in areas of light pumping west and south of Plainview. One showed a net decline of 0.1 foot and the other a net decline of 2.5 feet from 1914 to February 1943.

Hereford District

Decline of water levels from 1938 to 1941:-- The records of 48 observation wells have been selected as a basis for computing the rise and fall and net change in water levels in the Hereford pumping district from 1938 to 1943. These wells are fairly well distributed over an area of about 400 square miles comprising most of the district. Partial records of water level measurements in 20 representative wells showing the trend throughout the greater part of the district are given in the table on page 21 . The location of these wells is shown on the map comprising figure 8. None of the 48 wells are near known areas of important recharge. All of the wells showed a decline in water level from 1938 to March 1941, the decline ranging from a fraction of a foot to about 6 feet and averaged 2.9 feet. The greatest average decline, 3.1 feet, occurred in the heavily pumped areas in central and southern parts of the district. In the northern part of the district the average decline was about 2.5 feet.

Rise of water levels from 1941 to 1943:-- The records show an average rise of 2.2 ~~2.3~~ feet in the Hereford district from March 1941 to February 1943.

Net change in water levels from 1938 to 1943:-- The observation wells showed an average net decline of 0.7 foot in the Hereford pumping district from 1938 to February 1943. The average decline was 1.1 feet in areas of heavy pumping and 0.5 foot in areas of moderate to light pumping.

Net change in water levels from 1934 to 1943:-- Three of the observation wells in the Hereford district located in areas that are rather heavily pumped were measured in 1934. Two of them showed the same net decline, 2.1 feet, from 1934 to February 1943. The third showed a net rise of 5.7 feet from 1934 to February 1943. The record of one of these wells (245) is shown graphically in figure 9.

Net change in water levels from 1914 to 1943:-- One observation well (no. 26) in an area of heavy pumping was measured in 1914. This well showed a decline of 8.5 feet from 1914 to 1941, a rise of 0.8 feet from 1941 to 1943 and a net decline of 7.7 feet from 1914 to 1943.

Muleshoe District

Thirty-six observation wells distributed fairly evenly over the Muleshoe district showed an average decline of 1.6 feet from March 1938 to March 1941 an average rise of 8.0 feet from March 1941 to February 1943, and a net rise, therefore, of 6.4 feet from 1938 to 1943. Partial records of water level measurements in 20 representative observation wells in the district are given in the table on page 22 . For three of the wells the data are shown graphically in figure 12. The location of the wells is shown on the map comprising figure 11.

Lubbock-Littlefield District

The records of 26 well distributed observation wells that are at considerable distances from any known areas of important intake were selected for computing the changes in water levels in the Lubbock-Littlefield pumping district. These wells showed a decline from the spring of 1938 to the spring of 1941 ranging from .05 feet to 5.39 feet and averaging 1.6 feet, and a rise from the spring of 1941 to the spring of 1943 ranging from 1.11 feet to about 8 feet and averaging 3.9 feet. This represents a net average rise of 2.3 feet.

Texline District

Records of observation wells in the Texline district show little change in water levels from the spring of 1937 to the fall of 1941. No records are available for 1942 and 1943.

Fluctuations of water levels in wells near areas of intake

Most of the observation wells in the High Plains which are near areas of intake (stream beds, depression ponds and sand dunes) are in the irrigated districts or closely adjacent to them, and are affected to some extent by the pumping. Such wells showed a more or less persistent downward trend from 1938 to the spring of 1941, the average in their principal districts being: Plainview 4.1 feet and Hereford 2.1 feet. In contrast to this, very little change or a slight net rise was shown during the same period by a few observation wells near areas of intake in localities which border the irrigated districts but are far enough away to be not appreciably affected by the pumping. All the observation wells near areas of intake in the irrigation districts showed a sharp rise in water levels from the spring of 1941 to the spring of 1942 the average rise being as follows: Plainview district 5.2 feet (25 wells), Hereford district, 2 feet (8 wells), Lubbock-Littlefield district, 5.1 feet (20 wells). Most of these wells continued to rise slowly during 1942 but a few showed a small decline.

Fluctuations of water levels in wells remote from pumping districts and areas of intake

Of 36 observation wells in 12 counties that are remote from both the pumping districts and known areas of intake, 23 wells showed a small net rise and 13 a small net decline from 1937 or 1938 to 1941. The algebraic sum of the net change in all 36 wells gives a rise of about .3 foot. From 1941 to 1943 these same wells showed an average rise of about 1.9 feet.

NET LOSS OR GAIN OF STORAGE IN THE PUMPING DISTRICTS 1938 TO 1943

In the section entitled "fluctuation of water levels in wells in pumping districts", the average net change in water levels in observation wells from March 1938 to February 1943 is given as follows: Plainview district decline,

1.1 feet; Hereford district decline, 0.7 foot; Muleshoe district, rise, 6.4 feet Lubbock-Littlefield, rise 3.2 feet.

To translate these figures into the quantities of water withdrawn from or added to storage during the 5 year period it is necessary to know the average specific yield of the materials in which the fluctuations in water levels occurred. The average specific yield can be calculated in water table areas such as the High Plains during a period of water table decline of considerable length, preferably several years; if, during the period, the additions to and subtractions from storage by recharge and natural discharge are approximately equal; and if adequate information is available regarding the total amount of water pumped and the decline of the water table caused by the pumping. These conditions were fairly well met in both the Plainview and Hereford districts during the three years from the spring of 1938 to the spring of 1941.

It is estimated that during this period the total pumpage amounted to 300,000 acre-feet in the Plainview district and 100,000 acre-feet in the Hereford district. As this water was withdrawn by the pumps it was replaced by water which moved downward, thereby causing a decline in the water table and unwatering the saturated material in the belt of water table decline. It is estimated from the water level records that the total volume of material unwatered during the three year period amounted to about 2,060,000 acre-feet in the Plainview district and 710,000 acre-feet in the Hereford district. The ratio between the two, or specific yield, therefore was as follows:

Plainview district $\frac{300{,}000 \text{ acre-feet of water pumped}}{2{,}060{,}000 \text{ acre-feet of material unwatered}} = 14.5\%$

Hereford district $\frac{100{,}000 \text{ acre-feet pumped}}{710{,}000 \text{ acre-feet unwatered}} = 14.1\%$

Using these figures for specific yield and the figures for the average net decline in water levels given above the net total amount of water removed from storage in the two districts during the 5 year period 1938 to 1943 is computed as follows:

Plainview district, 1,000 square miles, comprising the greater part of the irrigation well area

640,000 acres x 1.1 x .145 = 102,000 acre-feet.

Hereford district, 450 square miles: 288,000 acres x .7 x .141 = 28,400 acre-feet.

In the Muleshoe district, comprising approximately 65 square miles, there was a net rise in water levels of about 6.4 feet from 1938 to 1943. If the average specific yield of the water-bearing material is 14 percent, this rise represented a net addition to the ground water in storage of about 37,000 acre-feet during the period 1938 to 1943. In the Lubbock-Littlefield district also there was a net addition in storage of considerable magnitude during 1938 to 1943.

SUMMARY

The increase of irrigation from wells in the High Plains in Texas during the last 8 years has been exceedingly rapid. In 1934 there were only about 300 irrigation wells in the entire region and the development was restricted to relatively small areas in the vicinities of Plainview, Hereford and Muleshoe. By 1942 the total number of wells had reached approximately 2,700 and the total area susceptible of irrigation from them had reached more than 300,000 acres.

The total pumpage in the region from 1937 to 1940 inclusive amounted to about 630,000 acre-feet, practically all of which is believed to have been derived from reduction in underground storage.

In 1941 the rainfall was nearly twice the long-time average and the recharge to the subterranean reservoirs was probably several times the recharge in most years. In 1942 the rainfall was about normal but was exceptionally well distributed during the growing season. The total pumpage during the two years 1941 and 1942 amounted to only about 100,000 acre-feet. As a result of these

conditions there was a general rise of the water table.

Because of the replenishment of 1941 and small irrigation requirements of 1941 and 1942 the net loss from underground storage in the Plainview and Hereford districts from 1937 to 1940 was largely compensated. In most other parts of the region there was a net rise of the water table and net increase in storage. With normal rainfall and the continuation of pumping at a rate comparable with that of 1940 the decline of the water table which was general throughout the area from 1938 to 1941, and was rather large in the heavily pumped districts, will be resumed with a corresponding loss in storage.

Water levels in wells in Plainview district, Texas

(Depth in feet below measuring point)

Date of measurement	Floyd County												Swisher County							
	Well number (For location of wells see map on page)												Well number (For location of wells see map on page)							
	32	57	108	140	157	410	416	428	446	459	510	525	254	258	332	354	362	370	380	383
1914			50.0	47.0		41.7	51.2	45.2												
1934 Apr.					49.5					44.3										72.2
1936 Apr.		61.1			59.3	49.4							36.9	51.1					54.5	74.6
June																61.6	70.1	72.7		
1937 Apr.						51.8														
May	91.2	60.9			58.3							41.0	37.3	51.7	64.8	61.9	69.9		54.6	77.7
Dec.		61.5			55.1				43.4	46.9	41.2	40.8	37.2						54.1	73.9
1938 Mar.			58.3	53.0	54.4	52.4		51.5	43.4	47.8		40.6	37.5	52.1	70.3	62.2	70.2	73.5	54.5	74.2
Dec.				53.9	55.5	50.1	53.2	51.3	43.7	48.4	43.7	40.9	38.2	52.5		62.3		73.3		73.8
1939 Mar.				53.8	55.0	49.6	63.0	51.0	43.7	48.3	43.1	40.9	38.3	52.5	63.2	62.4		73.4	54.8	73.3
Dec.		62.6		55.3	57.5	53.5	65.8	52.8	44.1	49.7	47.3	41.6	39.2		65.3	62.6	71.2	74.2	55.1	75.3
1940 Mar.	90.2	62.8	58.9	55.3	56.8	51.5	65.4	52.5	44.2	49.6	45.8	41.6	39.4	53.8	64.4	62.7	71.3	74.1	55.2	74.2
Nov.	91.5	63.9		58.0	62.9	55.1	71.5	55.5	45.2	51.9	51.9	42.4	40.5	55.1		63.6	72.9	75.2	55.7	76.8
1941 Mar.	91.0		60.9	57.8	59.4	54.0	69.1	54.8	45.1	51.6	50.7	42.6	40.9		69.2	63.2	71.9	75.3	55.7	75.2
Nov.	91.8	63.5		55.5	57.2		66.4	53.4	44.1	48.9	43.0	39.9	40.0	54.8	68.3	62.8	71.3	76.0		75.2
1942 Mar.	90.4		58.8	55.4	56.4	50.9	65.5	52.9		48.5	41.9	38.5	39.8	54.6	68.3	62.6	69.2	75.8		75.0
Oct.	90.9	62.8	60.2	57.4	57.6	52.0	67.7	54.0		48.8	43.4	37.9			65.2		68.8	77.2		75.7
1943 Feb.	90.2	63.0	59.1	56.1	56.5	50.9	65.6	53.1	42.2	48.4	42.0	37.5	40.5	54.7	64.7	63.3	69.2	76.5	-	74.7

Jan. 7

Water levels in wells in Plainview district, Texas

(Depth in feet below measuring point)

Hale County

Well number (For location of wells see map on page)

Date of measurement	123	202	212	220	238	259	307	330	338	357	428	436	443	459	462	552	567	834	923	936
1914	62.5		52.5			23.7							57.5	36.6	36.5					
1934 Apr.		64.1		50.2			61.6									58.4				
1936 Apr.	60.8	67.8			50.7	19.4		44.6	45.5	36.2	52.5	52.8	57.8			61.3	52.4			43.2
June					50.8									39.7	40.8					
1937 Apr.												54.4	59.0	40.1	42.1	59.9	52.9			44.5
May											49.9									
Dec.		65.3		53.3				44.8	45.5	35.8	47.9	51.3		38.8	39.4	58.6	52.1		55.0	44.7
1938 Mar.	62.2	65.2	62.5	53.7	52.1	17.8	63.4	45.4	45.5	36.1	47.8	51.1	57.8	38.7	39.9	58.6	52.2	77.2	55.0	44.4
Dec.		66.6				18.5	64.4	45.2	46.0	36.8		52.6	58.4	40.7	42.2	59.5	52.8		55.5	46.0
1939 Mar.	62.1	66.1		54.2	52.5	18.6	63.9		45.9	37.0		52.2	58.3	40.4	41.8	59.3	52.8	77.3	55.4	
Dec.	63.1	67.0	67.3	56.4	53.6	19.7	65.2	47.2	47.2	38.2	52.1	54.3	59.4	43.8	44.4	60.2	53.2	77.4	55.8	47.8
1940 Mar.	63.1	66.7	63.9	55.6	53.5	19.9	65.1	46.0	47.2	38.4	50.6		59.0	42.3	44.1	60.0	53.6	77.5	55.9	47.3
Nov.	66.3	68.6	69.4	58.3	55.9	21.7	68.4	46.7	48.7	40.0	53.3	57.3	61.9	45.3	48.0	61.3	53.9	77.9	56.7	50.1
1941 Mar.	64.4	68.0	65.5	57.3	55.4	20.8	66.5	46.7	48.6	40.2	52.5	56.3	60.9	44.7	46.4	62.1	54.1	77.9	56.7	49.0
Nov.	63.8	67.9	65.4	56.8	54.9	15.3	66.2	46.2	47.0	36.7		53.5	60.1	38.6	37.6	60.0	53.0	77.2	54.5	46.4
1942 Mar.	63.0	67.3	63.8	55.5	54.2	16.3	65.3	46.0	46.4		48.1	52.0	60.1	37.9	37.8	59.3	52.5	76.9	53.9	45.5
Oct.	63.4	67.8	65.1	57.0	55.0	16.9	66.4	46.3	47.1	37.4	48.8	53.0	60.8	39.2	39.7	59.6	53.1	76.7	53.8	45.9
1943 Feb.	62.6	66.9	63.7	56.1	54.7	16.8	65.5	46.8	45.6	37.2	48.4	52.2	60.0	38.6	39.0	59.2	53.1	76.6	53.2	44.1

Water levels in wells in Hereford district, Texas

(Depth in feet below measuring point)

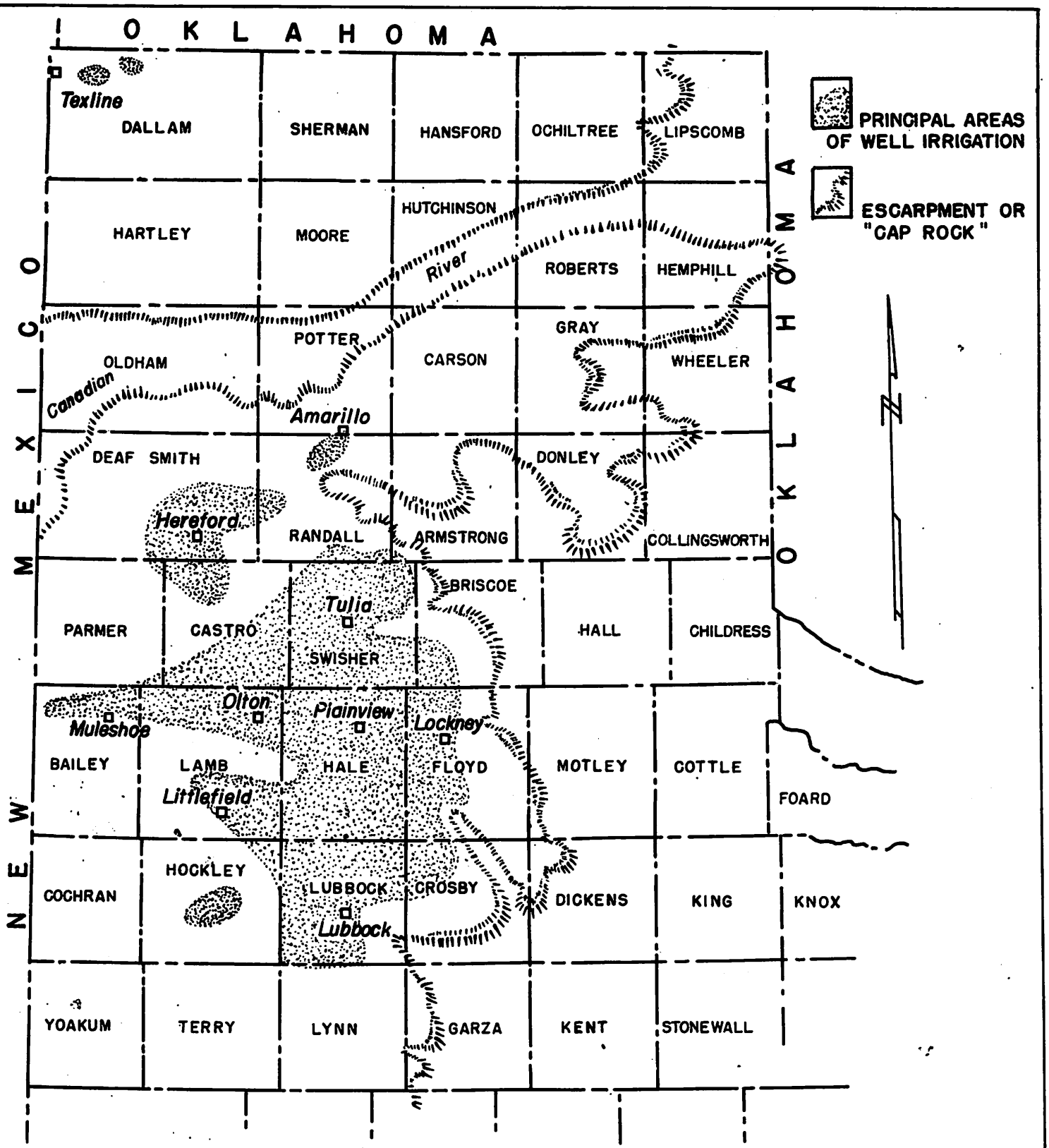
Date of measurement	Castro County						Deaf Smith County													
	Well number						Well number (For location of wells see map on page)													
	8	12	32	36	48	52	150	212	217	219	224	237	258	261	265	283	311	315	502	513
1914														47.0						
1934 Nov.												42.7					54.8			
1936 Apr.			65.2		66.4			71.4	84.9			42.5	55.5	53.6		61.5	55.8	60.8		
June			64.9		63.4			71.6				42.2					52.0	55.4		
1937 Mar.												44.0					48.9			
May			64.8						92.8				55.8	54.8	66.1			56.1		
Dec.	76.6	100.7	63.8	84.8	69.0	72.1		71.3	105.4	79.6		45.4	56.0	51.2	64.6	65.1		56.4	94.3	79.3
1938 Mar.	73.2	100.5	63.6	83.7	62.4	71.8		72.5	93.3	75.6	58.6	44.2	54.3	52.7	63.9	64.6	51.5	55.8	96.2	79.4
Dec.	74.7	100.8	64.4	84.3	62.7	71.6	96.7	72.1	92.3	76.2		44.7	54.3	52.9	65.0	64.3	51.7	56.0	95.6	79.5
1939 Mar.	74.6		63.7	83.2	61.3		96.5	71.7	88.9	75.4	58.3	44.1	53.8	51.0	64.1	63.4	50.5	55.5	96.3	79.5
Dec.	75.2	101.1	64.9		79.2	71.6	96.6	75.6	93.7		57.7		55.4	53.1	66.7		52.4	56.2	96.7	80.8
1940 Mar.	74.8	101.3	64.5	85.2	64.4	71.6	96.8		91.6	76.8		45.2	55.7	52.8	65.2	64.7	51.7	55.9	96.2	79.9
Nov.		102.7	68.2	92.4	78.9		98.3	81.7		79.9	57.8	48.9	58.0	55.8	76.1	70.7		60.2	103.1	
1941 Mar.		103.0	66.6	87.9	65.9	79.6	98.3	75.6	93.0	77.5	57.9	46.8	57.8		67.4	66.8	52.9	58.4	99.8	
Dec.	73.7		64.2	86.0	63.2	75.2	97.7		89.2	77.2	57.9	45.8								
1942 Feb.	73.4	103.1	63.2	86.5	62.3		97.5	72.9	88.9	77.0	57.8	45.6	56.3	54.5	66.7	65.1	49.6	56.3	98.5	80.7
Nov.	72.8	102.1	62.7	83.2	60.5	74.9	97.4	72.0	88.8	77.2		45.3	57.2	55.0	66.6					
1943 Feb.	73.8	102.0	62.6	85.0	59.7	71.8	97.4	72.1	88.3	76.9	57.9	44.8	57.1	54.7	65.7	64.9	49.1	55.9		81.8

Water levels in wells in Muleshoe district, Texas

(Depth in feet below measuring point)

Date of measurement	Lamb County			Bailey County																
	Well number			Well number (For location of wells see map on page)																
	13	16	30	5-A	9	11	25	33	34-A	36	45	53	63	67	69	79	92	95	120	132
1914																				20.0
1934 Nov.	22.2												26.0						25.8	
1936 May	21.3	37.6	24.0									26.3	31.8	21.2	16.8	24.6	24.1	25.7	27.6	24.0
Nov.	19.9		24.5		40.4	25.5	23.3	28.2		19.6		26.5	29.4		16.3	24.2	23.3	24.7		
1937 Mar.			23.7										26.4						27.3	
May							25.3	30.4	43.8		20.8	26.4			15.9		22.2	24.9		23.5
Nov.				64.5	39.8	25.5	22.3	29.0	43.5	17.9	20.0	25.5		19.8	16.4	23.4	21.9	24.2	28.4	22.2
1938 Mar.	18.7	36.0	23.1		39.7		22.5	28.8		17.6	19.9	25.9	24.8	19.9		23.6	22.1	24.4		22.3
Dec.	19.7			64.4	39.3	24.9	20.8	29.0	43.2	17.0	19.6		24.9	19.6			21.5	24.6		22.7
1939 Mar.	19.5		23.3	64.2	39.1	24.8	20.4	28.7	43.1	17.2	19.1	25.1	24.0	19.4	15.5	22.8	21.1	24.4		22.4
Dec.	20.2	36.5	23.6	64.2	39.3	25.9	22.0	30.9	43.2	19.0	20.6		25.2	20.4	16.7	24.3	22.3	25.1	28.0	23.0
1940 Mar.	20.1	36.3	23.7	64.1	39.1	25.6	21.9	30.1	43.1	18.8	20.3		24.6	20.3	17.5	24.4	22.0	24.9	27.8	22.8
Nov.	21.1	37.5	24.0	64.3	40.2	27.2	24.9	33.3	43.4	20.0	21.8	28.9	30.8	22.8	17.9	25.5	24.7	26.3	29.7	24.3
1941 Mar.	21.4	37.0	24.0	64.3	39.8	27.7	23.9	32.9	43.6	19.7	21.5	26.4	26.6	21.2	17.8	25.2	23.5	25.9	29.1	23.7
Nov.	11.0	32.0	17.0	40.2	38.2	22.3	16.6	29.0	42.3	13.9	11.5	18.3	21.1	13.8	9.0	16.2			22.9	13.8
1942 Mar.	11.1	30.7	17.4	54.6	37.4	21.0	15.4	27.4	41.8	12.5	12.4	18.3	18.3	12.4	8.8	17.1	15.3	18.7	20.5	13.9
Nov.	11.7	29.9	17.2		37.1	21.2	15.6	28.1					18.3	12.0	8.4	18.0	15.3	18.7	20.5	13.5
1943 Feb.	12.1	29.5	17.7		36.8	21.0	16.1			13.1	13.3	17.5	17.6	12.0	8.8	18.4	15.4	18.7		14.0

Fig. 1



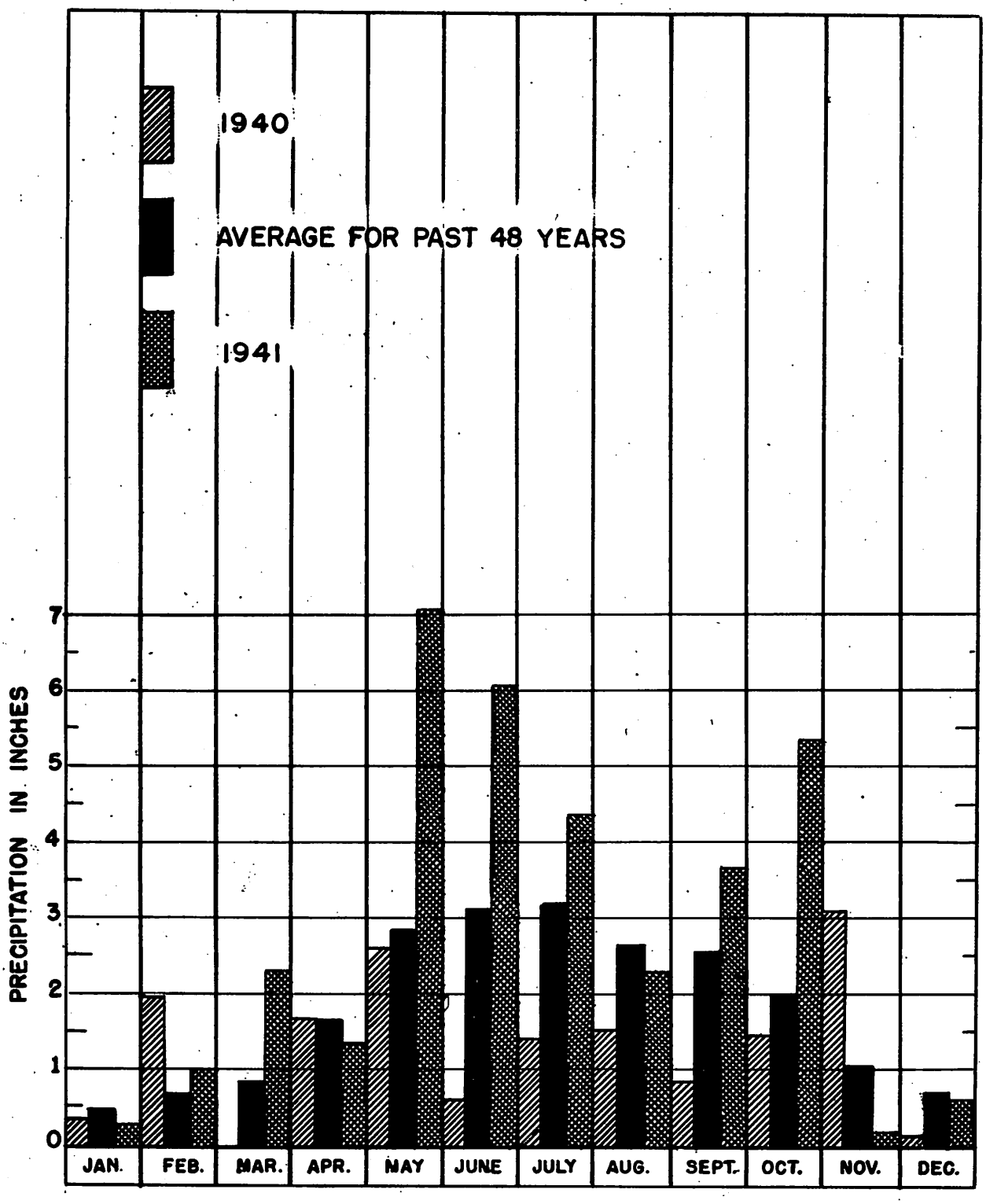
PRINCIPAL AREAS OF WELL IRRIGATION IN HIGH PLAINS OF TEXAS

SCALE

20 10 0 20 40 MILES

K.
7-9-42.

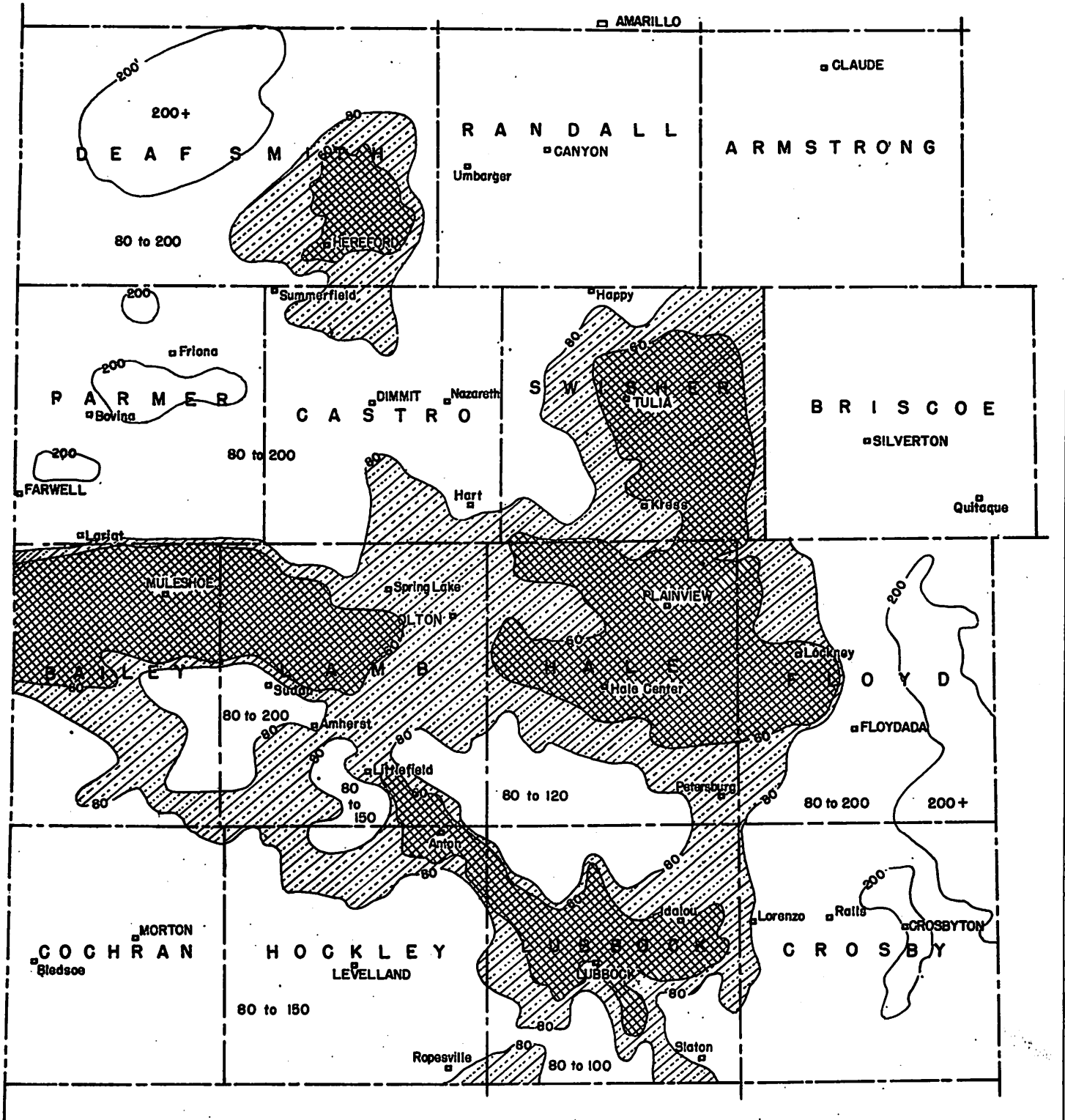
Fig. 2



MONTHLY PRECIPITATION, PLAINVIEW, TEXAS

7-9-42.

Fig. 3



DEPTH TO WATER IN FEET, IN WELLS IN PART OF HIGH PLAINS, TEXAS

SCALE

10 5 0 10 20 MILES

O. G. K.
6-6-42

Fig. 4

REPRESENTATIVE OBSERVATION WELLS IN PLAINVIEW DISTRICT, TEXAS

— EXPLANATION —

● OBSERVATION WELL WITH PUMPING PLANT

◊ OBSERVATION WELL UNUSED

-o- OBSERVATION WELL WITH WINDMILL

100 HYDROGRAPH IN THIS REPORT

TEXAS BOARD OF WATER ENGINEERS IN COOPERATION WITH U. S. GEOLOGICAL SURVEY — 1942 —

SCALE 0 1 2 3 4 5 MILES

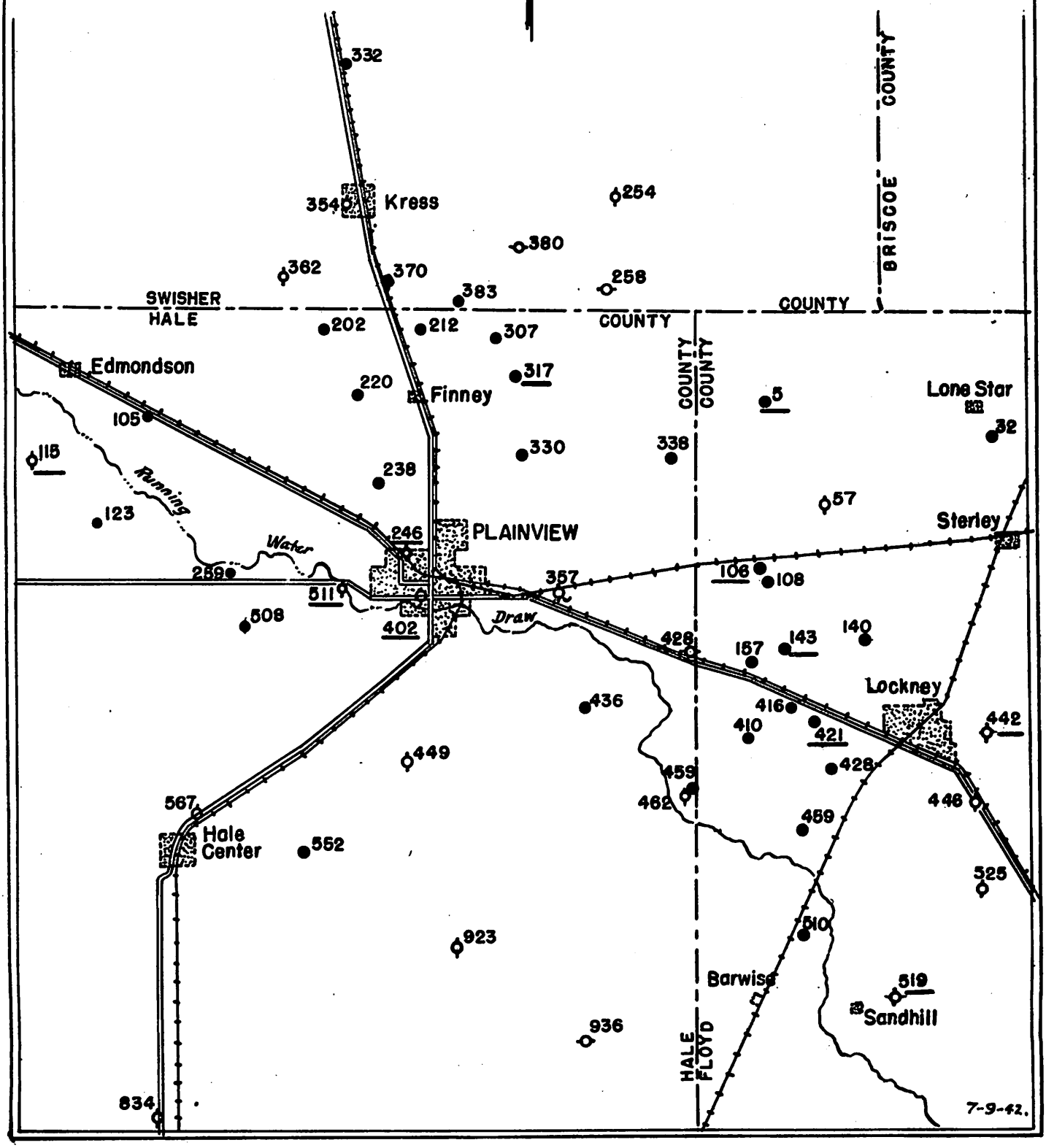
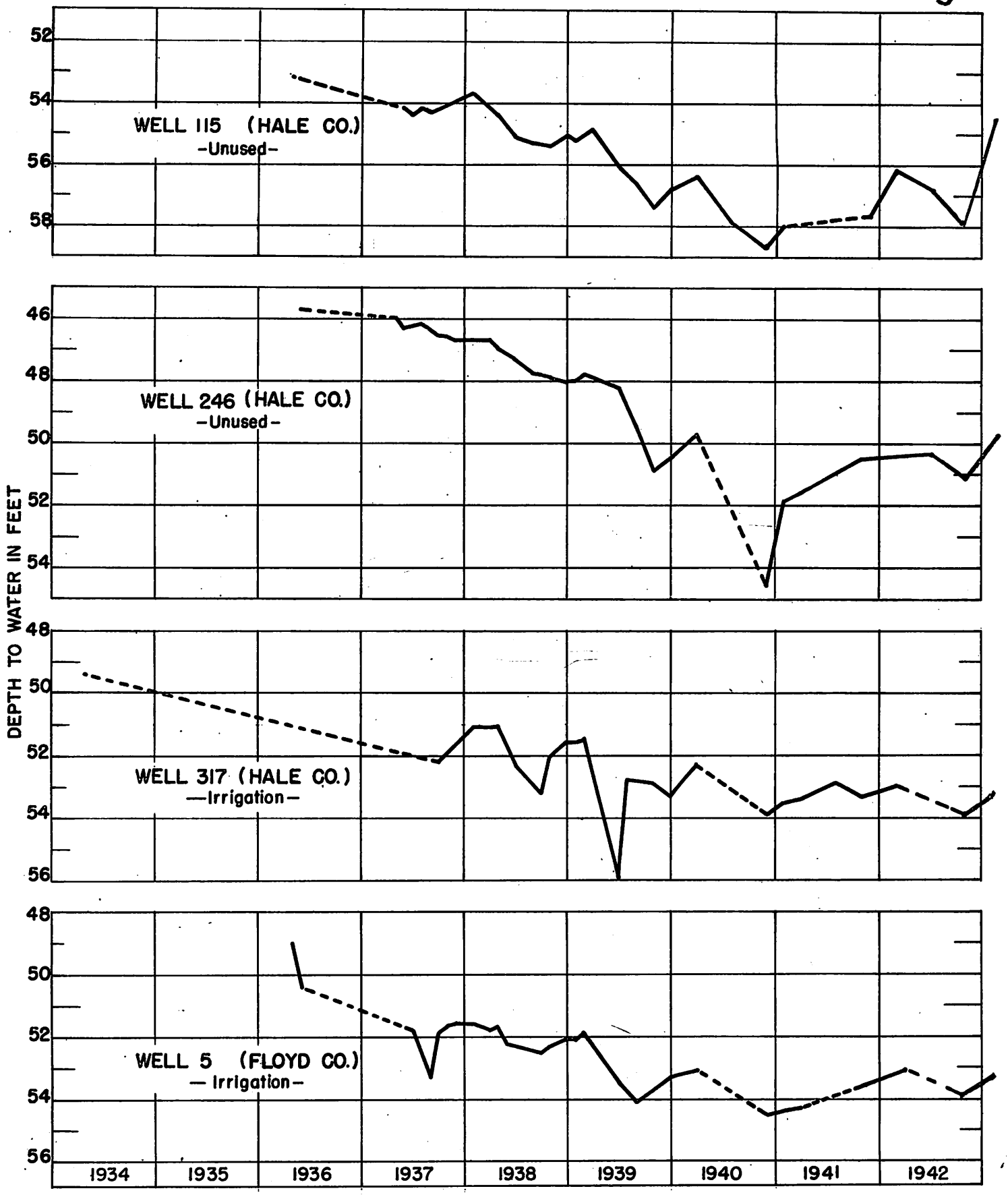


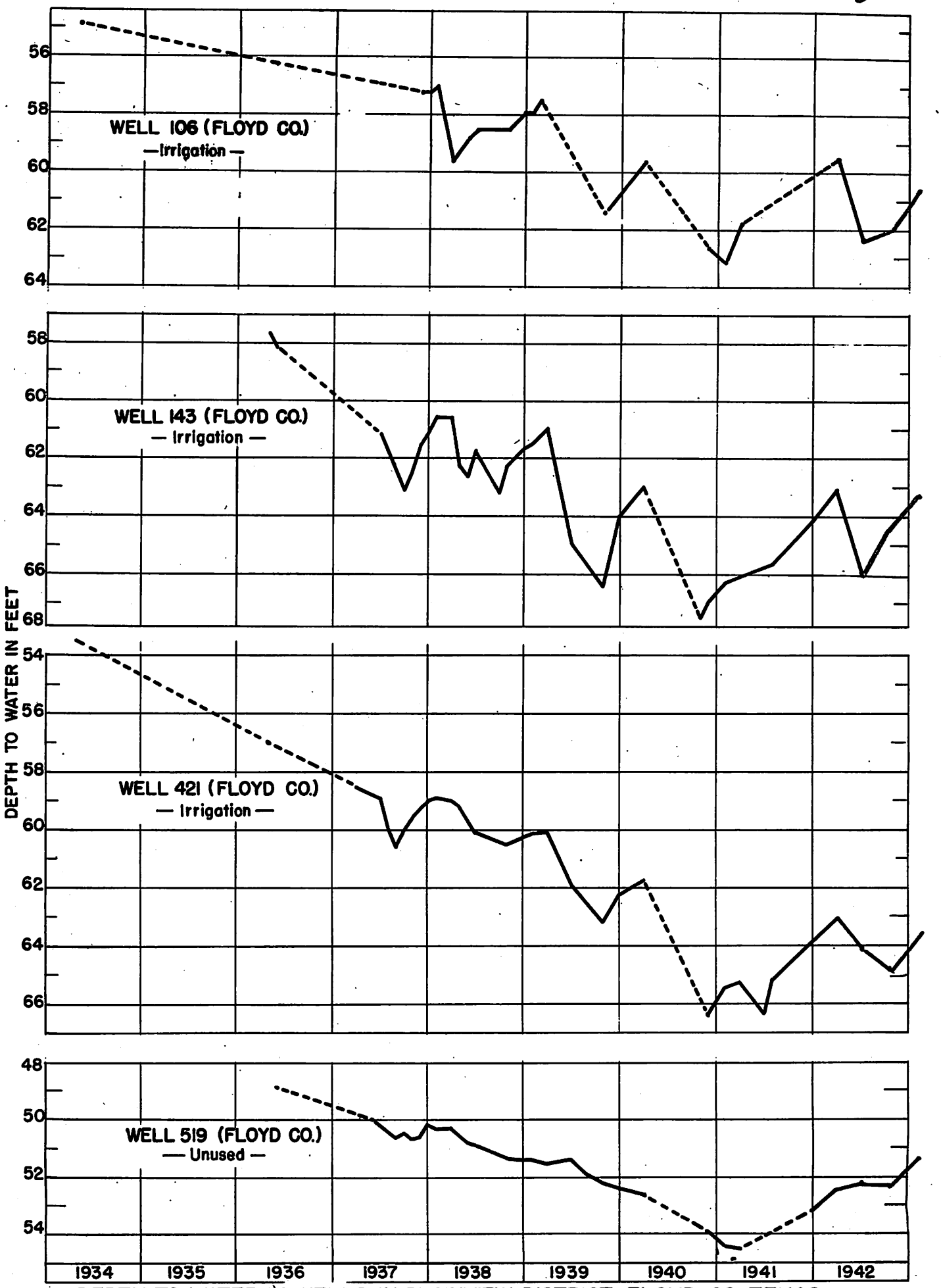
Fig. 5



DEPTH TO WATER IN WELLS IN PLAINVIEW DISTRICT, HALE AND FLOYD CO,S. TEXAS

(Areas of moderate pumping)

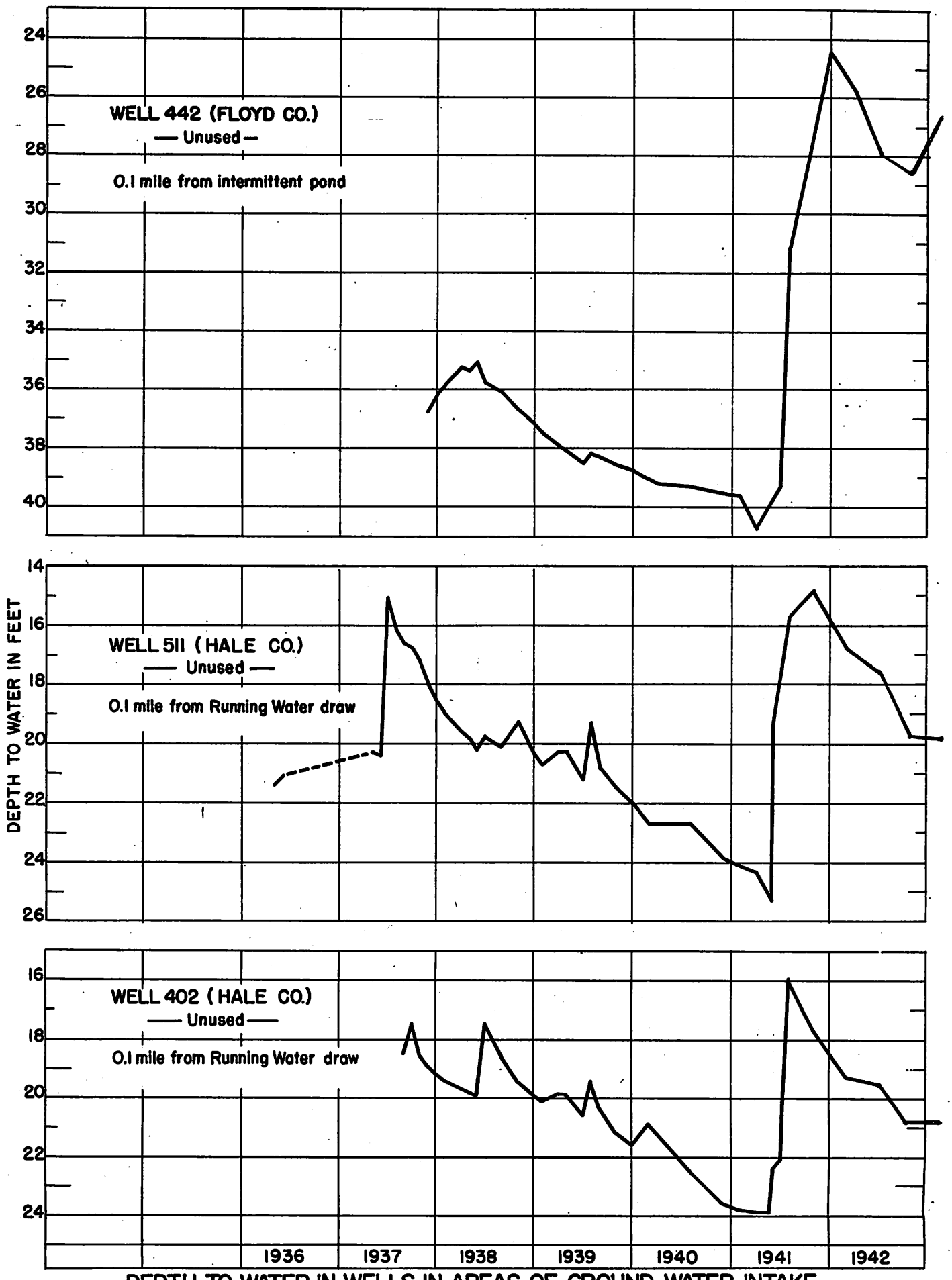
Fig. 6



DEPTH TO WATER IN WELLS IN PLAINVIEW DISTRICT, FLOYD CO. TEXAS

(Areas of heavy pumping)

Fig. 7



DEPTH TO WATER IN WELLS IN AREAS OF GROUND-WATER INTAKE, FLOYD AND HALE CO.S. TEXAS

Fig. 8

REPRESENTATIVE OBSERVATION WELLS IN HEREFORD DISTRICT, TEXAS

● OBSERVATION WELL WITH PUMPING PLANT

◊ OBSERVATION WELL UNUSED

-o- OBSERVATION WELL WITH WINDMILL

100 HYDROGRAPH IN THIS REPORT

TEXAS BOARD OF WATER ENGINEERS
IN COOPERATION WITH
U. S. GEOLOGICAL SURVEY
—1942—

SCALE
0 1 2 3 4 5 MILES

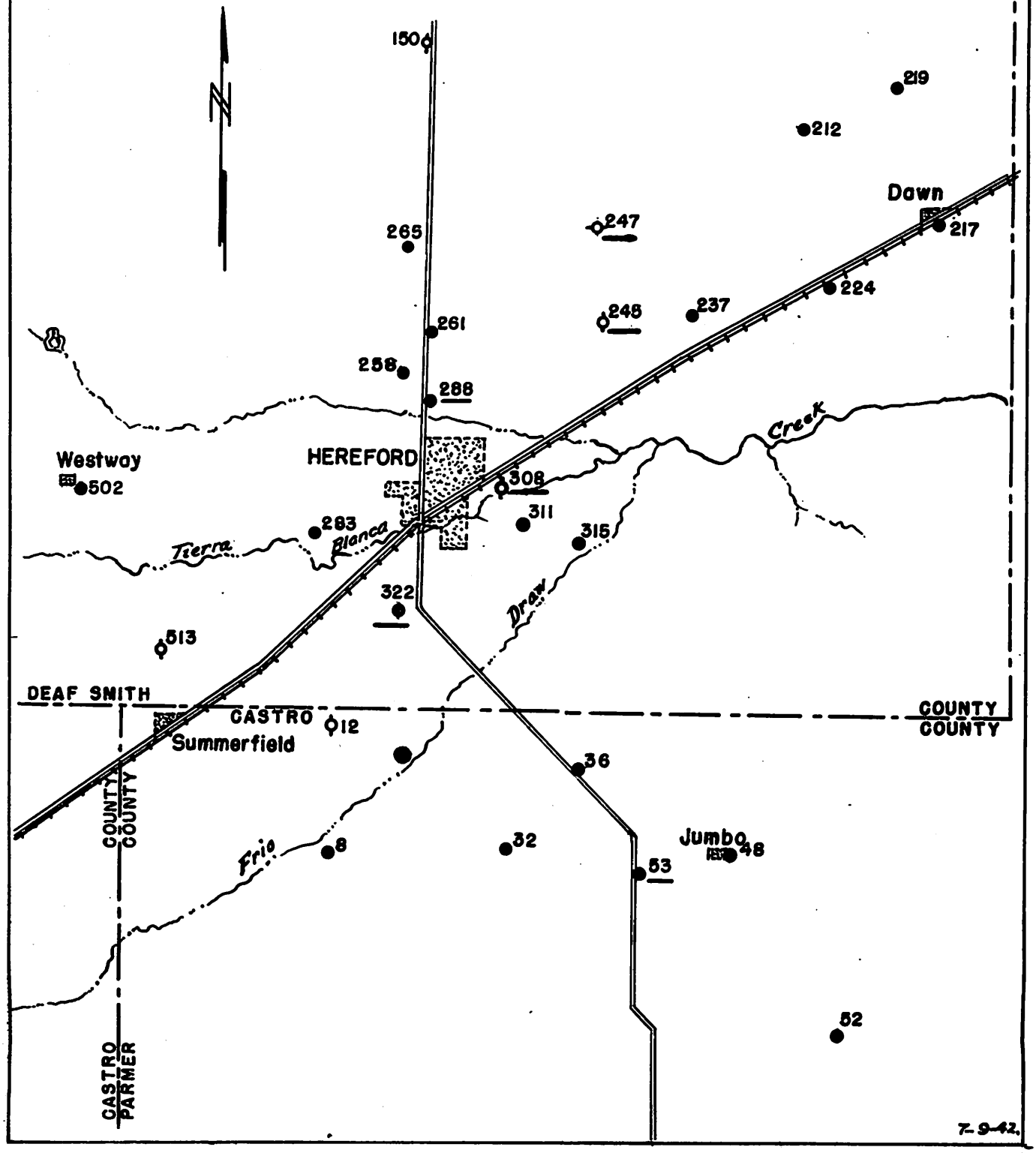
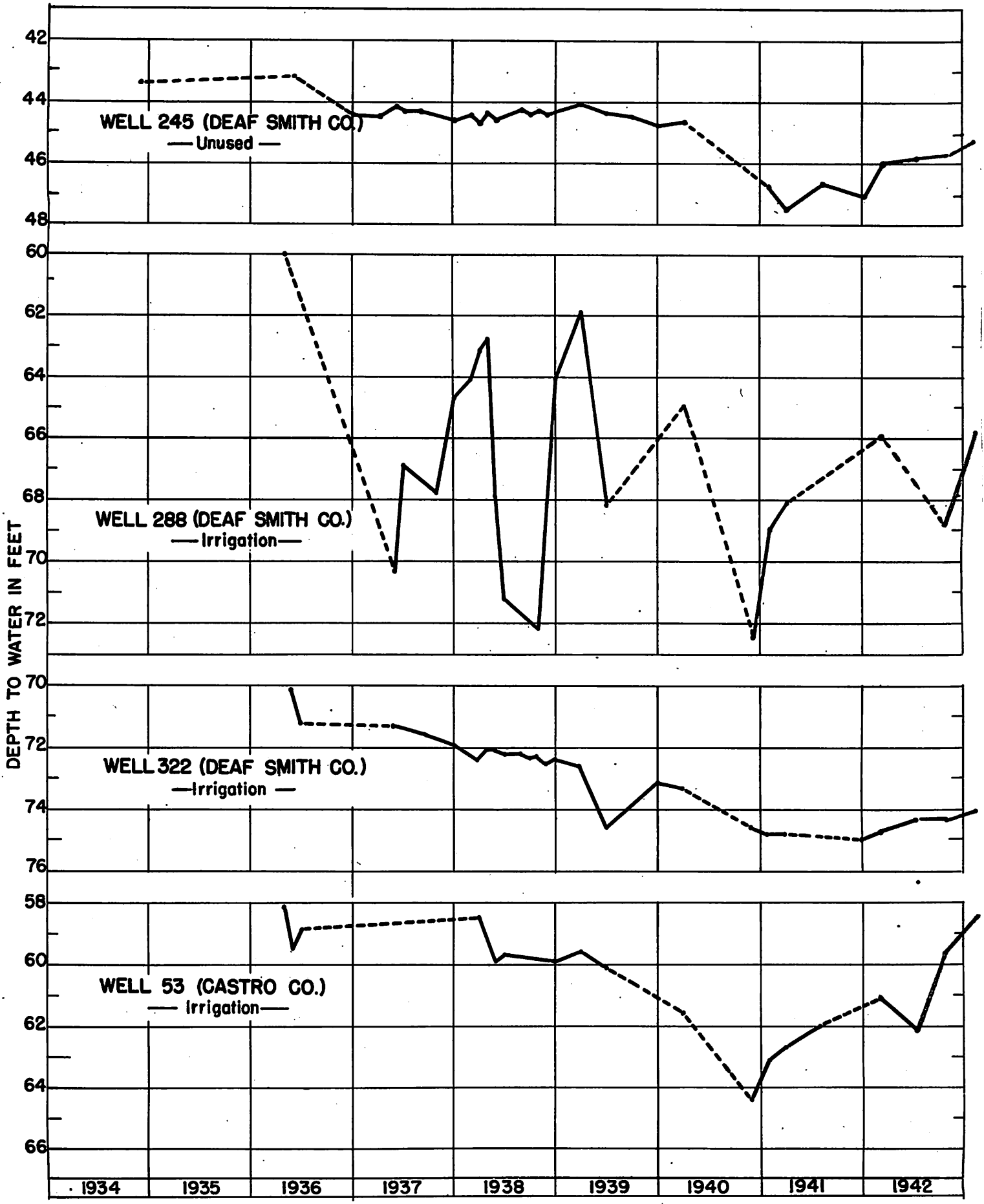
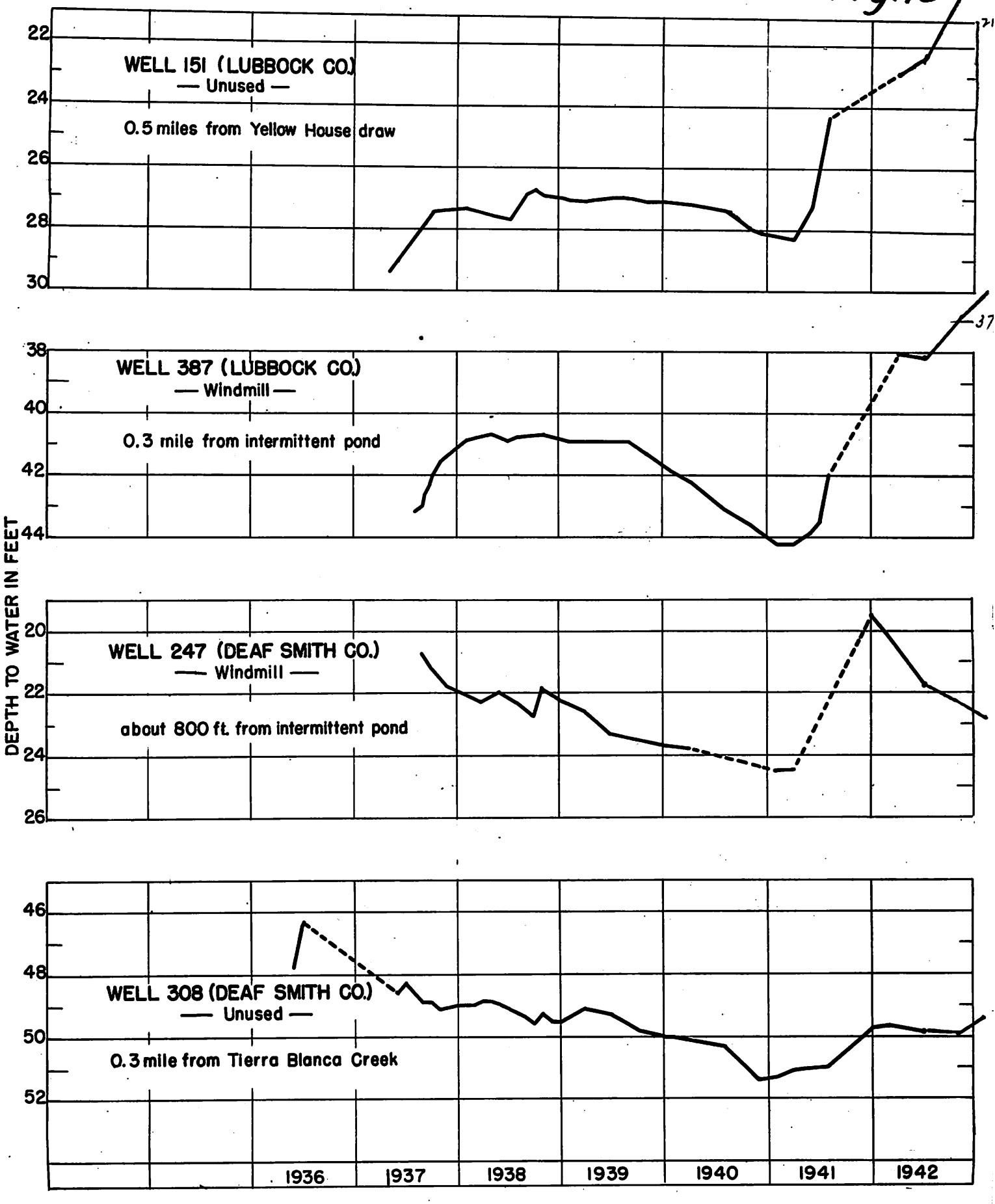


Fig. 9



DEPTH TO WATER IN WELLS IN HEREFORD DISTRICT,
DEAF SMITH AND CASTRO CO'S. TEXAS

Fig. 10



DEPTH TO WATER IN WELLS NEAR AREAS OF GROUND-WATER INTAKE, LUBBOCK AND DEAF SMITH CO.S. TEXAS

REPRESENTATIVE OBSERVATION WELLS IN MULESHOE DISTRICT, TEXAS

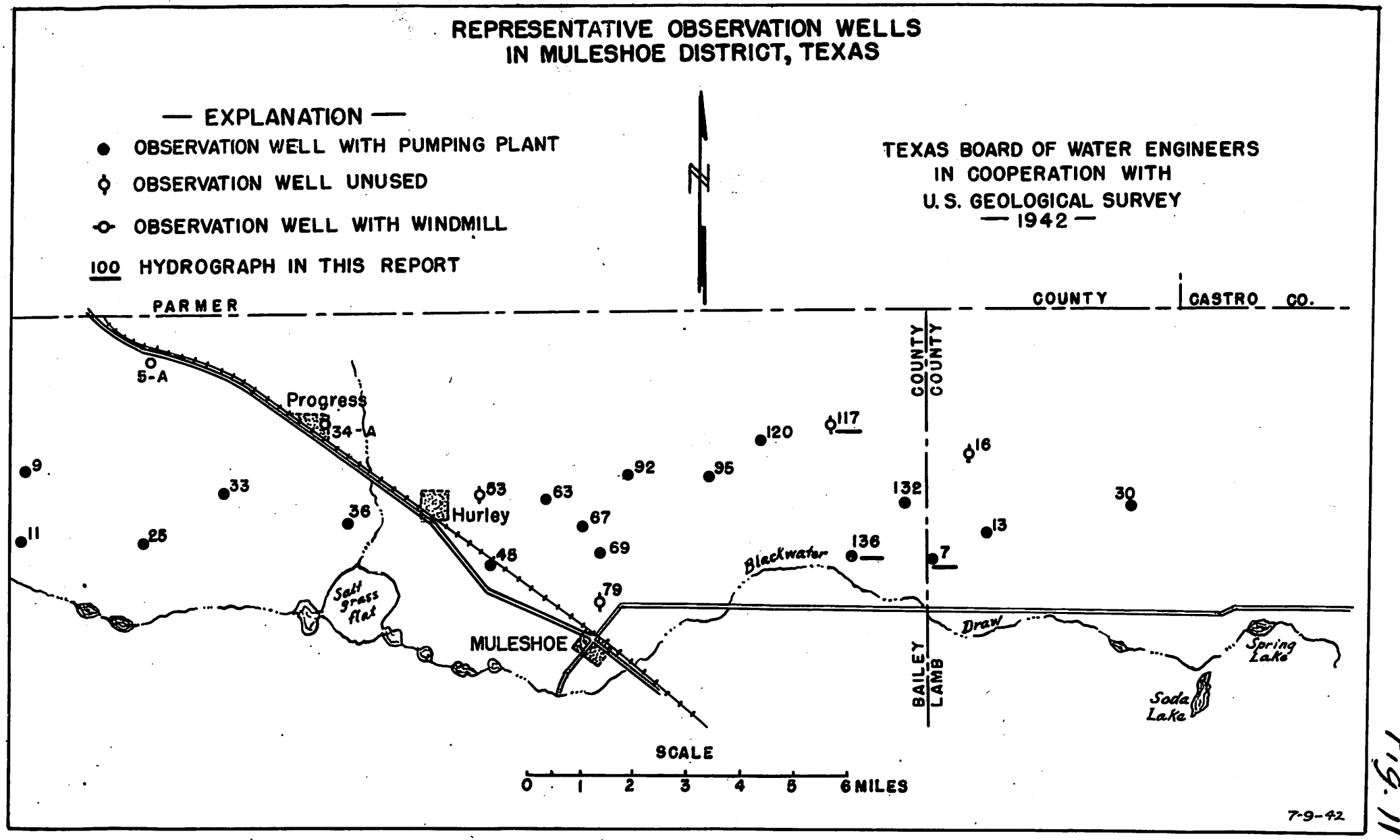
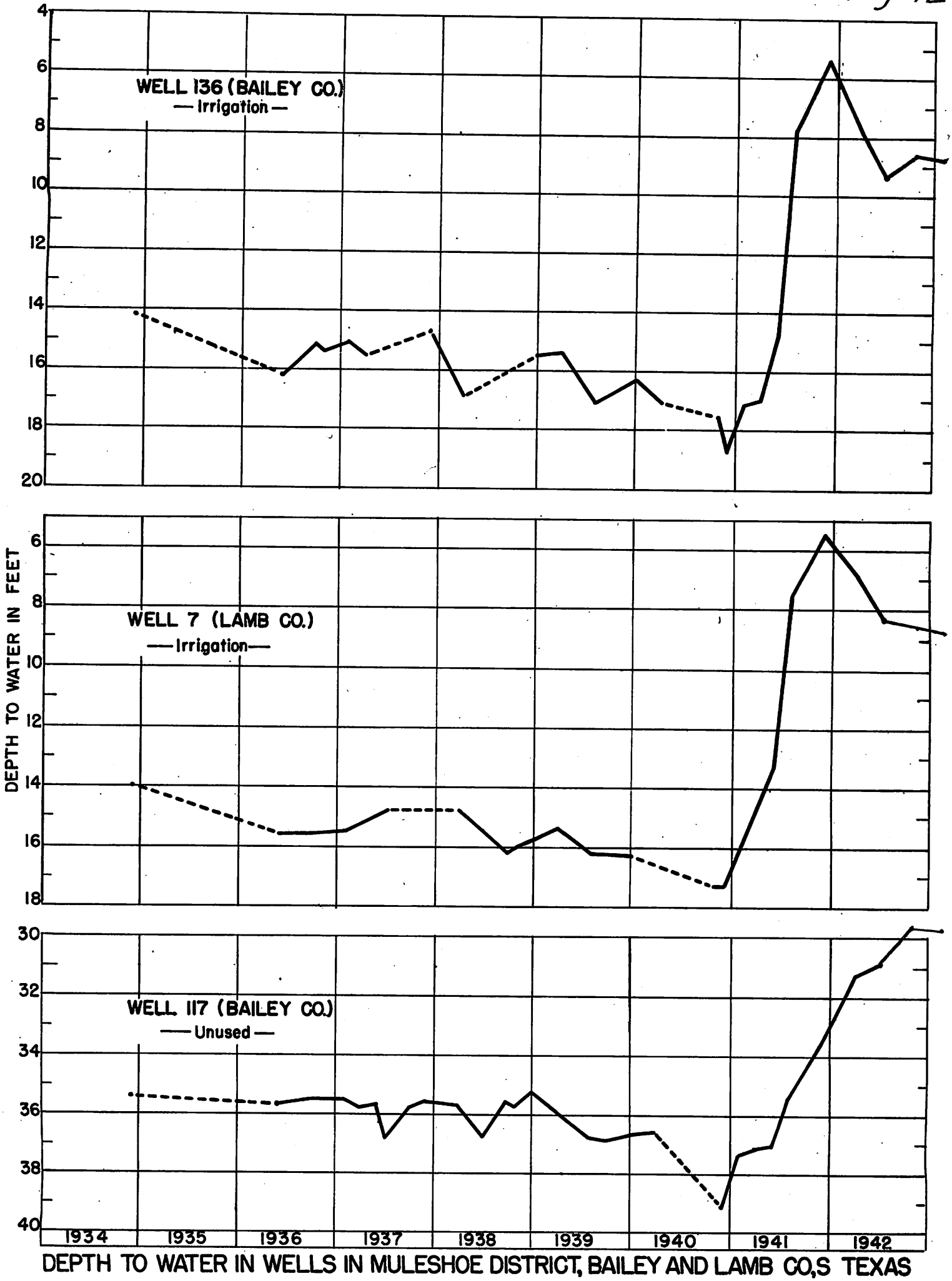


Fig. 11

Fig. 12



DEPTH TO WATER IN WELLS IN MULESHOE DISTRICT, BAILEY AND LAMB CO,S TEXAS