OKLAHOMA GEOLOGICAL SURVEY

ROBERT H. DOTT, Director

Bulletin No. 59

GEOLOGY AND GROUND WATER RESOURCES OF TEXAS COUNTY, OKLAHOMA

By

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Prepared in cooperation between the Oklahoma Geological Survey and the Geological Survey, United States Department of the Interior.

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1939

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GEOLOGY AND GROUND WATER RESOURCES OF TEXAS COUNTY, OKLAHOMA

by

STUART L. SCHOFF

Prepared in cooperation between the Oklahoma Geological Survey and the Geological Survey, United States Department of the Interior.

ABSTRACT

Texas County is located in northwestern Oklahoma in the Panhandle, 210 to 270 miles northwest of Oklahoma City and 90 to 120 miles north of Amarillo, Texas. It covers about 2065 square miles. The county is part of the Southern High Plains, and about three-fourths of it consists of flat upland, which has been dissected by the present streams to form several rather distinct tablelands.

The county is drained by Beaver River and its tributaries. The Beaver is a perennial stream in the central and eastern parts of the county, but is intermittent in the western part. Paloduro, Hackberry, and Coldwater Creeks are permanent, but all others are intermittent. The mean annual precipitation is about 18 inches.

The exposed rocks are of sedimentary origin and range from Carboniferous to Recent in age. The Tertiary deposits are at the surface in more than three-fourths of the county, and lie nearly parallel with the upland surface, which slopes about 18 feet to the mile southeastward. Structurally, the older rocks appear to be part of the Western Oklahoma-Dodge City basin.

The oldest rocks exposed in the county are red beds of the Cloud Chief formation, of Carboniferous (Permian) age. They consist mainly of red shale or clay, with minor amounts of gray and green clay, and buff to brown sandstone, and a little gypsum. The exposed thickness is about 70 feet. The formation yields meager supplies of water that are generally adequate for domestic and stock purposes, but the water is highly mineralized.

Red beds tentatively assigned to the Triassic and Jurassic systems crop out in several inliers near the middle of the county. They consist of red shale, with minor amounts of green, gray, and yellow shale, and soft, red and gray sandstones. Few wells have been drilled on or near the outcrop area of these rocks, and it is not known whether the few now in use actually draw water from these beds, or obtain it from older rocks.

The Cretaceous system is represented by fossiliferous sandstones and shales of Washita age which are exposed at one locality in the west central part of the county. The known thickness is about 28 feet. No wells are known to draw water from the Cretaceous, but it is probable that in well drilling the sandstones would not ordinarily be distinguished from Ogallala strata.

The Ogallala, of Pliocene (Tertiary) age, is the principal water-bearing formation in the county. It consists of a varied assortment of nearly unconsolidated, calcareous sands, gravels, silts, and clays which are arranged in many lenses and interpenetrating tongues or fingers. The formation was deposited largely by shifting streams which obtained rock debris from mountains to the west, but some parts may be wind-blown material. The thickness varies from a few feet to several hundred feet. The logs of gas test wells indicate maximum thicknesses of about 600 feet, and considered together with logs of several water wells and an electrical resistivity test, suggest that two pre-Ogallala valleys joined in the east-central part of the county and left at the northeast corner. Specific capacities of the larger wells drawing from the Ogallala range from 7.7 to 62.8 gallons per minute per foot of drawdown. Mechanical analyses of water-bearing sands from several wells show that most of the material is medium-grained. The average uniformity coefficient for Ogallala sands is 2.8.

Caliche is widely exposed as a cliff-making unit along the valleys just below the upland, and is found in most wells. No wells take water from the caliche, but it probably has an important bearing on recharge of the ground water reservoir because it is impermeable and will stop or greatly retard the downward movement of rainwater.

The alluvium of the present valleys consists of sands, gravels, silts, and clays deposited by the streams. Water occurs in the alluvium at shallow depths, and is satisfactory for domestic, stock, and irrigation purposes except in areas where the Permian rocks are exposed nearby and the water has had opportunity to become more or less mineralized.

Fine- to medium-grained quartz sand heaped by the wind into dunes covers the Ogallala formation in the eastern and northern parts of the county, to a maximum of about 25 feet. The sand absorbs much of the rainfall, and the dune areas therefore favor recharge of the underground reservoir. The sands are far above the water table and do not supply water directly to wells.

The possibilities of developing additional water supplies from wells for irrigation in different parts of the county are discussed.

Seven upland areas, seven valley (flood plain) areas and one area of intermediate elevation, are discussed in detail. The most favorable area in the county appears to lie roughly between Optima, Tyrone, and Adams, and includes about 80 square miles where the water table ranges from 70 to 100 feet below the surface. Test drilling to determine the thickness, character, and water-yielding capacity of the water-bearing sands, and the thickness of the saturated part of the Ogallala formation, should be undertaken in this area. The flood plains of the major streams afford adequate supplies of water at shallow depths in most places, but are of secondary importance for irrigation because the soils are less favorable than those of the uplands and because there is possibility of damage to crops by flooding.

The water that is added each year to the underground reservoir in the Ogallala formation of Texas County appears to come largely from local precipitation. The water probably enters the ground through areas of sandy soils and sand dunes, through the channels of intermittent streams, and through the bottoms of the temporary lakes. A significant part of the flood waters which come down Beaver River from outside areas probably reaches the ground water reservoir through the intermittent part of the channel, and flood waters which seep into the alluvium in Cimarron River valley in southeastern Colorado and southwestern Kansas may move southeastward into Texas County. There may also be some recharge from the Dakota sandstone where it thins and pinches out between the Ogallala and the underlying impervious red beds.

INTRODUCTION

Purpose and Scope of this Investigation. By the end of 1937 the Oklahoma Panhandle had experienced about seven successive years of below average precipitation. As a result there had been repeated partial or complete crop failures and a corresponding decline in farm incomes, together with increasing damage by wind erosion on lands where no protective covering was afforded either by growing crops or by natural vegetation. During this period there has been increasing interest in the possibilities of irrigating with ground water, both as a regular practice and as an occasional subsistence measure to carry the farmers through the dry years. Active irrigation from an old well was begun about 1932 on the flood plain of a tributary of Beaver River about 8 miles west of Goodwell, and beginning in 1934 a few farmers installed new pumping plants, both on the uplands and in the valleys. The Panhandle Agricultural and Mechanical College at Goodwell began experimental irrigation from two deep wells in the summer of 1937, and a number of farmers are interested in trying irrigation from wells if its success can be demonstrated. It was therefore considered desirable to make a scientific study of the ground water conditions in the area.

Ground water, next to the soil has already proved to be the most important natural resource of the Oklahoma Panhandle. The fact that an abundant supply of good water for domestic and stock use can be obtained from wells almost everywhere in the Panhandle was largely responsible for its settlement and continued occupancy. At present nearly all town, industrial, and farm supplies of water are obtained from wells. Surface water supplies are both small and unreliable in most parts of the area because precipitation is relatively low and is likely to be flashy, so that the streams are dry or carry very little water most of the time. Some attempts have been made to store flood water for the irrigation of small tracts of meadow on flood plains, and some surface run-off is caught in small earth reservoirs (known as tanks) for stock, but the amount of surface water so used is but a fraction of that which is taken from wells. In the early days

of settlement, wells were drilled at widely-spaced intervals on the upland plain and were equipped with large windmills for pumping water for stock. Now there is a windmill on nearly every farm. Up to the present time, the drain on the underground reservoir has been small in proportion to its capacity, and there is little danger of depletion at the present rate of withdrawal. The effect of a large number of irrigation wells, each pumping thousands of gallons of water a day, is obviously of vital interest both to the present users of ground water and to those who may install the irrigation plants, and it is therefore desirable to make an inventory of the possible supply before extensive irrigation begins. Accordingly the chief purpose of this investigation has been to obtain information bearing on the availability of water from wells for irrigation, and to indicate where test drilling may be undertaken.

Large supplies of ground water are known to occur in the sands and gravels that underlie parts of the High Plains in Kansas, Texas, and New Mexico, where successful irrigation from wells has been practiced for longer or shorter periods. The feasibility of using water from wells for irrigation depends to a considerable extent on three factors: (1) the permeability and thickness of the water-bearing sands, (2) the depth to the ground water table and the pumping lift, and (3) the ability of the ground water reservoirs formed by the sands to withstand a heavy draft from wells over a period of years without being seriously depleted. This report gives the results obtained from an investigation of the ground water resources of Texas County, and it is expected that similar studies will be conducted in the near future in Cimarron and Beaver Counties. The investigation was made through co-operation between the Oklahoma Geological Survey and the Geological Survey of the United States Department of the Interior. It was made under the general direction of O. E. Meinzer, Geologist in charge of the Division of Ground Water in the United States Geological Survey, and Robert H. Dott, Director of the Oklahoma Geological Survey. W. N. White, Senior Engineer in the United States Geological Survey, who is in charge of ground water studies in Texas, exercised supervision over the work and contributed much to the field work and to preparation of the report through letters and field conferences.

Location of the Area. Texas County is located in Northwestern Oklahoma, in the middle of the Panhandle. Guymon, the county seat, is about 250 miles northwest of Oklahoma City, and 100 miles north of Amarillo, Texas (Fig. 1). The county extends from Lat. 36°30′ N. to Lat. 37°00′ N., and from a few miles east of Long. 101° W. to a few miles west of Long. 102° W. It is 60 miles long from east to west, about 34.5 miles from north to south, and covers about 2,065 square miles.

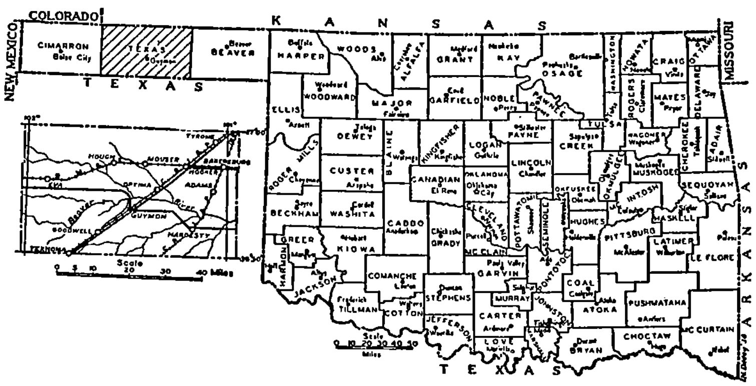


FIG. 1. INDEX MAPS SHOWING LOCATION OF TEXAS COUNTY, OKLAHOMA, AND PRINCIPAL FEATURES IN THE COUNTY.

Three railroads serve the county. The main line of the Chicago, Rock Island and Pacific Railroad from Kansas City to El Paso crosses it from northeast to southwest, passing through Tyrone, Hooker, Optima, Guymon, Goodwell, and Texhoma. A branch line from Liberal, Kansas to Amarillo, Texas, passes through Bakersburg, Adams, and Hardesty. The Beaver, Meade and Englewood (Missouri-Kansas-Texas) Railroad crosses the county from east to west and provides freight service between Forgan, in Beaver County, and Keyes, in Cimarron County. It intersects the branch line of the Chicago, Rock Island, and Pacific Railroad at Bakersburg, and the main line at Hooker, and passes through Mouser, Hough, and Eva. A branch of the Atchison, Topeka, and Santa Fe Railroad crosses the extreme northwestern corner of the county, but makes no regular stops within the area.

Federal highway 64 crosses the county from east to west and is a bituminous-surfaced road all the way. Federal highway 54 crosses the county from northeast to southwest, paralleling the Chicago, Rock Island, and Pacific Railroad, with a gravel surface except where it coincides with highway 64. Gravel or dirt roads varying from good to poor are to be found on nearly every section line. For the most part, country roads are passable at all seasons, although at times drifting sand or mud may impede travel temporarily. Near stream valleys many of the section lines are closed, but here and there winding, narrow roads descend to the valley by the most convenient route and give access to the bottom lands.

Previous Investigations. The fundamental facts regarding the occurrence of ground water in the Southern High Plains, of which Texas County is a part, its source, its availability, and the limitations on its use, were set forth by W. D. Johnson[1] about 1900. In 1905 Gould[2] reported on the geology and water resources of Oklahoma, including the Panhandle under the heading "High Plains." The name Texas County does not appear in his report because at that time the entire Panhandle constituted a single county under the name of Beaver. Records of 10 wells in the Panhandle are tabulated, and include four from the present Texas County. The geology of the county and the occurrence of water in both the Tertiary rocks (Ogallala formation) and in the older red beds are discussed by Gould and Lonsdale[3] in a bulletin published in 1926. Two years later Bullard[4] mapped and described six outliers of fossiliferous lower Cretaceous sandstone resting on Triassic (?) red beds at the Red Point locality, near the

1. Johnson, W. D., "The High Plains and Their Utilization": *U. S. Geol. Survey 21st Ann. Rpt.* Pt. IV, pp. 601-741, 1899-1900, and *22nd Ann. Rept.* Pt. IV, pp. 631-669, 1900-1901.
2. Gould, C. N., "Geology and Water Resources of Oklahoma": *U. S. Geol. Survey Water Supply Paper* 148, p. 88, 1905.
3. Gould, C. N., and Lonsdale, J. T., "Geology of Texas County, Oklahoma": *Okla. Geol. Survey Bull.* 37, 1926.
4. Bullard, F. M., "Lower Cretaceous of Western Oklahoma": *Okla. Geol. Survey Bull.* 47, pp. 90-92, 1928.

The areal geology is taken from Gould and Lonsdale[9] modified by the writer from field observations and from the Texas County soil map[10] and some minor changes due to corrections in the mapping of the drainage have been made.

Wells which were measured, or for which other significant information is available, are shown on Plate I, their position being determined largely from speedometer distances, but to a limited extent from aerial photographs. The upper number beside the well symbol corresponds with that used in the well tables in the text, and the lower number is the depth of the water table below a fixed measuring point. Areas that are irrigated from wells are shown in approximate position and size.

The wells are numbered by townships from left to right across the map, beginning with T. 1 N., R. 10 E., in the southwestern corner of the county. Within the townships they are numbered in section order. Gaps in the sequence of numbers have been left following each township so that additional wells can be added to the record later if desirable. Thus wells 1 to 9 inclusive are in T. 1 N., R. 10 E., with well number 1 in section 2, well number 2 in section 5, well number 3 in section 12, etc. Numbering in T. 1 N., R. 11 E. runs from 13 to 27 inclusive; in T. 1 N., R. 12 E., from 31 to 47 inclusive. This sequence of numbering is broken in places, however, because the original field numbers have been retained for wells in which periodic measurements of water levels are being made. Cross references have been placed in the well tables so that all such wells can be located readily, either in the tables or on the map.

This map shows the depths to water in all parts of the county at the time the investigation was made, and the depth lines should be considered as arbitrary boundaries between areas. Thus the 50-foot line separates the area where the depth to water is less than 50 feet from the area where it is between 50 and 100 feet. The lines are broken where the available data are limited. In upland areas, where the slopes of both the land surface and the water table are fairly uniform, the depth lines of Plate I have been drawn with reference to the measured wells, and without regard for minor topographic irregularities.

9. Gould, C. N., and Lonsdale, J. T., *Op. cit.*, Map.

10. Fitzpatrick, E. G., and Boatright, W. C., "Soil Survey of Texas County, Oklahoma": *U. S. Dept. Agri. Bur. Chem. and Soils, Ser.* 1930, No. 28, Map.

Along valleys the location of the depth lines was determined from cross sections based on measurements and elevations of upland and valley wells, or lacking the latter, of the stream channel. Where the land surface is uneven, aneroid elevations at intermediate points permitted a more accurate profile. Between such locations the depth lines were drawn with reference to the topography as studied in the field and from aerial photographs. Because slopes near the valleys are both steep and irregular, depths to water differ widely within short distances, and estimates based on the depth lines in such places are necessarily less accurate than estimates for upland locations.

Figure 8 shows the general slope and the irregularities of the ground water surface in the northeastern part of the county by means of lines of equal elevation of the water table above sea level, just as a contour map of the surface of the land shows its slope and irregularity. The movement of the ground water ordinarily is at right angles to these lines, in the direction of maximum slope.

Acknowledgments

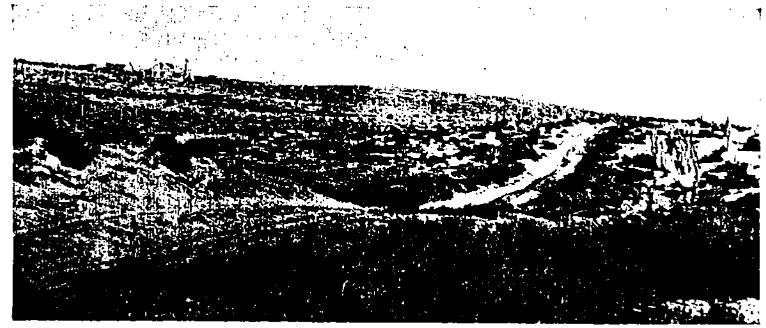
The writer is indebted to the many residents of the county who readily gave permission to measure their wells, and who supplied information regarding them. Well logs, samples of water-bearing materials, and information on pumping plant equipment and other data on the wells at Goodwell were supplied by administrative and technical staff members of the Panhandle Agricultural and Mechanical College. Other logs were supplied by W. G. Thompson, of the Oklahoma Electric and Water Company, K. E. Sharpe, of the Cimarron Utilities Company, J. C. Cooke, C. F. Kauffman, W. N. Ballinger, and the Hagy, Harrington, and Marsh Company. Williard Mayberry, of the Liberal Deep Well Irrigation Company, supplied information for an irrigation well recently drilled at Liberal, Kansas, and Jack Doty, of the Well Works Manufacturing Company, Garden City,

Kansas, supplied the log of a city-owned well near it. Frank M. Perry supplied well logs and water analyses for wells drilled at Guymon for the General Atlas Carbon Company. Several Texas County water well drillers freely described subsurface conditions and gave information regarding specific wells, and Guy C. Sanborn provided the log and samples of the rocks from an irrigation well drilled by him in the winter of 1938. County Agricultural Agent H. C. Hyer provided much information regarding local agriculture. The writer is greatly indebted to the members of the Oklahoma Geological Survey, and especially to Director Robert H. Dott, for assistance in handling details of field work and preparation of the report, and for advice on the geologic problems.

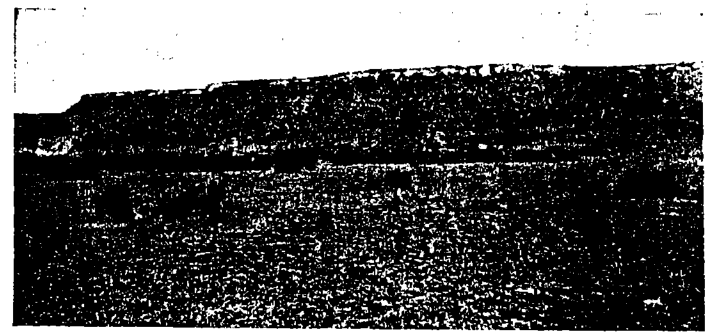
GEOGRAPHY

Topography and Drainage. Texas County is part of the High Plains section of the Great Plains physiographic province. About three-fourths of the county consists of upland plains, and the remainder of stream flood plains and intermediate slopes. The upland plain slopes southeastward from elevations of about 3,700 feet above sea level along the boundary near the northwest corner to about 2,750 feet along the east-central boundary on the upland plains north of Beaver River. Elevations in Beaver Valley are 100 feet or more lower, but of course do not indicate the slope of the upland. From bench marks of the United States Coast and Geodetic Survey it is estimated that the maximum average slope of the upland plain is about 18 feet to the mile southeastward. Large areas on the uplands are comparatively flat and featureless, without stream valleys, large or small, to break the monotony. In detail, however, most parts of the uplands are more or less uneven, with broad, gentle swells or hills, and shallow depressions which are likely to become lakes or ponds after heavy rains. Where the swells and the depressions are fairly pronounced, the topography may be described as undulating.

The county is drained by Beaver River (North Canadian on some maps). It enters the county about 6 miles east of the southwest corner, runs northeastward to a point about 10 miles west of Guymon, thence takes an easterly course, and leaves the county about 12 miles north of the southeast corner. The channel



A. Sand dune topography in vicinity of Buena Vista school, T. 6 N., R. 18 E.C.M.

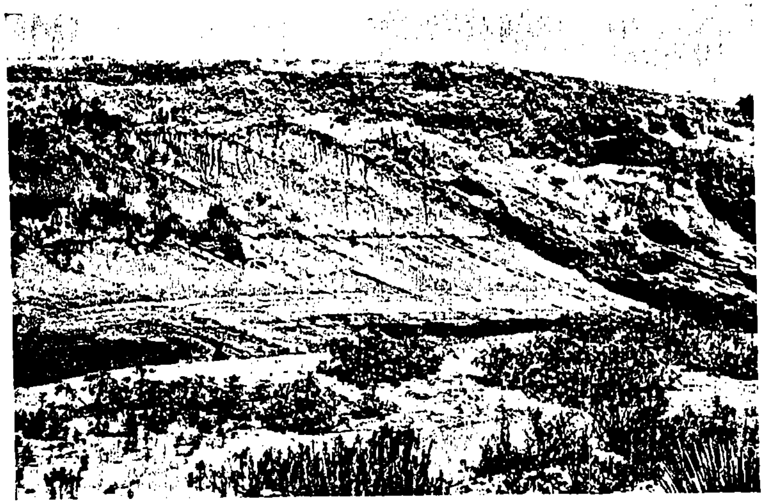


B. Escarpment of caliche west of Guymon.

C. Flat, monotonous plain type of topography characteristic of much of the upland areas of Texas County, looking west from sec. 27, T. 6 N., R. 15 E.C.M.

PLATE III

A. Arenaceous caliche exposed on the east side of South Fork near southwest corner of Guymon.



B. Steeply dipping clays and sandstones exposed on west side of South Fork west of Guymon. Horizontal lines near base of exposure were left as pool of water dried up.

carried a small flow in the central and eastern parts of the county throughout 1937, but in the upper 13 or 14 miles in the western part of the county it was dry, at least while field work was in progress during the last half of the year. The more important tributaries of the Beaver within the county enter from the south, in the eastern half of the county. Both Paloduro Creek and its tributary, Hackberry Creek, are reported to be permanent streams, but Chiquita Creek (locally called "Skeeter"), the other main tributary of the Paloduro, is not. Coldwater Creek is also said to be permanent, but its tributary Frisco Creek is generally dry in most of the upper part of its course. Other tributaries to the Beaver are South Fork, North Fork, Tepee Creek, Goff Creek, and Pony Creek. With the exception of a short stretch near the mouth of Tepee Creek, these tributaries are usually dry.

The valleys of the main streams range from 1 to 4 miles in width, and from 100 to 200 feet or more in depth. The shallowness of the larger valleys in contrast to their width has been emphasized by Gould and Lonsdale[11], who point out that the steep-sided tributary valleys are gorges or canyons by comparison. Nevertheless, the major valleys are prominent topographic features because of the white cliffs of caliche which occur at the edge of the upland in many places. Where these cliffs are present, the change from upland plain to the valley is abrupt. Below the cliff, slopes gradually lessen until they merge into the flats of the flood plains. In some places there are cliffs of caliche on both sides of the valley, in others the slopes on both sides are moderate and more or less dissected, but more commonly one side has a steep cliff and the other a moderate slope. Thus there are cliffs and steep slopes on both sides of Beaver River for a dozen miles upstream from the mouth of Tepee Creek. Between Guymon and Optima conspicuous cliffs line the north side of the Beaver, but the south side is a moderate slope 2 miles and more in length, whereas in the vicinity of Hardesty conditions are reversed. Paloduro Creek and its tributaries have cut away the cliff-making caliche, and both sides of the Paloduro Valley have moderate slopes. The transition area from upland flat to valley flood plain is also characterized by broken slopes and gen-

11. Gould, C. N., and Lonsdale, J. T., *Op. cit.*, pp. 15-16.

erally uneven land forms which have been given the descriptive name "breaks" because they occur at the place where the plain breaks into the valley. As defined by Gould and Lonsdale[12], the term includes the "rough broken land lying between the essentially level lowland, or valley flats, and the essentially level uplands, or undissected stream divides", and thus is roughly equivalent to "valley bluff." The "breaks" support a natural vegetation consisting largely of sand sage with lesser amounts of bluestem, tall sage, Indian grass, buffalo grass, blue grama, catclaw, and yucca.[13] In general the slopes are too steep for agriculture, and are useful only for grazing. Flood plains are well developed in all the major valleys, and in places exceed a mile in width. These bottom lands generally support a natural growth of water grasses, little bluestem, tall bluestem, buffalo grass, needlegrass, blue grama, and side-oats grama[14], and generally make good hay meadows.

The Beaver and its tributaries actually drain only one-fourth to one-third of the county. At one time the uplands probably constituted a single flat plain, but the depositing streams which built the plain changed to a degrading habit and began to dissect it. The dissection is only well started, and there remain large areas of upland flats which stand up as distinct table lands and have no exterior drainage. The rain that falls on them drains into temporary ponds and small lakes, where it either is lost by evaporation or percolates downward to the ground water reservoir.

The plains on which Hooker, Adams, Hough, and other towns of the northern part of the county are located have been separated from uplands to the south by Beaver River in the eastern part of the county, and by Goff Creek in the western part. Other tablelands are the Eva plain, located between Goff Creek and Beaver River; the Guymon-Texhoma plain, between Beaver River and Coldwater Creek; and the Hardesty plain, between Coldwater and Hackberry Creeks.

The native vegetation of the uplands consisted of buffalo and blue grama grass, together with wire grass, Indian grass, needlegrass, tall sage grass, side-oats grama, sand sage, and bluestem[15], but much of it was lost when the land was broken for agriculture.

12. Gould, C. N., and Lonsdale, J. T., *Op. cit.* pp. 18-19.
13. Fitzpatrick, E. G., and Boatright, W. C., *Op. cit.*, pp. 24-25.
14. Fitzpatrick, E. G., and Boatright, W. C., *Op. cit.*, pp. 20, 21.

In the vicinity of Paloduro Creek there are lands of intermediate elevation which are neither typical upland nor typical breaks. Nearly all of T. 1 N., R. 19 E., and considerable parts of T. 1 N., R. 18 E., and T. 2 N., R. 19 E. consist of gently rolling lands that are neither as high as the upland nor as low as the flood plains, nor so broken and uneven as the breaks. Except near the smaller streams, the slopes are gentle. The flat areas on the divides are generally small, especially in comparison with the upland plains of other parts of the county. Erosion has obviously progressed much further in this small area than it has in most of the rest of the county.

From the standpoint of stream dissection, most of the county is in the stage known as topographic youth, but this small area has advanced to maturity. The reason for this difference is that here a number of streams, some of which are permanent, come together. With tributaries more closely spaced than in other parts of the county, they have accomplished a relatively greater amount of dissection, and have stripped off much of the uppermost rock formation southward to the Texas state line, where caliche cliffs end in bold, northward-facing escarpments.

The relation of the caliche to the preservation of the uplands and to the development of the breaks is suggested by an area of several square miles immediately west of Hough, where the caliche is either absent or is not resistant, and tributaries of Goff Creek have produced a moderately rolling topography.

Two areas of sand dunes are superimposed on the upland plain. The larger area, about 40 square miles, is located on the north side of Beaver River to the south and southeast of Adams, and continues eastward into Beaver County. The larger dunes are 20 feet or more high, and make a hilly, or gently rolling topography. They begin low on the north bluff of the river, just above the flat lands of the flood plain, are most strongly developed at the edge of the upland, and gradually disappear to the north.

15. *Idem*, pp. 15, 17-21.

Their position on the lee side of the river suggests that the sand was blown off the flood plain or channel by the prevailing southwest wind, and lodged against the valley bluffs. Some of these dunes are still being shifted about by the wind, but most of them are more or less anchored by native vegetation consisting of tall sage grass, sand sage, Indian grass, yucca, and sand plum[16]. The sandy soil of the dunes and the steep slopes are less well suited to agriculture than the nearby rich soils and almost flat lands of the normal upland plains, and there has been little attempt at farming them.

The northern sand dunes consist of three somewhat disconnected patches totaling about 32 square miles, mostly located west of Tyrone. These dunes have not been shown on previous geologic maps of Texas County, and their outlines were first sketched in the field by the writer and later corrected from aerial photographs. The dunes are separated from the valley of the Beaver by 15 or 20 miles of nearly flat and almost unbroken upland plain. If the sand had been derived from the river flood plains, some of it should have stopped nearer the valley, but there is no evidence of dunes in the intervening areas. Neither is there any apparent reason why sand from the valley should have stopped in the present dune areas after crossing many miles of upland plain. It seems probable that the sand hills were formed at or near where they are now located. Wherever the streams which deposited the surface formation left dominantly sandy beds, or where the soils were loose enough so that the finer portions were sorted out and blown away, the sand could be heaped by the wind into hills without being transported any great distance. These dunes are inactive, being anchored by native vegetation.

Small circular depressions dot the surface of the uplands and their origin has attracted considerable interest. It has been suggested that they are natural depressions which have been enlarged by the joint action of milling buffalo and wind erosion[17]. Thus buffalo would come upon a depression containing some water,

16. *Idem*, p. 25.
17. Explanation as summarized orally to the writer by W. N. White.

break the sod, and trample the moist soil into the mud. When dry, some of the soil might be blown away. If the animals returned when water was scarce, they would pulverize the dried mud to a powder that could be easily blown away. An objection to this explanation is the very large number of depressions, not only in Texas County, but in other parts of the High Plains. In the vicinity of Plainview, Texas, the depressions have been found to average about one to the square mile[18]. Further objections to this mode of origin were suggested by W. E. Baker[19], County Agricultural Agent of Cimarron County, who points out that the present depressions are filling up rather than enlarging, and that they are generally the places best protected from wind erosion because vegetation grows abundantly in them. In his opinion, the depressions are much larger than true buffalo wallows, and if buffalo were like domestic cattle they would not spend much time at a dry water hole.

Johnson[20] has shown that the depressions probably are caused by the settling and compaction of subsurface materials. Thus removal of calcium carbonate from the topmost rock formation and rearrangement of the loosely consolidated sands and gravels in it could result in settling, and the gypsum and salt which occur in the underlying red beds are readily soluble, and subject to formation of caverns. Collapse of a cavern would result in the settling of the overlying rocks and the appearance of a depression at the surface. Ordinarily such a depression would be roughly circular in outline, but the collapse of a very long cavern would result in an eliptical depression or an elongate trough.

Climate. Texas County has a mild and dry climate. The average annual mean temperature as recorded by the Weather Bureau observers at Goodwell and Hooker is about 56° F.[21] In summer the days generally are hot, but the nights are cool because of the relatively high elevation. July and August are the

18. White, W. N., oral communication.
19. Baker, W. E., oral communication.
20. Johnson, W. D., "The High Plains and Their Utilization": *U. S. Geol. Survey 21st. Ann. Rept.*, Part IV, 1899-1900.
21. Except as noted, climatic data are either quoted or summarzied from *U. S. Weather Bureau*, "Climatic Summary of the United States, Section 42, Western Oklahoma," 1930; and "Climatological Data, Oklahoma Section," published annually 1931-1937.

warmest months, and January and December the coldest. The highest recorded temperature is 112° F., at Hooker, in June, and the lowest, also at Hooker, is —20° F., in January. The growing season averages about 180 days, but has varied from 157 to 220 days. The last killing frost in spring occurs about the middle of April, but has varied from March 27, to May 22. The first frost in the fall usually occurs in October, but has varied from September 26 to November 14.

Much of the precipitation comes in torrential rains which quickly saturate the upper part of the soil so that a large part of the water runs off into depression ponds, or escapes into the main drainage lines. The annual precipitation of the county averages about 18 inches, but the precipitation differs from year to year. For example, see the total precipitation for years 1907-11, 1915-16, and 1923-24 in the table for Hooker, and 1915-16 and 1923-24 in the table for Goodwell. At Goodwell the annual precipitation has varied from 9.69 inches to 26.75 inches, and at Hooker from 9.39 inches to 29.59 inches. No continuous record has been obtained at Guymon, but the maximum annual precipitation for the county, 34.99 inches, was reported there in 1915 by the Weather Bureau. Since 1921 D. P. Bissell has kept a private record of precipitation at Guymon, and reports a minimum of 11.23 inches, and an average of 18.1 inches for the 17 years. Part of the precipitation comes as snow, the average amount to the end of 1930 being about 15 inches of unmelted snow per year. Besides the variations from one year to another, the annual precipitation varies widely from one place to another in any given year, as the tables below indicate. For example, compare precipitation at Goodwell, Guymon, and Hooker for the years 1915, 1920, and 1930.

The tables show that the annual precipitation is likely to be below average two years out of three, but that there may be several years of above average precipitation followed by several dry years. Beginning in 1931 and continuing to the end of 1937, Texas County experienced seven years in which the precipitation was below average. Based on the average at the end of 1937, the departures from the average ranged from 1.18 inches to 7.73 inches per year at Goodwell, and from 0.75 inches to 7.4 inches

per year at Hooker. Precipitation at Guymon has been below average since 1932, with departures from average ranging from 1.34 inches to 6.87 inches per year. From 1931 to 1937 the accumulated deficiency in precipitation amounted to 31.16 inches below the 25-year average at Goodwell, and 33.16 inches below the 31-year average at Hooker[22]. The total accumulated deficiency at Guymon from 1932 through 1937 is 24 inches below the average for the past 17 years[23].

The following tables give the monthly, annual, and average precipitation at Goodwell, Guymon, and Hooker, with departures from average by years, and the average monthly and annual temperature at Goodwell and Hooker:

22. The period of record is 28 years at Goodwell and 32 years at Hooker, but records for some of the early years are incomplete and are not included in the averages.

23. The average for the 17 years of unofficial record, 1921-37, rather than the average for all the years of record, is used as a basis of comparison because only three annual totals are included in the Weather Bureau record for the period 1909-15, and these three are abnormally high. Their inclusion results in a high average annual precipitation, and correspondingly high departures from average.

TABLE I.

CLIMATIC DATA FOR GOODWELL, TEXAS COUNTY, OKLAHOMA
Monthly and annual precipitation (inches) and average monthly and annual temperature (F°)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual Departure from 25-year average
1910	......	......	0.00	1.83	0.80	0.26	3.69	2.07	0.55	0.02	0.05	0.03	....	
1911	T	1.77	T	0.70	3.12	0.09	3.65	2.59	0.28	1.65	0.50	1.18	15.53	—1.89
1912	0.10	1.48	0.95	1.32	2.51	3.01	1.90	3.31	2.63	T	0.26	T	17.47	+0.05
1913	0.45	0.90	0.10	0.52	1.32	3.65	1.10	1.81	3.63	0.07	2.75	2.69	18.99	+1.57
1914	0.03	T	0.15	1.28	6.89	2.54	4.70	2.32	0.00	4.42	0.00	0.18	22.51	+5.09
1915	0.30	1.25	0.30	3.63	2.45	5.02	4.32	4.06	3.52	1.50	0.10	0.30	26.75	+9.33
1916	0.35	0.00	0.15	2.20	0.20	6.53	0.33	2.14	1.95	0.12	0.16	0.53	11.66	—5.76
1917	0.50	0.25	0.20	0.38	2.75	1.03	2.36	5.89	2.48	0.20	0.52	0.00	16.56	—0.86
1918	0.47	0.17	1.32	1.81	3.46	0.72	1.41	3.75	1.75	1.73	0.74	2.80	20.13	+2.71
1919	0.10	1.39	2.60	2.15	2.59	0.00	0.48	......	2.76	1.19	0.93	0.73	....	....
1920	0.40	0.10	0.43	0.58	2.47	2.90	0.71	1.22	3.50	1.15	0.73	0.60	14.79	—2.63
1921	0.94	0.85	T	1.48	4.02	2.33	5.60	1.36	T	0.25	T	T	16.91	—0.51
1922	0.49	0.80	2.25	1.15	1.38	......	......	......	......	......	1.25	0.00	....	....
1923	0.00	0.61	0.78	1.57	1.34	4.47	1.54	1.75	5.02	4.21	1.53	1.30	24.12	+6.70
1924	0.30	0.20	1.70	1.85	2.00	0.41	1.15	2.65	1.05	0.62	0.06	0.13	12.12	—5.30
1925	0.20	0.25	0.04	1.43	0.76	2.03	4.52	1.88	3.23	0.45	1.07	0.07	15.93	—1.49
1926	0.11	0.15	1.47	2.32	4.09	5.03	0.47	0.99	1.81	0.04	0.23	0.58	17.29	—0.13
1927	T	0.41	0.25	1.52	T	1.86	5.19	5.04	1.73	0.34	T	T	16.34	—1.18
1928	T	1.21	0.86	1.41	6.48	2.92	3.57	1.85	0.36	3.04	1.90	0.70	23.57	+6.15
1929	0.30	0.22	2.02	0.24	2.22	2.28	4.62	2.64	0.91	1.14	1.77	0.01	18.37	+0.95

TABLE I.

CLIMATIC DATA FOR GOODWELL, TEXAS COUNTY, OKLAHOMA (CONT.)
Monthly and annual precipitation (inches) and average monthly and annual temperature (F°)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual Departure from 25-year average
1930	0.32	0.03	0.25	0.63	0.57	2.59	4.24	1.75	3.15	4.39	0.33	0.28	18.53	+1.11
1931	0.11	0.81	2.37	2.08	2.61	1.42	0.96	2.27	1.21	1.08	0.53	0.79	16.24	—1.18
1932	1.06	0.45	1.08	2.99	2.09	2.70	0.32	1.34	1.15	0.50	0.19	0.84	14.71	—2.71
1933	T	0.41	0.19	0.77	2.29	0.67	1.10	4.60	0.10	0.56	1.90	0.03	12.62	—4.80
1934	0.12	2.28	0.31	0.40	2.27	1.97	1.65	0.84	2.14	1.92	0.22	0.15	14.27	—3.15
1935	0.27	0.11	1.48	T	2.82	1.97	0.82	1.68	0.98	0.47	0.97	0.12	11.69	—5.73
1936	0.62	0.05	T	0.15	3.85	0.67	0.43	0.26	2.48	0.27	T	0.91	9.69	—7.73
1937	0.12	0.20	0.69	0.80	3.07	1.86	1.09	1.44	1.16	0.87	0.07	0.19	11.56	—5.86
Average precipitation	0.30	0.53	0.76	1.53	2.54	2.37	2.66	2.31	1.84	1.32	0.74	0.52	17.42	
Average annual snowfall													15.1	
Average temperature (degrees F)	33.7	38.4	45.7	54.9	64.3	74.3	78.8	76.8	70.3	57.6	45.2	34.2	56.2	

T—trace

TABLE II.

Climatic Data for Guymon, Texas County, Oklahoma
Monthly and annual precipitation (inches)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual departure from 17-Year Average 1921-1937
1909	......	......	......	......	......	6.53	1.02	1.13	1.53	4.13	4.14	1.60	....	
1910	0.30	0.70	0.00	1.26	2.00	1.45	4.28	2.57	......	0.25	0.00	0.28	....	
1911	0.17	1.44	0.00	0.58	4.48	T	8.09	4.17	......	3.90	......	1.58	....	
1912	T	5.20	1.55	1.70	3.31	4.00	1.64	3.26	2.13	T	0.20	0.00	22.99	
1913	1.30	1.25	0.50	1.03	1.36	1.45	1.38	......	5.33	0.60	3.43	2.96	....	
1914	T	T	0.25	2.55	4.10	1.92	2.92	2.80	T	5.45	0.00	0.38	20.37	
1915	0.66	3.20	0.55	7.85	4.24	4.92	3.25	3.19	3.98	2.10	0.50	0.55	34.99	
1916-20	No	Record												
1921[1]	0.93	1.08	0.14	1.98	3.81	2.09	7.19	3.30	0.01	0.44	0.00	0.18	21.15	+3.05
1922[1]	0.36	0.87	3.03	2.06	2.83	2.33	0.75	0.64	0.66	0.07	0.91	0.00	14.51	—3.59
1923[1]	0.00	0.20	0.92	1.88	4.77	4.87	1.72	1.43	3.10	4.97	0.95	1.05	25.86	+7.76
1924[1]	0.00	0.14	2.53	2.16	2.66	1.10	2.03	2.02	0.98	1.56	0.06	0.21	15.45	—2.65
1925[1]	0.06	0.38	0.02	1.72	1.67	2.83	4.87	3.18	3.57	0.60	1.30	0.00	20.20	+2.10
1926[1]	0.07	0.67	2.05	2.57	3.29	2.66	2.67	1.05	1.37	0.21	0.27	0.90	17.72	—0.38
1927[1]	0.00	0.64	0.51	1.62	0.20	2.50	4.45	8.06	1.18	0.27	0.00	0.02	19.45	+1.35
1928[1]	0.00	1.82	1.10	1.66	6.44	3.06	4.51	1.41	0.17	3.33	1.79	0.71	26.00	+7.90
1929[1]	0.40	0.47	1.97	0.09	3.72	1.70	4.79	2.94	0.90	1.84	1.87	0.00	20.69	+2.59
1930[1]	0.10	0.01	0.02	1.43	1.14	3.78	3.83	1.42	5.44	3.45	0.26	0.20	21.08	+2.98
1931[1]	0.00	1.53	1.70	2.00	2.55	2.38	4.70	2.56	1.13	0.77	0.64	1.10	21.06	+2.96
1932[1]	1.09	0.35	1.43	2.72	2.64	2.61	0.00	1.15	1.01	0.39	0.12	0.68	14.19	—3.91
1933[1]	0.00	0.51	0.12	1.84	3.97	0.30	0.36	5.41	0.15	1.38	2.31	0.41	16.76	—1.34
1934[1]	0.18	1.33	0.57	0.67	1.43	1.38	1.35	1.64	0.88	3.30	0.40	0.20	13.33	—4.77

TABLE II.

Climatic Data for Guymon, Texas County, Oklahoma (Cont.)
Monthly and annual precipitation (inches)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual departure from 17-Year Average 1921-1937
1935[1]	0.21	0.10	1.66	0.00	3.10	1.43	1.12	1.24	0.74	0.65	0.83	0.15	11.23	—6.87
1936[1]	0.40	0.00	0.00	0.44	8.46	0.87	0.72	0.22	3.46	0.45	0.35	0.60	15.97	—2.13
1937[1]	0.28	0.33	0.96	0.55	3.06	1.91	0.91	2.16	1.55	1.13	0.07	0.21	13.12	—4.98
Average precipitation	0.24	0.97	0.94	1.75	3.27	2.42	2.86	2.47	1.78	1.72	0.89	0.58	19.30	
Average annual precipitation for 17 years 1921-1937													18.10	

[1] From private and unofficial record of D. P. Bissell. Rain gage constructed according to standard specifications.
T—trace

TABLE III.

CLIMATIC DATA FOR HOOKER, TEXAS COUNTY, OKLAHOMA

Monthly and annual precipitation (inches) and average monthly and annual temperature (F°)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual departure from 31-year average
1906	......	......	......	......	......	1.40	4.91	3.00	4.15	3.66	1.50	0.63	....	....
1907	0.50	T	T	1.80	3.19	5.95	1.96	1.95	1.77	1.02	0.28	0.70	19.12	+0.90
1908	T	1.50	T	0.80	0.50	1.12	3.37	0.68	0.60	0.90	0.97	T	10.44	—7.78
1909	0.20	0.10	0.94	1.00	2.48	4.86	1.09	0.24	1.56	1.57	3.41	0.20	17.65	—0.57
1910	0.26	0.25	T	1.11	0.99	1.03	3.22	2.39	0.06	0.02	0.03	0.03	9.39	—8.83
1911	0.04	2.78	T	0.49	3.81	0.09	3.47	2.74	0.63	2.49	0.59	2.95	20.08	+1.86
1912	T	2.92	0.67	1.65	2.86	3.71	2.19	2.19	1.95	T	0.05	T	18.19	—0.03
1913	0.30	0.69	0.10	1.08	1.55	1.42	1.89	0.93	2.89	0.36	3.05	1.75	16.01	—2.21
1914	T	0.05	0.05	0.82	6.01	1.18	4.41	2.57	0.14	3.98	0.00	0.18	19.39	+1.17
1915	0.44	1.87	0.18	4.75	6.64	5.45	2.09	2.54	3.76	1.40	0.05	0.42	29.59	+11.37
1916	0.31	T	T	1.96	0.04	3.14	0.29	1.82	6.50	0.54	0.03	0.51	15.14	—3.08
1917	0.25	0.20	T	1.70	1.44	1.58	1.21	5.69	1.62	0.33	0.60	0.05	14.67	—3.55
1918	0.30	0.16	1.72	1.37	3.14	0.64	3.40	0.98	3.41	3.11	0.50	2.85	21.58	+3.36
1919	T	1.60	1.61	1.73	2.45	2.66	2.43	0.25	2.38	1.26	0.46	0.20	17.03	—1.19
1920	0.50	T	0.40	0.56	3.90	2.27	2.28	3.69	3.07	3.89	0.78	0.94	22.28	+4.06
1921	0.68	0.70	0.05	1.50	3.06	3.54	4.94	2.12	0.05	0.18	T	0.26	17.08	—1.14
1922	0.21	1.14	2.58	1.81	1.85	1.67	1.35	0.20	2.24	0.17	0.71	0.05	13.98	—4.24
1923	0.00	0.25	0.39	1.31	5.33	3.99	2.19	2.14	3.23	6.39	0.88	0.45	26.55	+12.57
1924	0.15	0.35	2.40	1.48	1.05	1.29	2.95	2.45	0.81	1.01	0.18	0.35	14.47	—3.75
1925	0.15	0.13	0.12	3.57	0.79	1.86	2.54	2.20	3.58	0.57	1.23	T	16.74	—1.48
1926	0.02	0.55	1.34	2.06	3.01	3.17	1.60	1.94	1.89	0.09	0.18	0.85	16.70	—1.52

TABLE III.

CLIMATIC DATA FOR HOOKER, TEXAS COUNTY, OKLAHOMA (CONT.)

Monthly and annual precipitation (inches) and average monthly and annual temperature (F°)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Annual departure from 31-year average
1927	T	0.50	0.65	1.60	0.37	0.98	4.14	5.67	0.89	0.27	0.09	T	15.16	—3.06
1928	T	2.53	0.61	1.53	6.37	2.00	1.77	2.59	1.04	3.10	1.37	0.40	23.31	+5.09
1929	0.65	1.18	1.47	0.05	3.57	2.31	5.64	1.39	1.80	1.51	2.44	0.00	22.01	+3.79
1930	0.62	T	0.38	1.19	2.51	4.32	3.57	2.09	2.97	5.61	0.20	0.19	23.65	+5.43
1931	T	1.22	1.14	1.49	2.02	1.34	2.01	2.84	1.09	0.81	1.00	0.53	15.49	—2.73
1932	0.79	0.33	1.04	2.94	1.10	5.56	0.11	0.69	1.28	0.77	0.31	0.59	15.51	—2.71
1933	T	0.36	0.38	0.47	3.43	0.60	1.06	6.52	0.62	1.09	2.67	0.27	17.47	—0.75
1934	0.10	0.71	0.96	0.27	0.83	1.49	0.51	3.22	1.34	1.03	0.26	0.10	10.82	—7.40
1935	0.33	0.15	1.81	0.00	3.15	1.56	0.31	2.40	0.78	0.65	0.91	0.11	12.16	—6.08
1936	0.41	T	T	0.42	5.79	2.91	0.37	0.75	2.16	0.30	0.00	0.64	13.75	—4.47
1937	0.37	0.26	0.73	T	1.77	2.86	0.23	1.80	3.19	0.74	0.07	0.16	12.18	—6.04
Average precipitation	0.24	0.76	0.64	1.66	2.78	2.47	2.68	2.02	1.96	1.76	0.74	0.51	18.22	
Average annual snowfall													15.2	
Average temperature (degrees F)	32.8	37.1	45.1	54.6	63.4	74.2	78.5	77.4	70.2	56.9	44.2	33.6	55.7	

T—trace

Records of maximum and minimum daily relative humidity at Goodwell published by the Panhandle Experiment Station[24] for the years 1925-1931, inclusive, indicate a mean relative humidity of 61.16 per cent for the 7-year period. The following table summarizes the average daily maximum, average daily minimum, and average daily mean relative humidity by months.

TABLE IV.

RELATIVE HUMIDITY AT GOODWELL, 1925-1931 (inclusive)

	Average Maximum	Average Minimum	Average Mean		Average Maximum	Average Minimum	Average Mean
January	88.66	39.75	64.21	August	87.33	36.59	61.95
February	88.72	35.97	62.34	September	80.61	36.24	58.50
March	84.11	36.08	59.63	October	81.90	36.42	59.16
April	81.91	33.59	57.76	November	88.70	41.04	64.87
May	86.75	37.42	62.08	December	89.61	39.47	64.54
June	85.51	36.18	60.84	Annual	85.56	36.84	61.16
July	82.73	33.33	58.02				

The experiment station has also kept a record of evaporation of water in inches from a sunken tank 6 feet in diameter, in which the water was level with the land surface or lower. Evaporation from a water surface is greater than that from the soil, but the results suggest the amount of water that may be lost from open irrigation ditches or storage reservoirs. Results for the 7 year period 1925-31, inclusive, show that the average evaporation per day ranged from 0.0507 inch for December to 0.3244 inch for June.[25] The table below compares the annual evaporation with the annual precipitation.

TABLE V.

TOTAL ANNUAL EVAPORATION AND PRECIPITATION, 1925-31

Year	Evaporation (inches)	Precipitation (inches)
1925	70.8	15.93
1926	61.8	17.28
1927	70.5	16.34
1928	63.8	24.30
1929	63.3	18.67
1930	67.8	18.53
1931	63.2	16.18

24. Finnell, H. H. "Agricultural Significance of Climatic Features at Goodwell, Oklahoma": *Panhandle Agricultural Exp. Sta. The Panhandle Bulletin*, No. 40, pp. 37-38, 1929.
25. *Idem*, p. 40.

Prevailing winds are from the south and southwest. North winds are frequent, however, and during the winter months the wind blows from the north, northeast, or northwest about as much as it blows from the south, southeast, or southwest. Wind velocities are frequently high. The Panhandle Experiment Station has maintained a record of wind velocities at crop level, or 2.5 feet above the land surface, since 1925. Daily wind velocities averaged by months ranged from 6.3 miles per hour for August to 9.7 miles per hour for March, during the 7-year period 1925-31 inclusive, and the average annual wind velocity for this period was 7.9 miles per hour.[26] As there are many days when there is little or no wind, it is obvious that the wind velocity is very high at other times.

ECONOMIC DEVELOPMENT

Agriculture. Cattle raising was the principal industry in Texas County when settlement began. At first it was confined to lands along the permanent streams and the adjacent uplands, but soon it was found that the more remote uplands could also be grazed if deep wells were drilled to supply stock water.[27] Large ranches were established, but after a time they began to give way to wheat farms, and in recent years cattle raising on a large scale again has been confined largely to stream valleys and the adjacent breaks. Formerly most of the wheat growers maintained small herds of cattle, but they were forced to sell because of lack of pasture and forage, resulting from the drought of 1931-37. In 1936 about 63 percent of the land in use was devoted to crops, and about 37 percent to grazing.[28] The present importance of cattle is considered by Mr. Hyer, the county agricultural agent, to be much less than that of crops, but he expects it to increase materially as the pastures improve. There are now at least two large ranches in the county. The Anchor D. (Stonebraker-Zea) ranch extends from highway 64 north of Guymon, upstream along Beaver River for many miles, and embraces about 75,000

26. *Idem*, p. 25.
27. Fitzpatrick, E. G. and Boatright, W. C., "Soil Survey of Texas County, Oklahoma": *U. S. Dept. Agri. Bur. Chem. and Soils, Ser.* 1930, No. 28, pp. 6-7.
28. Land use survey, 1936. Information supplied by H. C. Hyer, County Agricultural Agent.

acres. In 1937 the owners of the ranch leased it to operators who grazed the lands carefully and systematically by moving small herds frequently and transferring them occasionally to another ranch. The Easterwood ranch extends from the Eva-Elkhart road for about 30 miles downstream along Goff Creek, and totals 40,000 to 45,000 acres. According to reports only about 50 head of cattle were maintained on it in 1937, pending improvement in pastures.

Until recent years wheat was the principal cash crop and ranked first in importance because it could be produced at a very low cost. In 1920 the county led the United States with an average yield of 22.5 bushels of wheat per acre, and the quality of the wheat has won first place in the International Wheat Exposition.[29] The soils on the upland flats range from sandy loam to silt loam, and with sufficient moisture are capable of high yields. Under present conditions, the row crops, including milo maize, kafir corn, hegari, and others, account for the larger part of both acreage and bushels of yield. Vegetables and fruits are largely restricted to small gardens watered from windmills and to a few fields of somewhat larger size on the flood plains, where ground water is close to the surface. The flood plains also yield good crops of hay, and can produce several crops of alfalfa each year, either by natural sub-irrigation in favorable places, or by artificial irrigation. The following list shows the use to which the cultivated land in the county was put in 1936.[30]

CROP DISTRIBUTION IN TEXAS COUNTY IN 1936

	Per cent
Small grains	7.4
Hay	.6
Row Crop	33.5
Idle	3.7
Fallow	54.7
All other	.1
TOTAL	100.0

The original homesteads were 160 acres[31], and the prevailing unit of measurement is still the quarter-section, but the size of

29. Gould, C. N., and Lonsdale, J. T., "Geology of Texas County, Oklahoma": *Okla. Geol. Survey Bull.* 37, p. 62, 1926.
30. Land use survey, *op. cit.*, 1936.
31. Fitzpatrick, E. G., and Boatright, W. C., *Op. cit.* p. 7.

the farms has been increased through purchase of the original homesteads until more than four-fifths of them are larger than 160 acres. The uncertain crop yield from year to year, and to a lesser extent, from place to place in a given year, has been largely responsible for the increase in the size of farm units. Another factor has been the flatness of the plains, which favors economical operation of large acreages by the use of tractors. Two partners are reported to have farmed 18 "quarters"—4.5 square miles, or about 2,800 acres—and one man is reported to have farmed 32 "quarters", or about 5,100 acres, in 1937. However, cultivated farm units larger than 640 acres are exceptional. The Land Use Survey[32] in 1936 found that 22 percent of the farms were between 240 and 400 acres; 41 percent were less than 400 acres; 58 percent were less than 640 acres; and 72 percent were less than 720 acres.

Mineral Resources. According to well logs filed with the Oklahoma Corporation Commission, 31 wells had been drilled in search of gas or oil in Texas County by the end of 1938. Six were reported as dry holes, and 18 showed initial production of gas ranging from 3,600,000 to 49,903,000 cubic feet per day, from depths ranging from 2,525 to 2,898 feet. Table VI gives the initial production of all gas test wells for which records are available. Some of the gas is sold in outside areas, some is used locally in Texas County towns, and some is used by farmers living along a gas pipe line north of Beaver River between Guymon and Optima. Late in 1937 work was begun on a plant to use natural gas in the manufacture of carbon black, at a site 1.5 miles northeast of Guymon. Many look to gas as a cheap source of power for pumping water from wells for irrigation. As yet there are no producing oil wells in the county.

Other mineral resources are distinctly limited and are little[33] used. Caliche is widely used as a road material, and formerly was burned to produce lime plaster for local use. Some of the sandy varieties, which closely approximate sandstone, were used for fence material and for dwellings in the early days, but are

32. Land Use Suvey. *Op. cit.*
33. Gould, C. N., and Lonsdale, J. T., "Geology of Texas County, Oklahoma": *Okla. Geol. Survey Bull.* 37, pp. 38-39, 1926.

not being quarried at present. A good grade of rock wool has been made experimentally from caliche.[34] (See chemical analyses table XI, page 81). Sand and gravel for use in concrete can be obtained from the streams. There are small deposits of gypsum in the southeastern corner of the county, but these have not been utilized.

34. Wood, F. C. "Rock Wood Possibilities in Oklahoma"; *Okla. Geol. Survey.* Bull. 60, 1939.

TABLE VI.

LIST OF GAS TEST WELLS DRILLED IN TEXAS COUNTY
(From logs in files of Oklahoma Corporation Commission)

Name of Farm	Name of Company	Location Sec.	T.	R.	Date of Completion	Total Depth (Feet)	Initial Production (Cubic Feet)
E. F. Allison	Washoma Petroleum Co.	SE¼ 4	1	12	4- 7-27	4071	Dry
Allison	Home Development Co.	SW¼ 4	1	12	12- 3-22	3040	25,000,000-30,000,000 (Wet gas)
Becker	Hagy, Harrington, & Marsh	NE¼ 4	1	13	11-11-37	3010	8,300,000
Peek	Hagy, Harrington, & Marsh	NE¼ 6	1	13	4- 2-38	2896	2,750,000
Kugle	Reiter-Foster Oil Corp.	NE¼ 10	2	11	12-17-26	3503	Dry
Wiggins (No. 1)	A. J. Hardendorf et al	NW¼ 1	2	14	3-13-38	2763	17,600,000
Wiggins (No. 2)	A. J. Hardendorf et al	NE¼ 2	2	14	4-24-38	2742	37,544,000
Gailey	Barnhill, Allison & Sturdevant	NW¼ 30	2	18	1- 5-37	2919	8,000,000
Stonebraker-Zea Live Stock Co.	M. M. Valerius	SW¼ 18	3	12	12-18-26	4000	Dry
E. W. Zea	H. F. Wilcox Oil & Gas Co.	SE¼ 28	3	13	3-17-27	4025	Dry
Safranko	Cimarron Utilities Co.	SE¼ 1	3	14	8-19-31	2725	22,208,000
Jackson Bros.	Cabot Carbon Co.	NW¼ 7	3	15	8- 6-35	2625	49,903,000
F. C. Mathews	Cabot Carbon Co.	SW¼ 8	3	15	12- 3-35	2740	4,300,000
Hurliman	Reiter-Foster Oil Corp.	SW¼ 9	3	15	11-25-26	3502	Dry
L. Bacon	Texas County Gas Co.	NE¼ 17	3	15	3-12-28	2650	6,750.000
A. Calvert	Cabot Carbon Co.	Cent. 14	3	16	4-19-37	2649	4,875,000
M. F. Casto	Cabot Carbon Co.	SE¼ 19	3	17	4- 2-37	2722	3,600,000

TABLE VI.

LIST OF GAS TEST WELLS DRILLED IN TEXAS COUNTY (Continued)
(From logs in files of Oklahoma Corporation Commission)

Name of Farm	Name of Company	Location Sec.	T.	R.	Date of Completion	Total Depth (Feet)	Initial Production (Cubic Feet)
Gabel et al	Western Production	NE¼ 24	4	13	6-25-31	2860	8,993,000
Geo. S. Hovey	H. F. Wilcox Oil & Gas Co.	SE¼ 21	4	14	11- 3-26	4411	3,000,000
....	M. M. Valerius	SE¼ 32	5	12	11- 1-26	4000	Dry
Kenny	Argus Production Co.	SW¼ 36	5	14	9-22-30	2886	4,941,000
F. L. Fitzgerald	Republic Natural Gas Co.	Cent. 17	6	14	5- 9-37	2840	7,014,000
Alice G. Clinkingboard	Republic Natural Gas Co.	SW¼ 21	6	14	10- 7-38	2848	14,800,000
Ina B. Thrall	Missouri Valley Gas Corp.	SE¼ 22	6	14	10-21-38	2875	9,400,000
W. A. Ralstin	Argus Production Co.	SW¼ 23	6	14	5-27-30	2915	4,162,320
J. W. Bunger	Republic Natural Gas Co.	SE¼ 13	6	15	10-24-38	2855	18,506,000
L. G. Blackmer	Missouri Valley Gas Corp.	NE¼ 15	6	15	10- 3-38	2841	20,800,000
Parker	Argus Production Co.	NW¼ 18	6	15	8-22-30	2831	2,724,480
A. N. Dulabahn	Missouri Valley Gas Corp.	SE¼ 21	6	15	11- 3-38	2842	12,970,000
F. A. Judd	Republic Natural Gas Co.	SW¼ 24	6	15	10-25-38	2871	17,265,000
J. C. Michael	Missouri Valley Gas Corp.	NW¼ 29	6	15	11-20-38	2840	8,725,000
J. O. Ferguson	Missouri Valley Gas Corp.	Cent. 23	6	16	10-26-38	2833	12,500,000

Population. The population of the county in 1930 was 14,100. Guymon, the county seat, located near the center of the county, had a population of 2,181, being the largest town in the Oklahoma Panhandle. Hooker, the second largest town in the Panhandle, is located 20 miles northeast of Guymon, and had a population of 1,628 in 1930. Both probably owe their relatively large size and importance to the fact that they are located on the main line of the Chicago, Rock Island, and Pacific Railroad from Kansas City to El Paso, which for many years was the only through railroad crossing the Panhandle. Goodwell, population 501 in 1930, is located 10 miles southwest of Guymon, and is the site of the Panhandle Agricultural and Mechanical College. Other towns and post offices are Texhoma (819), Optima (115), Tyrone (482), Hardesty, Adams, Bakersburg, and Eva. Mouser and Hough are stations on the Beaver, Meade and Engelwood (Missouri-Kansas-Texas) Railroad and function as grain shipping points and supply depots for gasoline and tractor fuels, but do not have post offices. Several post offices and towns formerly scattered about the county, are now abandoned because of shifting of population and easier communication as roads improved and the use of automobiles increased. These include Grand Valley, Range, Pony Creek, Fernwood, Red Point, Weitz, Barden, Camp, Postle, Kuhn, Shelton, Cosmos, Carthage, Ona, James, and Rice. These names appear on old maps of the county and state and on some highway maps, many survive as names of country schools, and some are still in use to designate localities, although the towns are completely gone.

GENERAL GEOLOGY

STRATIGRAPHIC SUMMARY

The exposed rocks are all of sedimentary origin, and range from Carboniferous to Recent in age. Outcrops of the formations are shown on Plate I. The older rocks are generally red shales and clays with minor sandstones, and some gypsum, and are both marine and non-marine in origin. The Ogallala formation, of Pliocene (Tertiary) age, consisting of light-colored, highly calcareous sands, gravels, and clays, is the surface formation in most

TABLE VII.

Geologic Formations Exposed in Texas County

System	Series	Formation	Thickness (Feet)	Lithology and Water-bearing Properties
QUATERNARY		Dune Sand	0-25?	Sand. Sand dunes absorb much of the rainfall and are areas favorable to recharge of the ground water reservoir, but are above the water table and do not supply water directly to wells.
		Alluvium	0-100?	Sand, silt, and gravel on flood plains. Coarser portions yield adequate supplies of water to shallow domestic wells. Water is of good quality except along Paloduro Creek and its tributaries. Supplies a small amount of water to scattered irrigation wells.
TERTIARY	PLIOCENE	Ogallala	150-500+	Calcareous sands, gravels, silts, and clays, in general but slightly consolidated. Principal aquifer. Furnishes adequate supplies of water of good quality to domestic, stock, and municipal wells, generally from depths greater than 100 feet. Sands and gravels probably would supply sufficient water to wells for irrigation in parts of the county.
		Unconformity		Irregular erosion surface on older rocks.
CRETACEOUS	LOWER CRETACEOUS	Purgatoire Kiowa (?) shale member	10	Brownish-gray shale containing an abundance of well-preserved *Gryphea corrugata*, exposed in a slump or fault block. Gryphea and some shale mixed with gravels at base of Ogallala. 5 feet.
				Red shales and thin-bedded white sandstone overlying Cheyenne sandstone. 5 feet.
		Cheyenne sandstone member	5	Soft, white to yellowish-brown, friable, ferruginous sandstone. Contains numerous casts of Lower Cretaceous pelecypods. Crops out as ledges in two localities and as outliers on Jurassic (?) red beds.
				Not known to yield water to wells in Texas County.

TABLE VII, Continued

Geologic Formations Exposed in Texas County

System	Series	Formation	Thickness (Feet)	Lithology and Water-bearing Properties
JURASSIC (?)		Jurassic (?)	30-70	Upper red shale containing some thin-bedded, rusty-brown sandstone. 18 to 20 feet.
				Sandstone-conglomerate, white to light gray, friable, massive, cross-bedded, fine to coarse grained. Pebbles of shale and dolomitic limestone. 10 to 50 feet.
				None of these beds are known to yield water to wells. Exposures are too small and too much dissected to furnish favorable intake area.
		Unconformity		Irregular erosion surface and angular unconformity.
TRIASSIC (?)		Triassic (?)	20-75	Red, yellow and gray clays, with interbedded soft, red and gray sandstones. Furnishes small supplies of water to a few stock and domestic wells. The water may be more or less mineralized.
CARBONIFEROUS	PERMIAN	Cloud Chief	75	Red clay or shale with minor beds of sandstone and gypsum. Yields small supplies of highly mineralized water from the sandstones and from joints in the clay.

parts of the county. These beds were deposited on land by streams, and are the principal sources of ground water. The older rocks are relatively impervious, are generally too deep for economical pumping, and contain soluble minerals which make the water undesirable. At or near the surface in most of the area there is a considerable thickness of caliche (locally called "gyp"), a white, limy material varying from very sandy and somewhat porous to very dense, hard, nearly pure limestone. Beds of the harder and more resistant type of caliche are responsible for the cliff that appears at the top of the valley bluffs, and in places two or more beds are present. The alluvial deposits of the flood plains and the sands of the dune areas have been derived largely from the Ogallala formation.

Table VII lists the geologic formations and summarizes their characteristics.

STRUCTURAL GEOLOGY

Texas County is in the western Oklahoma-Dodge City basin.[35] Meager subsurface evidence on key beds in the Pennsylvanian and Permian rocks indicates a gentle east dip, as shown by Six[36] for the Panhandle counties, by Green[37] for western Oklahoma, and by Dott[38] for the "Lansing Lime" of petroleum geologists, in Hamilton, and Finney and Seward Counties, Kansas. Mull[39] reports that formations below the Blaine, at least, dip eastward in Texas County from sec. 21, T. 6 N., R. 14 E., to sec. 23, T. 6 N., R. 16 E., at a rate of 18 feet per mile. This general east dip is also indicated by surface exposures of Lower Cretaceous sandstones and the underlying red beds at the Red Point locality in central Texas County, which are about 850 feet lower than exposures of corresponding rocks 50 miles to the northwest in Cimarron County.

The inliers of Triassic (?), Jurassic (?), and Cretaceous rocks at Red Point and farther west along Tepee Creek suggest a local fold of some magnitude, or possibly a hill on the pre-Tertiary erosion surface, or both. An apparent thickening of the Ogallala deposits both to the north and to the south helps substantiate both explanations, but proves neither. A study of the logs of gas test wells suggests that key beds in the Permian dip away from the Red Point locality and supports the suggestion that this red bed high is at least partly due to structural uplift.

The Ogallala formation was deposited on the uneven floor of older rocks, and appears to have been little disturbed. Where the beds are exposed in the banks of the streams they are seen to dip at low angles which probably are very nearly the angle of slope of the surface on which they were deposited. Locally, however, both the red beds and the overlying Ogallala have moderate to steep dips, of which the following are examples:

35. See *The Oil Weekly*, May 14, 1934, and February 11, 1935, map supplements.
36. Six, R. L., "Oil and Gas in Oklahoma; Beaver, Texas, and Cimarron Counties": *Okla. Geol. Survey Bull.* 40-WW, 1930, p. 12 and cross section.
37. Greene, Frank C., unpublished manuscript cross section.
38. Dott, R. H., "Kansas' Future Crude Oil Reserve Status": *The Oil Weekly*, Feb. 11, 1935.
39. Mull, J. O., personal communication to State Geologist R. H. Dott.

Eight miles west and three miles north of Guymon, in the NW¼ NW¼ sec. 23, T. 3 N., R. 13 E., red beds thought to be of Triassic age are exposed in the bank of a creek, and are arched in a structure whose exposed width is about 190 feet. A maximum dip of 14° NW was measured in beds at the northwestern end of the exposure, and the suggestion of a southwest dip was noted at the other end. About a tenth of a mile to the northwest, beds exposed in a road cut dip 17° NE and indicate that the structure is very small.

On South Fork, in secs. 25 and 26, T. 3 N., R. 14 E., there are small, closely-spaced exposures of the Ogallala formation which strike N. 62° E. to N. 39° W., and show dips ranging from 6° SE. to 39° NE. Most of the materials in these exposures are evenly bedded clays which should have been deposited in a horizontal position in quiet waters, hence cross-bedding or torrential bedding is not a probable explanation of the observed dips. Farther upstream in the northern part of sec. 1, T. 2 N., R. 14 E., similar beds exposed in the creek channel indicate a dome measuring but a few feet across.

Other small scale structures have been noted in the Dakota sandstone of Cimarron County, north of Boise City[40], and seem best explained by slumping of the rocks after removal of underlying gypsum or salt by solution, in the manner suggested by Clifton.[41] It will be recalled that the many depressions which dot the upland surface may also be due to solution and slumping in the subsurface rocks, and it is therefore probable that the rocks are actually more disturbed than surface exposures indicate.

No major faults are known to cross Texas County. Two small faults were discovered on the south side of Beaver River at the red bed inlier west of Guymon, in sec. 26, T. 3 N., R. 13 E. One of them is exposed in the bank of the river and brings

40. Stovall, J. W., Oral communication.
41. Clifton, R. L., "Permian Structure and Stratigraphy of Northwestern Oklahoma and Adjacent Areas": *Bull. Amer. Assoc. Petr. Geol.*, Vol. 14, pp. 161-173, 1930.

Jurassic (?) sandstone against Triassic (?) red shales. It has a minimum throw estimated at 20 feet, and is thought to strike about north-south. The other and less well exposed fault appears to displace the Jurassic (?) rocks. Another small fault was seen in the bed of a creek in sec. 14, T. 3 N., R. 13 E., and may account in part for a block of Kiowa (?) shale that is exposed nearby.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Paleozoic Rocks

CARBONIFEROUS SYSTEM

Permian Series

CLOUD CHIEF FORMATION

Character. The oldest rocks exposed in the county are red beds belonging to the Cloud Chief formation. They consist mainly of red shale or clay, with minor amounts of gray and green clay, buff to brown sandstones, and a little gypsum. Some shales are sandy or silty. Sandstones are neither thick nor conspicuous except east of former Range Post Office. In sec. 17, T. 1 N., R. 19 E., Gould and Lonsdale[42] found 8 feet of very fine-grained, buff to brown sandstone containing small, concretionary, dendritic-shaped aggregates thought to consist of manganese oxide, and larger rounded concretions of iron oxide. The same authors report gypsum in a 3-foot bed about a mile east of Paloduro Creek in secs. 13 and 24, T. 1 N., R. 19 E. An exposure with about 14.5 feet of gypsum was measured by the writer as follows:

Section on Chiquita Creek, Sec. 3, T. 1 N., R. 19 E.

		Feet
7.	Gypsum, massive bedded, showing wavy bands of red, and streaks giving marbled effect	9.6
6.	Highly gypsiferous red shale. Gypsum occurs (a) as thin flakes or sheets a few millimeters thick, bedded with the shale; (b) inclined sheets, 0.5 inch or more thick, some apparently originating in the layer below	3.6
5.	Gypsum, variable in thickness, more or less shaly	0.5
4.	Shale, like (2), but inclined gypsum sheets are more numerous and reach 0.5 inch thick. A lens in gypsum; observed length, 35 feet	0.6
3.	Gypsum, white, irregular, somewhat shaly	0.8
2.	Shale, red gypsiferous. Inclined sheets of gypsum 1-16 to 1-8 inch thick	1.8
1.	Gypsum, white irregularly bedded, much jointed	3.7
	Total	20.6

42. Gould, C. N., and Lonsdale, J. T., *Op. cit.* pp. 23-24.

Nomenclature and age. The name Cloud Chief formation is here retained for these beds in keeping with previous reports on the area, although there is some uncertainty as to details of classification. Thus, Clifton[43] finds that the Cloud Chief as defined by Gould represents a group of more or less continuous stratigraphic units, and suggests introduction of a new name for the beds from the base of the Day Creek dolomite up to the base of the Quartermaster formation. On the other hand, Evans[44] makes the Cloud Chief the uppermost member of the Whitehorse sandstone because "the base of the Cloud Chief horizon occurs near the middle of the Whitehorse sandstone as originally described by Gould."

The Cloud Chief formation is of Permian age, and exposures in Texas County are correlated with areas of better known Permian rocks farther east on the basis of tracing almost continuously across Beaver County[45] and on the lithologic character of the rocks. Arguments to show that the Permian-Triassic contact is an unconformity at the base of the Whitehorse sandstone, and therefore that the Whitehorse, Cloud Chief, and younger rocks are Triassic rather than Permian, have been presented by Roth[46], but have been refuted by Anderson.[47]

Distribution. The formation crops out in the southeastern part of the county along Paloduro Creek and its tributary Chiquita Creek, and extends a short distance up Hackberry Creek. On Plate I, the mapping by Gould and Lonsdale has been followed in general, but some changes based on observations by the writer and on the Texas County soil map[48] have been introduced. The Vernon very fine sand loam and the undifferentiated Vernon

43. Clifton, R. L., "Permian Structure and Stratigraphy of Northwestern Oklahoma and Adjacent Areas": *Amer. Assoc. Petro. Geol. Bull.* 14, p. 172, 1930.
44. Evans, Noel, "Stratigraphy of Permian Red Beds of Northwestern Oklahoma": *Amer. Assoc. Petro. Geol. Bull.* 15, p. 420, 1931.
45. Gould, C. N., and Lonsdale, J. T., *Op. cit.*, p. 25.
Gould, C. N., and Lonsdale, J. T., "Geology of Beaver County, Oklahoma": *Okla. Geol. Survey Bull.* 38, pp. 19, 21, 1926.
46. Roth, Robert, "Evidence Indicating the Limits of Triassic in Kansas, Oklahoma, and Texas": *Jour. Geol. vol.* 40, pp. 688-725, 1932.
47 Anderson, G. E., "The Permian-Triassic Problem in Western Oklahoma": *Jour. Geol. vol.* 41, pp. 834-839, 1933.
48 Fitzpatrick, E. G., and Boatright, W. C., *Op. cit.*, Map.

soils ("eroded phase") doubtless are derived from the Cloud Chief.

Thickness. The maximum exposed thickness of the formation east of Paloduro Creek is reported by Gould and Lonsdale[49] as 70 feet. The writer measured 75 feet of red shales and fine-grained sandstones south of Hackberry Creek, in the N½ sec. 10, T. 1 N., R. 18 E. In a summary of the rock formations of Oklahoma, Gould[50] assigns a thickness of 115 feet to the Cloud Chief. However, in Beaver County[51] there may be 140 feet, and Evans[52] says the formation is 150 feet thick northwest of Woodward, Oklahoma. In the Texas County outcrop, some of the upper part has been removed by erosion, but it is thought that enough remains concealed beneath the surface so that many of the wells east of Paloduro Creek probably do not reach into formations older than the Cloud Chief.

WATER SUPPLY

Well drillers who have worked in the area east of Paloduro Creek report that water is obtained in "joint clay"—probably the Cloud Chief, though possibly lower red bed formations. The clay or shale itself is so fine-grained, and the spaces between the mineral grains are so small, that water can not pass freely through it. Therefore practically all the water from it must come through joints. Although these beds appear to yield enough water for domestic wells, it is doubtful whether water passes through the joints fast enough and in large enough quantities to supply a large well, and any such well should be expected to draw the water level down many feet while pumping, thereby increasing the pumping lift and the cost of operation. The thicker sandstones probably yield larger quantities of water more freely than the clays or shales but afford only a limited supply because they are not widely exposed at the surface and so can not receive large amounts

49 Gould, C. N., and Lonsdale, J. T., "Geology of Texas County, Oklahoma": *Okla. Geol. Survey Bull.* 37, p. 23, 1936.
50. Gould, C. N., "Index to the Stratigraphy of Oklahoma": *Okla. Geol. Survey Bull.* 35, p. 95, 1925.
51. Gould, C. N., and Lonsdale, J. T., "Geology of Beaver County, Oklahoma": *Okla. Geol. Survey Bull.* 38, pp. 20-21, 1925.
52. Evans, Noel, *Op. cit.*, p. 423.

of water from rainfall. The sandstones are lenticular, and being more or less surrounded by shales, probably derive most of their water by slow seepage from the shales. Water in the Cloud Chief is rather highly mineralized, and reports of bad-tasting water are common in the area of its outcrop. Houghton[53] mentions the reported saltiness of water in the northeastern quarter of T. 1 N., R. 18 E., and calls attention to salt beds encountered in the so-called Three-Way test for oil and gas which was drilled in that locality. He attributes the saltiness of some nearby wells to an assumed salt dome, but it should be noted that the salt beds were encountered in the test well at 545 feet, 815 feet, and 1,435 feet—much deeper than most water wells. If the water is contaminated from salt beds at such depths, upward circulation of ground waters must be assumed. A more likely possibility is that there are thin salt beds at higher horizons which went unnoticed in drilling the test well.

Mesozoic Rocks

Rocks of pre-Ogallala age consisting of red beds and sandstones, crop out as inliers in several localities near the middle of Texas County. The largest and most interesting outcrop is about 5 miles long and 2 to 3 miles wide, in Beaver River valley west of Guymon, near the site of old Red Point post office. Other outcrops occur along Tepee Creek and its tributaries.

Most of the red beds and part of the sandstones are tentatively referred to the Triassic and Jurassic, respectively. Fossils of Washita (Lower Cretaceous) age identify one sandstone ledge and numerous slump blocks, as probably the Cheyenne sandstone member and a slump or fault block of gray and brownish shale as probably the Kiowa shale member of the Purgatoire formation. These latter have been found only in the Red Point area.

Gould[54] originally classed these beds as "Red Beds of Uncertain Relationship," and later[55] as Triassic (?), out of deference to

53. Houghton, H. W., "Water Survey of Texas County, Oklahoma": *Panhandle Agri. Exp. Sta. Bull.* 20, 1930.
54. Gould, Charles N., "Geology and Water Resources of Oklahoma": *U. S. Geol. Survey, Water Supply Paper* 148, Pl. I, p. 73, 1905.
55. Gould, Charles N., "Index to the Stratigraphy of Oklahoma": *Okla. Geol. Survey Bull.* 35, p. 103, 1925.

the opinions of other geologists, but with the reservation that he was more inclined to consider them of Permian age.

The discovery by Clifton[56] of Lower Cretaceous invertebrate fossils in sandstones at the Red Point locality in 1925 proved the presence of at least remnants of Cretaceous rocks. Somewhat later, Bullard[57] studied the fossils from the sandstone, which he mapped as small outliers resting on the red beds of Triassic age.

No stratigraphic section of the rocks at the Red Point locality has been published heretofore, so in the autumn of 1938, Robert H. Dott, Director, Oklahoma Geological Survey, and the writer studied the area for the purpose of preparing such a section, and obtained evidence suggesting that Jurassic rocks may be represented in addition to Triassic and Cretaceous. The study of the area is not complete, and it is possible that some of the problems may never be completely solved, but it is considered desirable to present the available data and suggested interpretations in this report. All these rocks are shown on the geologic map (Plate I) as Triassic (?), because of the incomplete field data, and the tentative character of the conclusions, and because some of the outcrops are too small to be shown individually.

TRIASSIC (?) SYSTEM

Character. The Triassic (?) rocks consist chiefly of red shales and fine-grained buff, pink, red, and white sandstones, and minor beds of fine conglomerate in which most of the pebbles are gray or white clay. The red shales range from sandy to nearly free of grit, they break in small, angular fragments, and the bedding is generally obscure. In many places there are thin layers of white shale or fine sandstone bedded with them. Locally the white shale occurs as irregular blotches in the red, without evident relation to bedding planes. The following measured sections illustrate the lithology of the formation.

56. Clifton, R. L., Letter to C. N. Gould, 1925.
57. Bullard, Fred M., "Lower Cretaceous of Western Oklahoma": *Okla. Geol. Survey Bull.* 47, pp. 90-92, 1928.

SECTION ALONG CREEK IN SW¼ SEC. 19, AND NW¼ 30 T. 3 N., R. 14 E.

Triassic (?) red beds	Feet
19. Shale, gray, and yellowish-gray	1.0
18. Clay-shale, bright red, hard, breaks in small angular fragments	3.0
17. Sandstone, red, very fine, rather regular bedding in layers 0.5 inch to 1.25 inches thick	2.5
16. Shale, white, massive, silty	0.25
15. Conglomerate, with shale pebbles, red, white, and yellow (bedding at an angle with that of overlying shale)	0.85
14. Sandstone, white, very fine, weathers brownish-gray	0.3
13. Clay-shale, white	0.15
12. Clay-shale, yellowish-red, jointed, but otherwise without obvious structure	0.3
11. Clay-shale, mostly yellow, but some also red and white	4.0
10. Shale, soft, red, and very fine hard red sandstone	2.3
9. Shale, white	0.3
8. Clay-shale, mostly red, some white	1.0
7. Shale, red and yellow, hard, sandy	1.0
6. Shale, red and yellow, irregularly bedded	0.7
5. Shale, red and white, and irregularly blotched white; lens or pocket of white muscovitic clay-shale, 2.3 to 2.5 feet	5.0
4. Sandstone, massive, brown, medium-grained	2.1
3. Shale, massive, red, sandy, with thin white layers; some yellowish shale	3.5
2. Conglomerate, gray, with shale pebbles, mostly less than 1 inch in diameter; and coarse gray sandstone, grading laterally into white, thin-bedded, sandy, muscovitic shale	4.0
1. Shale, red and gray	1.3
Base not exposed. Total	33.55

SECTION ON SOUTH SIDE OF TRIBUTARY OF TEPEE CREEK NEAR W¼ COR. SEC. 8 T. 3 N., R. 12 E.

	Feet
3. Very fine red sandstone, with white spots and blotches, on the whole rather soft, but locally dense and fairly hard	6
2. Shale, sandy, red, with some white shale in layers and blotches. Within 25 feet laterally this bed becomes harder and somewhat coarser—i. e., fine, shaly sandstone	10-11
1. Shale, sandy, white	2.5-3.3
Total	18.5-20.3

Age. The age of these red beds is uncertain because no fossils of any kind have been found in them. They are stratigraphically the lowest, and therefore the oldest, of the rocks exposed at the Red Point locality, and appear to be separated from the next higher rocks by an angular and erosional unconformity (page 51). Unfortunately, the age of the rocks above the unconformity is also uncertain, but Cretaceous fossils have been found in still higher beds. Hence it is plausible that all the rocks of the area belong to Mesozoic systems rather than to the Paleozoic, and accordingly the tentative assignment of these lowest beds to

the Triassic is retained. Lithologically, the rocks resemble the Triassic rocks (Dockum) of northwestern Cimarron County.

Thickness. The total thickness of the Triassic (?) in Texas County is not known because the base does not seem to be exposed, and the Triassic (?) cannot be distinguished in well logs from red beds that occur above and below it. Measurements of the scattered exposures at the Red Point locality range from 20 to 75 feet, and it is possible that even the maximum figure does not account for all the Triassic (?) beds that crop out.

WATER SUPPLY

Few wells have been drilled on or near the Triassic (?) rocks, and it is not possible to say whether the few now in use draw water entirely from them or obtain part from higher and lower formations. Well number 294 is located near the NW cor. sec. 25, T. 3 N., R. 13 E., about a third of a mile east of Beaver River, and seems almost certainly to end in the Triassic (?). It is unused, and no sample of the water could be obtained.

Wells 287 and 288, described on pages 101-2, are located near an outcrop of the Triassic (?) on Tepee Creek, and according to the driller's report[58] entered red beds which may be Triassic (?) in part. Wells 403 and 412 also may draw more or less water from Triassic (?) rocks.

In general, the Triassic (?) rocks are too impermeable to permit ready movement of water through their pores. This is especially true of the shales, but applies also to the sandstones, which are thin, fine-grained and discontinuous, and many of them may not crop out in places where rainfall can seep into them.

Water analyses 287, 403 and 412 represent waters from the Triassic (?) or mixtures thereof, and are briefly discussed on page 94.

UNCONFORMITY

Triassic (?) red beds crop out in the bluff on the east side of Beaver River in the NW¼ NE¼ sec. 26, T. 3 N., R. 13 E., and

58. Freeman, Frank, oral and written communications.

extend to a height of 20 feet above the stream level. They strike N 53° E and dip 20° SE, and are overlain by sandstones that appear to be essentially horizontal. Thus there is evidence for an angular unconformity amounting to about 20° in dip.

At nearby points both upstream and downstream the horizontally overlying sandstone descends to stream level, suggesting relief on the surface of unconformity amounting to 20 feet or more.

This angular and erosional unconformity was not observed at other places, and in the absence of fossil evidence to indicate the age of the beds above and below it is not possible to state its true significance. The suggestion is offered that it marks the systemic boundary between the Triassic and the Jurassic.

JURASSIC (?) SYSTEM

Rocks that may be of Jurassic age occur above the Triassic (?) in the north half of sec. 26, T. 3 N., R. 13 E., are thought to be present at several places in the W½ sec. 14, T. 3 N., R. 13 E. and immediately adjacent parts of sec. 15, in the NW¼ sec. 28, and probably can be found elsewhere.

Character. The Jurassic (?) rocks can be subdivided into a lower sandstone-conglomerate unit and an upper red bed unit.

The sandstone is best exposed along the east side of Beaver River in the NE¼ sec. 26, T. 3 N., R. 13 E., where it attains a maximum known thickness of about 50 feet. It is white or light gray, massive, cross-bedded, micaceous, and varies from fine- to coarse-grained. Most of it is moderately well indurated, but locally it is so friable that it crumbles when struck with a hammer. There are included shale zones, some of which are red, and these shales contain thin-bedded, red and brown sandstones.

At the mouth of the small tributary which heads near the SE cor. sec. 26, T. 3 N., R. 13 E., this unit is nearly all sandstone, with only three or four thin conglomerate beds, but as it is traced northward along the river into the SE¼ sec. 23, the conglomerates thicken and become coarser, and in part are red. Similar coarse and thick sandstone-conglomerates that crop out

along a tributary of Beaver River in the W½ sec. 14, and on the north side of Beaver River near the middle of sec. 28, T. 3 N., R. 13 E., are thought to represent the same horizon.

Pebbles in these conglomerates consist of shale and dolomitic limestone. The thickness of this unit is variable, ranging from 10 to 50 feet. Part of this variation is probably due to the relief on the unconformity below.

The lithology of the overlying red bed unit is illustrated by the following two sections.

Section of Jurassic (?) Red Beds Measured in NE¼ NE¼ Sec. 26, T. 3 N., R. 13 E.

		Feet
4.	Shale, red, breaking in sharp-edged polygonal fragments, with some interbedded white layers	11.0
3.	Sandstone, fine-grained, thinly but irregularly bedded, rusty-reddish-brown in color, makes ledge	3.3
2.	Shale, white	0.4
1.	Shale, red, sandy with thin white layers	3.8
	Total	18.5

Section of Jurassic (?) Red Beds Measured Along Gulches Near Middle of N½ Sec. 26, T. 3 N., R. 13 E.

		Feet
11.	Conglomerate, white, fine	0.3
10.	Shale, red	4.0
9.	Covered	3.0
	(Moved 700 feet to NW around point of hill to west side of minor draw and continued section from beds considered to be numbers 7 and 8.)	
8.	Sandstone, fine-grained, thinly but irregularly bedded, rusty reddish brown (at fork in creek)	2.6
7.	Shale, white	0.1
6.	Shale, red	2.2
5.	Covered	2.0
4.	Sandstone, white, thin-bedded	2.0
3.	Covered	1.0
2.	Clay, yellow, overlain by thin-bedded, buff to gray sandstone	1.2
1.	Covered	1.0
	(Sandstone of underlying Jurassic (?) unit)	
	Total	19.4

Age. No fossils have been found in either the sandstone-conglomerate or the overlying red beds. These rocks underlie a sandstone from which lower Cretaceous fossils have been obtained, and overlie an unconformity which may mark the top of the Triassic.

In a measure, the sequence resembles part of the Jurassic of northwestern Cimarron County, as described by Stovall,[59] and observed by the writer. The thick sandstone unit is not unlike either the Exeter sandstone, nor some of the massive, light-colored sandstones in the Morrison formation, while the red beds unit is somewhat reminiscent of variegated shales in the Morrison. On the basis of these considerations, these two units of the Red Point section are tentatively referred to the Jurassic.

Thickness. As indicated by the sections that were measured, the combined thickness of the Jurassic (?) beds at Red Point, ranges from about 30 to 70 feet.

WATER SUPPLY

No wells are known to draw water from the Jurassic (?) rocks, and they are not regarded as important aquifers in Texas County. Part of the moderately-cemented sandstone in the lower unit is coarse enough and appears uniform enough to have a high permeability. It would yield water readily to wells, if it were widely enough exposed so that appreciable amounts of rainfall could enter it. In Texas County the Jurassic (?) crops out only in the exposures of the Red Point area, which are too small, and too severely cut up by erosion and faulting, to furnish a favorable intake area.

CRETACEOUS SYSTEM

PURGATOIRE FORMATION

Cheyenne Sandstone Member

In 1925 Clifton[60] discovered Cretaceous fossils in a sandstone at the Red Point locality, west of Guymon, and called the matter to Gould's attention. Later Bullard[61] mapped and described the small area where the fossils are found, and listed several species.

Character. As described by Bullard, the fossiliferous sandstone is soft, white to yellowish brown, contains lenses and layers of quartzite, and is about 5 feet thick. It weathers reddish be-

59. Stovall, J. Willis, "The Morrison of Oklahoma and Its Dinosaurs": *Jour. Geol. Vol.* 46, pp. 583-600, 1938; and unpublished notes.
60. Clifton, R. L., *Op. cit.*
61. Bullard, F. M., *Op. cit.*

cause of the oxidation of the iron in it. Much of it is very friable, but locally it is well indurated. It crops out in place on either side of the small creek in the northern part of sec. 30, T. 3 N., R. 14 E., and in the NE¼ NE¼ sec. 15, T. 3 N., R. 13 E. It also occurs more prominently as large angular blocks lying in various positions on top of long, narrow ridges. The ridge tops have similar altitudes, and evidently the blocks once formed a continuous bed, although they have been more or less let down by erosion.

Origin. The marine pelecypods found in this sandstone are conclusive evidence of marine origin. The fine- to medium-grained sand of which the sandstone is composed suggests deposition in moderately shallow water off shore, rather than on or near the beach, where wave activity is ordinarily greatest.

Age and fossils. The following fossils were reported by Bullard[62], who considered them to indicate Washita age (Lower Cretaceous), and suggested that the sandstone represents erosional remnants of a once continuous stratum, possibly the eastward extension of the Purgatoire formation of northwestern Cimarron County:

Oxytropidoceras belknapi Marcou
Trigonia sp.
Turritella sp.
Inoceramus sp.
Poorly preserved pelecypods similar to Cucullaea sp., and Tapes, sp.

Additional fossils from the sandstone were collected by the writer and were identified by T. W. Stanton, as follows:

Pteria salinensis White?
Inoceramus sp. Fragments of another (?) species
Yoldia microdonta Meek?
"Roudairia" quadrans Cragin, which appears to be really a Protocardia.

Concerning them, Dr. Stanton wrote: "In addition to the above there are several pelecypod casts probably belonging to the Veneridae that cannot be satisfactorily identified. The collections clearly belong to the Comanche fauna and represent a horizon near the base of the Washita."

The nearest exposures of Cretaceous rocks are in Morton

62. Bullard, F. M., *Op. cit.*, p. 90.

County, Kansas, but better ones are found in northwestern Cimarron County, Oklahoma, where the section contains, from the base upward: Purgatoire formation with two members, the Cheyenne sandstone, and the Kiowa shale; Dakota sandstone; and locally some higher beds which have been referred to the Graneros.[63]

No fossils have been found in the Cheyenne sandstone in Cimarron County, but the Kiowa shale carries a prolific Washita (Lower Cretaceous) fauna, and on this basis the two units were referred to the Purgatoire formation by Rothrock.[64] The fossiliferous sandstone of the Red Point area is very similar in age and lithology to the Cheyenne and its equivalence to that unit is highly probable.

WATER SUPPLY

The Cheyenne sandstone is porous enough to hold considerable water, coarse enough to yield it to wells, and consolidated enough so that a well probably would stand without being cased, but it probably is of little or no significance as a source of water. It may occur under the Ogallala formation to the west of the Red Point locality, but if the exposed parts are indicative it may be present only in isolated patches. Even if the patches increase in size and number until they become a continuous layer in western Texas County, the formation may still be so thin that no great quantity of water could be taken from a single well. No wells are known to draw water from this sandstone, but it is probable that in drilling it would not be distinguishable from sandstones in the Ogallala formation.

Kiowa (?) shale member

Red shales and thin-bedded white sandstones are exposed in the washed-out ruts of an old road on the east side of the creek in the northern part of sec. 30, T. 3 N., R. 14 E. They are stratigraphically above the Cheyenne sandstone, therefore at the horizon of the Kiowa shale, but the red bed lithology is not normal to

63. De Ford, R. K., "Areal Geology of Cimarron County, Oklahoma": *Bull. Amer. Assoc. Petro. Geol. Bull.*, Vol. XI, pp. 753-755, 1927.
Stovall, J. Willis, op. cit.
64. Rothrock, E. P., "Geology of Cimarron County, Oklahoma": *Okla. Geol. Survey Bull.* 34, p. 47, 1925.

the Kiowa. No fossils have been found in the post-Cheyenne beds at this point.

A large slump or fault block of gray and brownish-gray shale containing an abundance of very well-preserved *Gryphea corrugata*, was found on the east side of a creek near the center of the W½ sec. 14, T. 3 N., R. 14 E., in contact with Triassic (?) red shales.

The *Gryphea* and microscopic species found in a washed shale sample convinced R. W. Harris[65] of their Lower Cretaceous age, that they represent a basal Washita fauna, and are essentially contemporaneous with the species reported by Stanton[66] from the upper Purgatoire (Kiowa shale member) of northwestern Cimarron County. Because the lithology of the shale closely resembles the Kiowa of Cimarron County, and the age of the two faunas is so similar, this shale is considered a remnant of the Kiowa, with a query to indicate the tentative character of the correlation.

The materials tentatively assigned to the Kiowa are chiefly impermeable and probably supply little or no water to wells.

TERTIARY SYSTEM

Pliocene Series

OGALLALA FORMATION

Character. The Ogallala formation consists of a varied assortment of calcareous sands, gravels, silts, and clays, which almost everywhere are capped by a bed of caliche. These several lithologic types are arranged in many lenses and interpenetrating tongues, or fingers, and gradations from one kind of material to another take place within short distances, both vertically and horizontally. Two exposures separated by only a few hundred feet may show nearly identical materials, and perhaps in almost the same proportions, but their distribution into individual beds may be quite different. Figure 2 is a generalized cross section to illustrate the arrangement of beds within the formation and their relation to the water table and to water wells.

In exposures near Guymon, the sands are found to vary from

65. Harris, R. W., University of Oklahoma, Oral communication.
66. Stanton, T. W., quoted by Rothrock, E. P., *op. cit.*, p. 47.

fine- to coarse-grained, some of the coarser containing scattered pebbles and thin pebble zones. They are made up mostly of milky or colorless quartz grains, with some pink quartz, and dark, unidentifiable grains which are either dark-colored minerals or fragments of dark-colored igneous rock. Some grains are angular, but most are rather well rounded.

The gravels are similar to the sands except that the particles are pebbles rather than grains or granules. In a cliff-like exposure on South Fork in the SW¼ sec. 36, T. 3 N., R. 14 E., about 1 mile west of Guymon, a semi-consolidated gravel contains pebbles ranging from 1.5 to 3 inches in diameter, and varying from flat and slabby to well rounded. The pebbles are commonly brown or white, but some are yellow and black. Although pebbles of quartz and quartzite are common, probably the most abundant are sandstone, a fact suggesting that most of the grains in the Ogallala sands may have been derived from the break-down of older sandstones rather than directly from igneous or metamorphic rocks. The gravel at this locality is underlain by a white, limy bed, and down-stream from it, and at a lower elevation, clays are exposed in the bank of the creek, and the bottom of the channel is floored with an arenaceous type of caliche. The gravel is also exposed about a third of a mile upstream, where it makes a cliff beside the channel, and is capped by arenaceous caliche.

The silts and clays are the finer products of rock disintegration. They are generally calcareous and thin-bedded, and vary from gray, greenish, and drab to yellow, brown, and pinkish. Thin, white, limy layers are commonly interbedded with them.

Although the prevailing colors of the Ogallala are light grays, browns, and whites, there are places where the formation contains so much red material that it might be mistaken for the pre-Ogallala red beds. Close examination, however, shows that the beds are a paler red than the older red beds, and that the clays are crumbly and quite unlike the older red shales, which break in small, sharp-edged, polygonal fragments. One of the largest exposures of red Ogallala is in the SW¼ sec. 35, T. 3 N., R. 17 E., about 4.25 miles north of Hardesty on the road to Hooker. Here the red clays have been exposed by road cuts, and are evident,

though less obvious, to the east of the road along a tributary of Beaver River. The clays range from pale red to nearly brick red, are practically without silt or grit, and tend to break in massive chunks. They are overlain by fine- to coarse-grained, friable, highly calcareous sandstones, locally containing pebbles, which are undoubted Ogallala strata. On the whole, the red color is very strong for the Ogallala, but there is none of the gypsum that might be expected in Permian rocks and the reddest beds are lithologically unlike the red shales of the Mesozoic (?) rocks.

Other red clays crop out in the east side of a small creek in the S½ sec. 29, T. 3 N., R. 14 E., and along a dry tributary of the Beaver on the line between secs. 31 and 32, T. 3 N., R. 13 E., so near the main outcrop of the Mesozoic (?) red beds that they could easily be mistaken for them. However, the red color is not as strong as in the Mesozoic (?) shales. The Ogallala age of the red clays at the first of these localities is further shown by: (1) the clays crumble instead of breaking in sharp-edged fragments; (2) caliche overlies the clays directly, and may even be interbedded with them; (3) the analysis of the water from well 305, which is located a quarter of a mile to the north at a lower elevation on the opposite side of the creek, is typical of waters from the Ogallala formation, although the well should be entirely in the Mesozoic (?) if the red clays are really a part of the Mesozoic (?). At the second locality, supplementary evidence for the Ogallala age of the red beds is provided by the fact that, although most of the red material is shale or very fine sandstone, there are pebbles, cobbles, and angular rock fragments included as irregular beds, which suggest torrential deposition.

It is evident that such red clays encountered in the drilling of a well might be mistaken for Mesozoic (?) or Permian red beds, especially if the well were drilled by the rotary method, in which drilling mud would be mixed with the material from the bottom of the hole.

The following section showing Ogallala deposits and the caliche illustrates the formation as it is exposed at the surface.

SECTION NEAR GUYMON ON EAST SIDE OF SOUTH FORK, NW¼ SEC. 25, T. 3 N., R. 14 E.

		Feet
10.	Caliche, hard, dense, with little sand. Resembles fresh-water limestone	5.5
9.	Caliche, light brown on surface, but in part pale pinkish and white, very arenaceous, showing cross-bedding; pebbles, mostly less than 1 inch in diameter; weathering produces cavities	22.0
8.	Caliche, arenaceous, pale pinkish, tuff-like	8.0
7.	Sandstone, very fine, with white, nodular, calcareous layers	11.0
6.	Sandstone, fine, friable, white and brown, and clay beds and calcareous layers. In part, this unit is poorly exposed	11.0
5.	Clay and very fine sandstone, gray, iron-stained, chocolate-colored	3.0
4.	Sand, fine, light-brown, slightly consolidated, grading into clay of the same color	11.0
3.	Clay, chocolate	1.0
2.	Sand, fine, clayey, pinkish and yellow	2.0
1.	Clay, pinkish, chocolate, gray, yellowish; and inter-bedded fine, pink and yellow sand in beds up to 2 inches thick	2.5
	Total	77.0

The character of the Ogallala formation as it is revealed by well drilling is illustrated by the well logs, pages, 174-184. Most of the beds are described as "sand" or "clay", or as combinations of "sand and clay", or "sandy clay." The use of the term "sand" implies loose deposits, and indicates that the sands are but slightly consolidated even at depth. The few layers of "sand rock" reported in some logs probably are sands that have been more or less thoroughly cemented with calcium carbonate.

The logs of closely spaced wells suggest that the beds of sands and clay are irregularly distributed. At the experimental farm of the Panhandle Agricultural and Mechanical College at Goodwell, three test holes were drilled, and the one showing the greatest thickness of saturated sands, and the coarsest sands, was selected for development as an irrigation well. The four wells drilled for the Kansas City Light and Power Company at Elkhart, Kansas (logs K-1 to K-4), illustrate the variations which may be expected in closely spaced wells. Albert Hughey[67], a former well driller of Hardesty, reports that he found five or six water-bearing beds in some domestic wells, and but one in others. The log of the Hooker exploration well (page 180) specifically mentions seven water-bearing beds in the Ogallala, but the actual number of such beds may be considerably greater because of the tendency of drillers to group thin, alternating layers of unlike materials in large units. The drilling of this well was observed by I. C. Seawright[68], of Hooker, himself a well driller at the time, who reports that many water-bearing beds varying from 2 to 10 feet in thickness were encountered below the water table, and that the intervening impervious clays varied from 2 to 15 or 20 feet thick. These reports all show the variability of the Ogallala deposits, and harmonize with the conditions which should prevail in stream-laid sediments.

67. Hughey, A., Oral communication.

Origin. The Ogallala was deposited by shifting streams which obtained the rock debris from the mountains to the west. This manner of origin explains the extreme variability of the beds from one place to another. The origin of the High Plains, which is also the origin of the Tertiary rocks, and their subsequent history, has been summarized by Johnson[69] as follows: "The original smooth plain . . was alluvial, i.e., stream built. It was spread, in substantially its present position as to elevation and inclination, by widely shifting, heavily loaded, and depositing streams from the mountains. Shifting deposition, burial, and plain building constitute the normal habit of desert streams . . . Virtually the same mountain streams are at present cutting away and degrading where formerly they made broad fan-formed deposits and built up." According to Theis, Burleigh, and Waite[70] the structureless clays and silts appear to have been deposited by the wind.

Fossils, age, and nomenclature. The rocks here described under the name Ogallala have been designated simply as "late Tertiary" on previous geologic maps of Texas County.[71] The late Tertiary age of the formation has been verified by large collections of vertebrate remains taken from excavations in the county. About 2 miles southwest of Optima, from NW¼ sec. 7, T. 3 N., R. 16

68. Seawright, I. C., Oral communication.
69. Johnson, W. D., "The High Plains and Their Utilization": *U. S. Geol. Survey 22d Ann. Rpt.* Part IV. p. 638, 1900-1901.
70. Theis, C. V., Burleigh, H. P., and Waite, H. A., "Ground Water in the Southern High Plains": *U. S. Geol. Survey Memorandum for the Press.* p. 1, Oct. 1935.
71. Gould, C. N., and Lonsdale, J. T., "Geology of Texas County, Oklahoma": *Okla. Geol. Survey Bull.* 37, 1926.
Six, R. L., "Oil and Gas in Oklahoma: Beaver, Texas, and Cimarron Counties": *Okla. Geol. Survey Bull.* 40-WW, 1930.

E., State Wide Projects[72] in 1937 removed about 10,000 horse teeth and between 900 and 1,000 bones of various animals from several excavations located on a slope not many feet below the general level of the upland, and smaller collections were obtained in other parts of the county. A small pit in a nearly vertical clay bank about 10 feet above the channel of South Fork, in SE¼ sec. 25, T. 3 N., R. 14 E., a quarter of a mile west of Guymon, yielded the skull of a rhinoceras. According to the writer's observations, the fossils from the Optima and Guymon localities are all from the upper 100 feet of the formation. Stovall considers the fossils to be middle Pliocene in age.

The name Ogallala is adopted for these late Tertiary rocks in keeping with the present practice of the geological surveys of adjacent states[73], with the mapping of the same formation by Stovall[74] in adjacent Cimarron County, Oklahoma, and with the usage followed by Theis, Burleigh, and Waite[75] in their report on ground water in the Southern High Plains. However, it is emphasized that so far as the late Tertiary deposits of Texas County are concerned, the use of the name Ogallala is only tentative, because their exact relation to undoubted Ogallala beds remains to be demonstrated, and although the upper part may be true Ogallala, an unknown thickness in the lower part may represent older Tertiary formations.

Distribution. The Ogallala formation covers almost the entire county. It is thinly overlain by dune sand on the upland plains of the eastern and northern part of the county, and in the valley bottoms it either has been removed so that the Permian or the so-called Triassic red beds are exposed, or it is covered by alluvium. In other parts of the county, it is the surface rock.

Thickness. The thickness of the Ogallala ranges from a few feet to several hundred feet. Along the valleys some of it has

72. A Works Progress Administration project under the direction of J. W. Stovall, of the School of Geology, University of Oklahoma.
73. See geologic maps of Kansas (1937), Colorado (1935), New Mexico (1928), and Texas (1937).
74. Stovall, J. W. "The Morrison of Oklahoma and Its Dinosaurs": *Jour. Geol.* Vol. XLVI, pp. 583-600. 1938.
75. Theis, C. V., Burleigh, H. P., and Waite, H. A., "Ground Water in the Southern High Plains": *U. S. Geol. Survey. Mimeographed Memorandum,* Oct. 30, 1935.

been eroded away so that what remains under the alluvium may be relatively thin, and it is also thin on the interstream divides in the southeastern part of the county, where erosion has destroyed the original High Plains surface. In areas of uneroded upland plains the thickness may be from 100 to 500 feet or more. Besides differences in thickness that are due to erosion of the upper part of the formation, there are differences due to the irregularities on the old eroded surface of the underlying red beds.

In the logs of deep wells the top of the red beds may be taken as the base of the Ogallala formation, although it should not be forgotten that some red clays are included in the Ogallala itself (pages 58-59), and that Cretaceous sediments not containing red materials may possibly occur between the base of the Ogallala and the top of the true red beds. The following table shows the reported depth to the red beds in wells for which the logs appear more or less reliable, together with rough estimates of the original thickness of the Ogallala, including the caliche. The latter ordinarily is not distinguished as a separate unit in the well logs, and its thickness appears to vary enough so that deduction of an average amount for it is unsafe. Where wells are located in valleys, an estimate has been made of the thickness of the formation that has been removed, to permit construction of the thickness map (fig. 3). This map shows the thickness of the formation in different parts of the county by means of lines which pass through points where thicknesses are roughly equal. It is crude, and probably would look considerably different if more information were available, but it does indicate general trends. Thicknesses should be greatest along pre-Ogallala valleys, and the map suggests that two such valleys joined between Optima and Adams and left the county near Liberal, Kansas, where deep water wells have penetrated a great thickness of Tertiary deposits (see well log K-6, page 184). One of the valleys entered the county from the north near the middle of the northern boundary line, and the other entered from the south in the vicinity of Texhoma.

From the table and from the map it will be seen that the original thickness may have varied from less than 100 feet over

TABLE VIII.

List of Wells Drilled in Texas County Showing Depth to Red Beds

Name of Farm	Name of Company, etc.	Location Sec.	T.	R.	Depth to Red Beds (feet)	Elevation Above Sea Level of top of Red Beds	Amt. of Ogallala Eroded	Original Thickness of Ogallala	Remarks
E. F. Allison	Washoma Petroleum Co.	4	1	12	245	3091	....	245	
Allison	Home Development Co.	4	1	12	200	3090	45	245	
Becker	Hagy, Harrington & Marsh	4	1	13	385	3041	....	385	
Kugle	Reiter-Foster Oil Corp.	10	2	11	160	....	....	160	
Experimental Farm	P. A. & M. College	36	2	13	356	....	....	356	Log page 175
Wiggins	A. J. Hardendorf et al	1	2	14	205	2903	....	205	Cuttings examined by the writer.
Gailey	Barnhill, Allison & Sturdevant	30	2	18	280	2625	....	280	
Stonebraker-Zea Live Stock Co.	M. M. Valerius	18	3	12	69	3340	....	69	On upland ½ mi. N. of red bed exposures on Tepee Ck.
Jackson Bros.	Cabot Carbon Co.	7	3	15	250	2759	100	350	On bluff north of Beaver R.
F. C. Mathews	Cabot Carbon Co.	8	3	15	310	2744	10	320	On Beaver River flood plain.
Hurliman	Reiter-Foster Oil Corp.	9	3	15	260	....	100	360	In Beaver Valley.
Bacon	Texas County Gas Co.	17	3	15	195	2766	100	295	Less than 10 feet above Beaver River channel.
A. Calvert	Cabot Carbon Co.	14	3	16	360?	2506	100	460	
Casto	Cabot Carbon Co.	19	3	17	440	2445	....	440	
Buzzard	Water well 412	25	4	12	170	....	....	170	Log page 178
....	M. M. Valerius	32	5	12	320	....	....	320	
Kenny	Argus Production Co.	36	5	14	609	2594	....	610	
....	Hooker Exploration Well	34	5	17	570	2410	....	570	Log page 180
F. L. Fitzgerald	Republic Natural Gas Co.	17	6	14	615	2725	....	615	
Alice G. Clinkingboard	Republic Natural Gas Co.	21	6	14	611	2716	....	611	
Ina B. Thrall	Missouri Valley Gas Corp.	22	6	14	544	2739	....	544	
W. A. Ralstin	Argus Production Co.	23	6	14	568	2708	....	568	
J. W. Bunger	Republic Natural Gas Co.	13	6	15	615	2548	....	615	
L. G. Blackmer	Missouri Valley Gas Corp.	15	6	15	575	2630	....	575	
Parker	Argus Production Co.	18	6	15	545	2709	....	545	
A. N. Dulabahn	Missouri Valley Gas Corp.	21	6	15	552	2661	....	552	
F. A. Judd	Republic Natural Gas Co.	24	6	15	645	2527	....	645	
J. O. Ferguson	Missouri Valley Gas Corp.	23	6	16	675	2158	....	675	

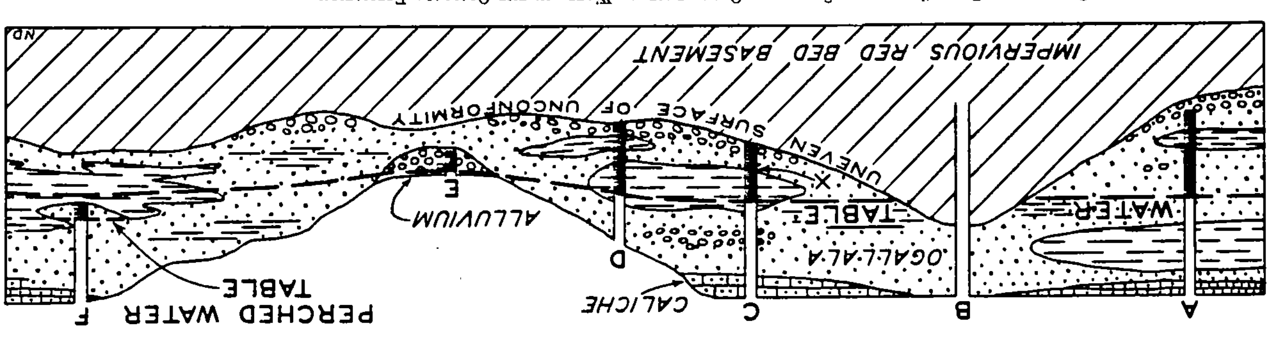


Fig. 2. Generalized Cross Section to Show the Occurrence of Water in the Ogallala Formation.

A. Well penetrates a considerable thickness of pervious, saturated sands and gravels, separated into two water-bearing zones by a lens of clay.

B. A hill on the uneven surface of the red bed basement rises above the water table, so that all of the Ogallala is dry. The well penetrates red beds without obtaining water, or perhaps obtains only mineralized water.

C. Well encounters a lens of impervious clay at the level of the water table. When pervious sands are entered at X, water fills the hole to the water table level.

D. Well encounters two clay lenses, and the driller reports two water-bearing beds. The total thickness of saturated materials is no greater than in well C.

E. Valley has been cut deeply into the Ogallala, drawing the water table down, and the stream has a permanent flow because it is fed from the underground reservoir. The well begins in valley fill (alluvium) practically at the water table, and obtains a good supply of water at slight depth.

F. Well encounters a small supply of water in a perched reservoir.

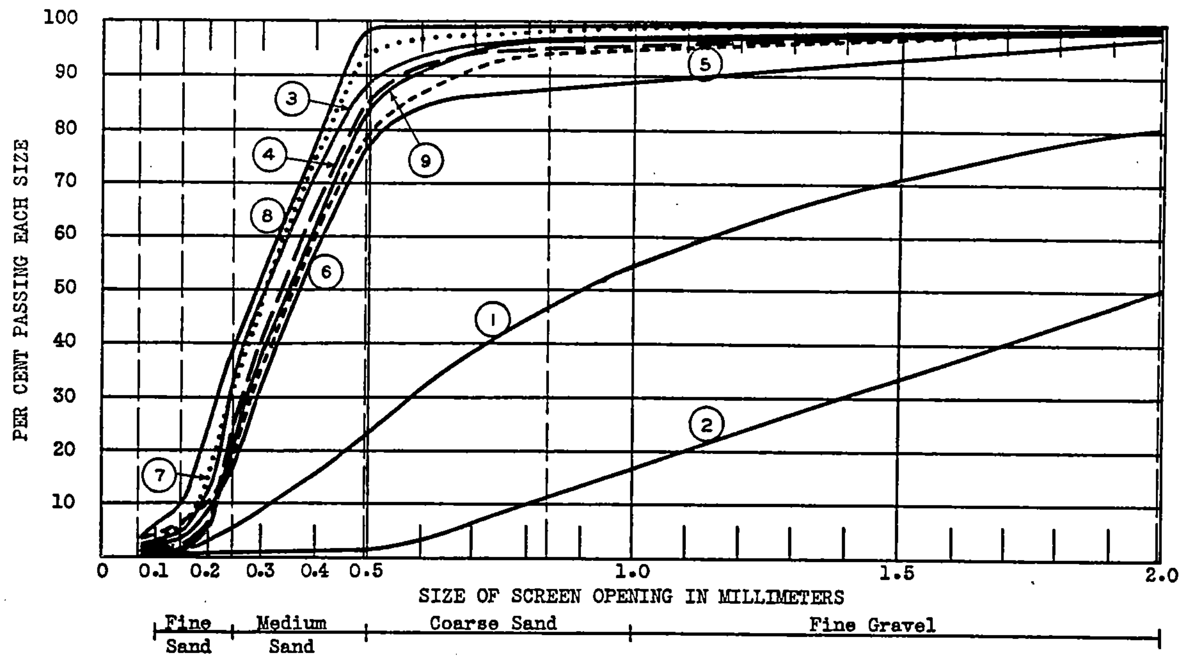


FIG. 4. MECHANICAL ANALYSES OF OGALLALA SANDS FROM WELLS AT EXPERIMENTAL FARM OF PANHANDLE AGRICULTURAL AND MECHANICAL COLLEGE, GOODWELL.

(1) Fine gravel, irrigation well (no. 181), depths 116-153 feet.
(2) Fine gravel, irrigation well (no. 181), depths 161-196 feet.
(3) Medium sand, test no. 1, depths 135-172 feet.
(4) Medium sand, test no. 1, depths 187-194 feet.
(5) Medium sand, test no. 1, depths 197-200 feet.
(6) Medium sand, test no. 1, depths 210-264 feet.
(7) Coarse sand, test no. 1, depths 290-300 feet.
(8) Medium sand, test no. 1, depths 318-325 feet.
(9) Medium sand, test no. 1, depths 325-330 feet.

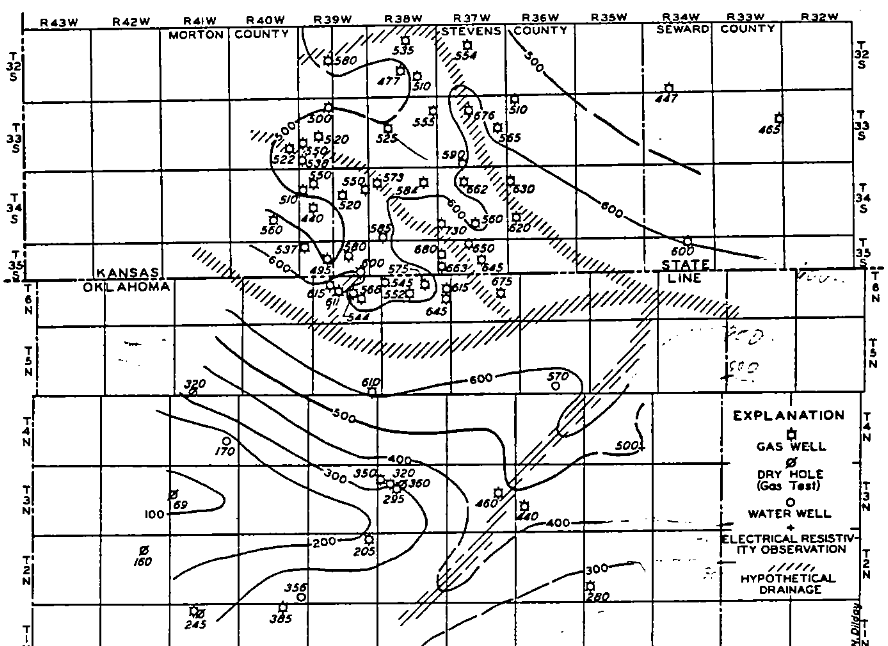


FIG. 3. THICKNESS OF THE OGALLALA FORMATION IN TEXAS COUNTY AND ADJACENT PARTS OF KANSAS, BASED CHIEFLY ON LOGS OF GAS TEST WELLS.

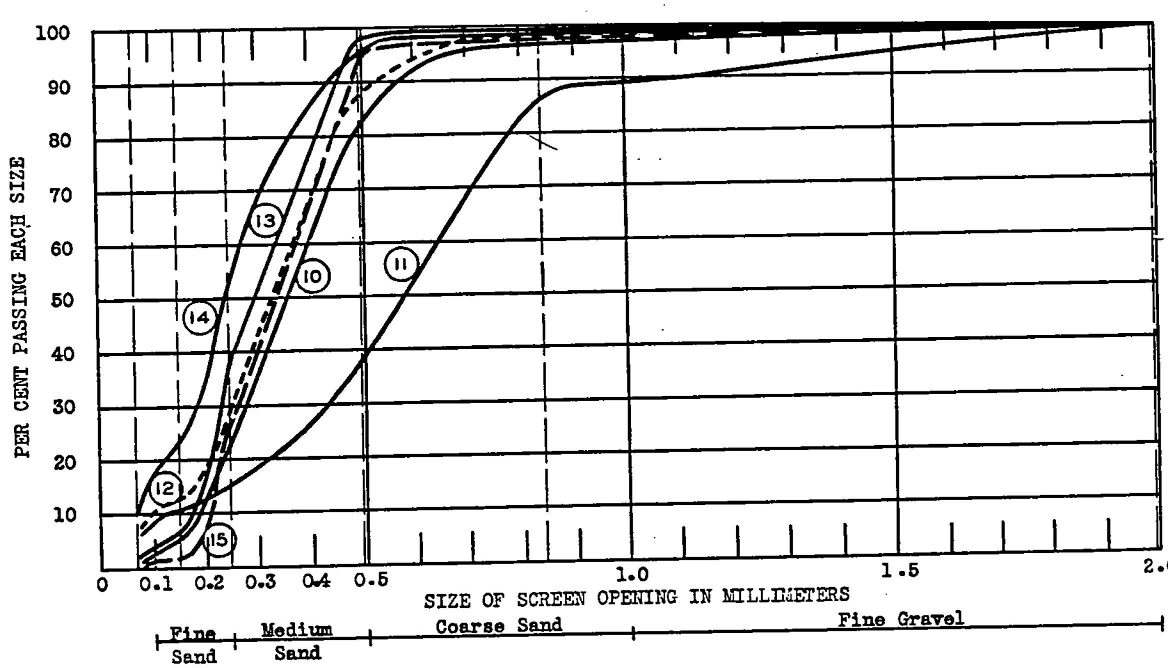


Fig. 5. Mechanical Analyses of Ogallala Sands From Irrigation Well on Campus of Panhandle Agricultural and Mechanical College, Goodwell.

(10) Medium sand, depths 135-145 feet.
(11) Coarse sand, depths 145-148 feet.
(12) Medium sand, depths 148-155 feet.
(13) Medium sand, depths 155-170 feet.
(14) Fine to medium sand, depths 170-178 feet.
(15) Medium sand, depths 178-182 feet.

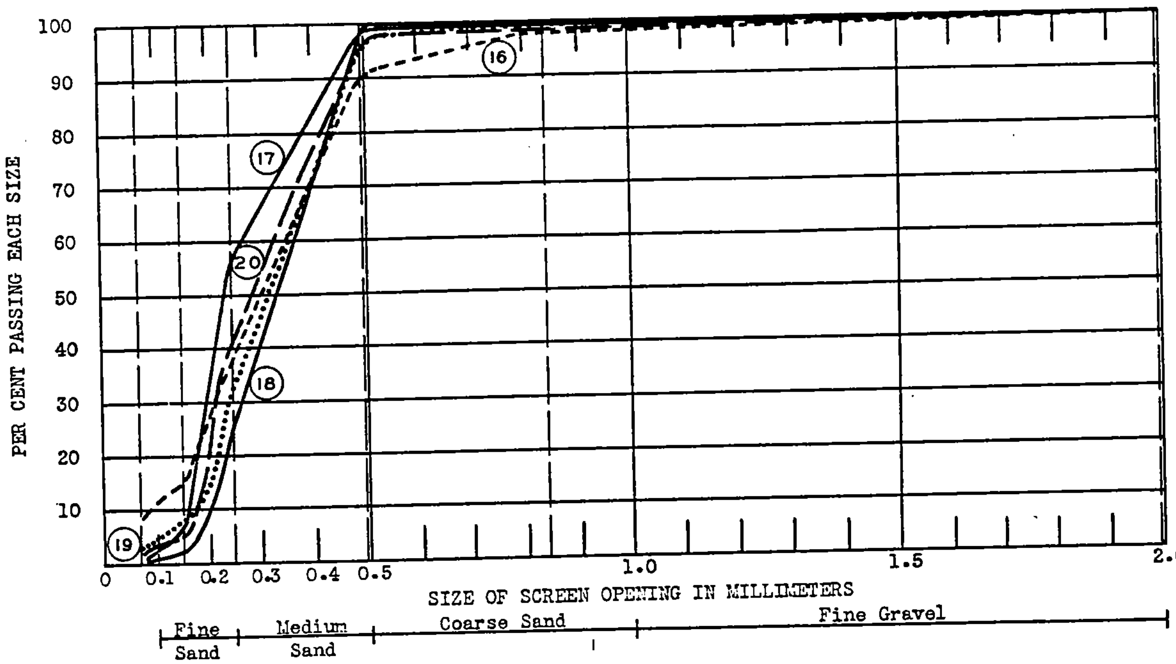


Fig. 5-A. Mechanical Analyses of Ogallala Sands From Irrigation Well on Campus of Panhandle Agricultural and Mechanical College, Goodwell. (Continued from Fig. 5)

(16) Medium sand, depths 182-184 feet.
(17) Fine sand, depths 184-200 feet.
(18) Medium sand, depth 200 feet.
(19) Medium sand, depth 208 feet.
(20) Medium sand, depth 251 feet.

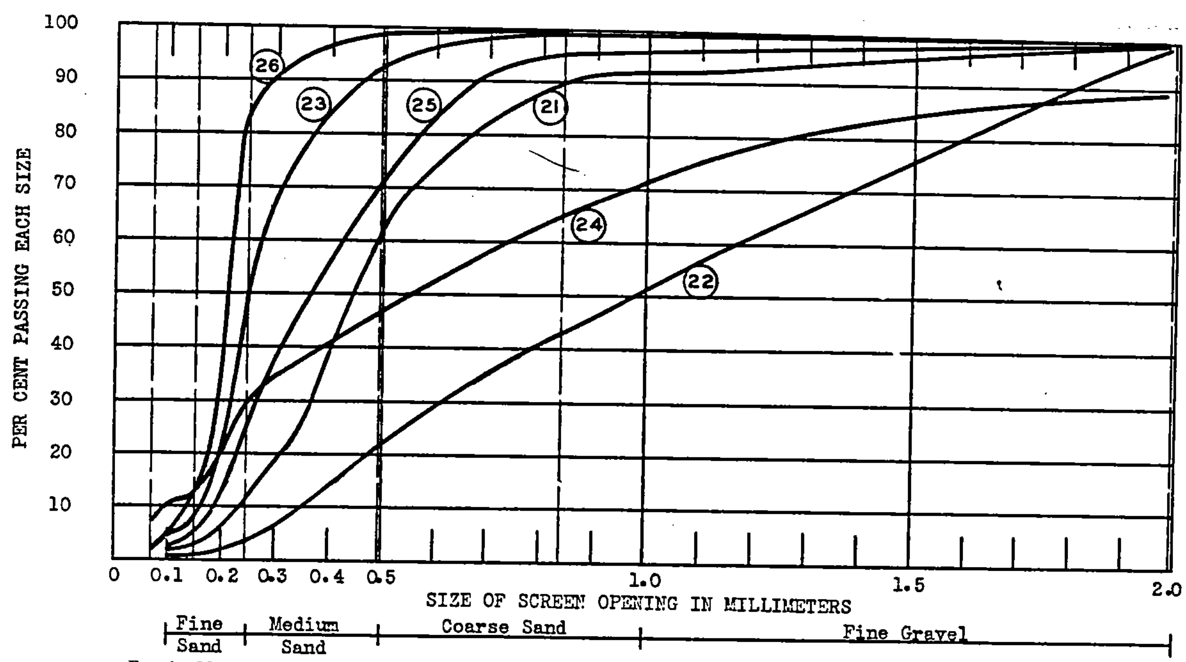


FIG. 6. MECHANICAL ANALYSES OF SANDS FROM WELLS COMPARED WITH ANALYSES OF JURASSIC (?) SANDSTONE AND ARENACEOUS CALICHE.

(21) Medium sand. Wiggins no. 1 gas well, depth 180 feet. Ogallala.
(22) Fine gravel. Wiggins no. 1 gas well, depth 200 feet. Ogallala.
(23) Fine to medium sand, water well no. 188, depth 270 feet. Triassic (?).
(24) Medium to coarse sand, water well no. 281, depths 103-103½ feet. Cretaceous (?).
(25) Arenaceous caliche from sec. 6, T. 1 N., R. 16 E., after digestion in acid.
(26) Calcareous sandstone from Red Point locality. Jurassic (?).

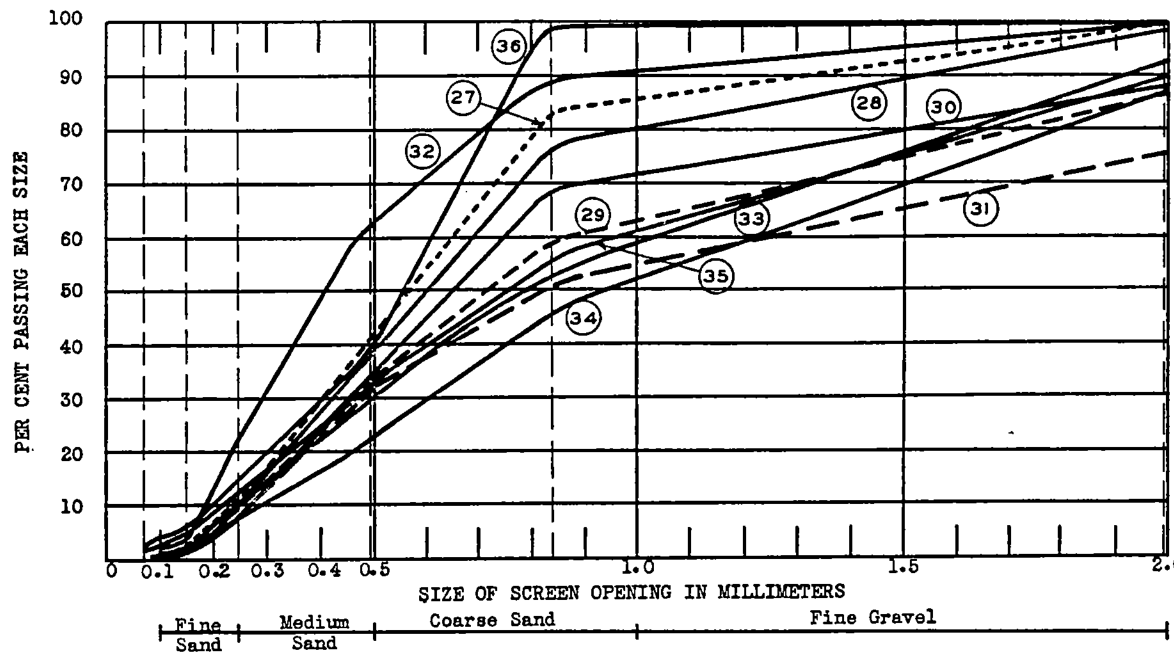
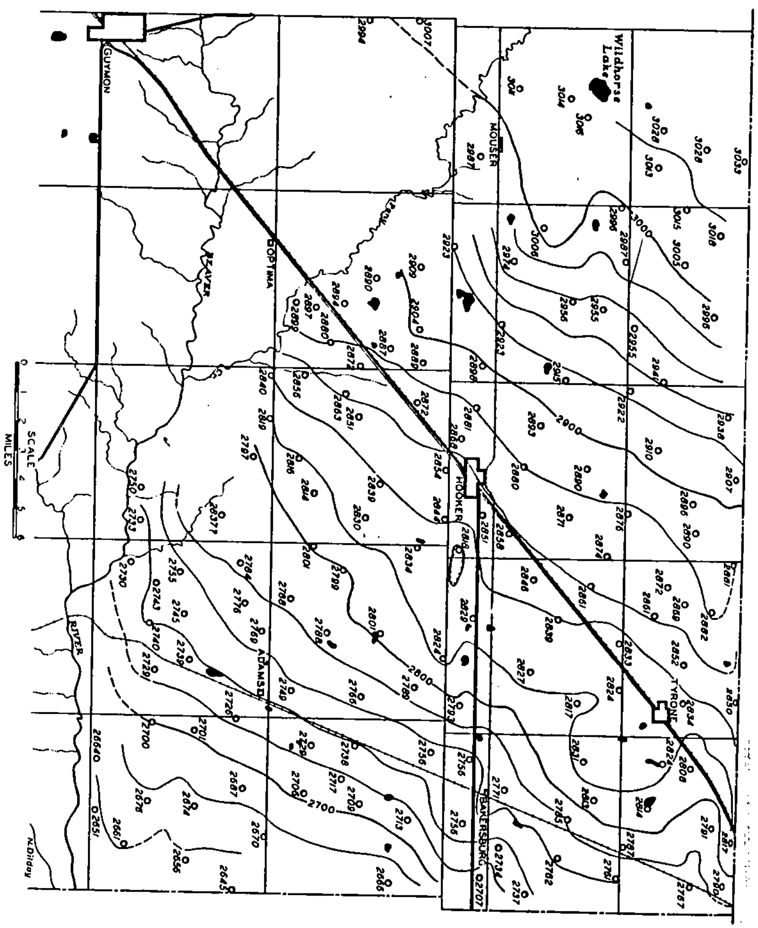


FIG. 7. MECHANICAL ANALYSES OF OGALLALA SANDS FROM FERGUSON NO. 2 GAS WELL, SEC. 14, T. 6 N., R. 16 E.

(27) Coarse sand and fine gravel, 120-130 feet.
(28) Fine gravel and coarse sand, 130-140 feet.
(29) Fine gravel and coarse sand, 140-150 feet.
(30) Fine gravel and coarse sand, 150-160 feet.
(31) Fine gravel and sand, 160-170 feet.
(32) Coarse calcareous sandstone, 170-180 feet.
(33) Fine gravel and coarse sand, 190-200 feet.
(34) Fine gravel and coarse sand, very calcareous, 200-210 feet.
(35) Fine gravel and coarse sand, very calcareous, 210-220 feet.
(36) Fine gravel with a little clay, 350-360 feet.

Fig. 8. Shape and Slope of the Water Table in the Northeastern Quarter of Texas County. Elevations on the Water Table Are in Feet Above Sea Level.



pre-Tertiary divides to more than 600 feet in the nearby valleys, and that correspondingly, the surface relief of the pre-Ogallala topography may have been about 500 feet. Over the High Plains in general, thicknesses for the Ogallala deposits greater than 300 feet appear to be unusual.[76] In records of 28 Texas County wells listed in the table 20 indicate thicknesses of the Ogallala greater than 300 feet, 14 indicate more than 400 feet, 12 indicate more than 500 feet, and 6 indicate more than 600 feet. It is worthy of note that all wells suggesting thicknesses greater than 500 feet are in the northern part of the county and that there are none that suggest less than 500 feet in the same locality. Where so many records point the same way, they cannot all be dismissed as unreliable, especially if, as in this case, there is no good evidence to the contrary. The possibility that some of the lower beds may belong to Tertiary formations that are older than the Ogallala should not be ignored, but the writer knows of no way to distinguish them in the well logs.

The evidence from wells is supplemented by the electrical restivity tests which were made in the northeastern part of the county in 1936 by the State Mineral Survey. Cross sections based on this work suggest thicknesses of the Ogallala ranging from about 200 feet to more than 500 feet, the maximum being indicated for the NW¼ sec. 24, T. 4 N., R. 18 E. This locality is marked by a cross on figure 3.

WATER SUPPLY

The sands and gravels of the Ogallala formation are the principal source of ground water in Texas County, as well as in a large part of the southern High Plains. In the county, all municipal wells, most domestic and stock wells, and the four irrigation wells that are located on upland plains (wells 179, 181, 496, and 497) draw water from the Ogallala. The yield of the wells ranges from a gallon or two per minute for some windmill wells to 960 gallons per minute for the irrigation well at the experimental farm of the Panhandle Agricultural and Mechanical College at Goodwell. Most of the larger wells that

76. Theis, C. V., Burleigh, H. P., and Waite, H. A., "Ground Water in the Southern High Plains": *U. S. Geol. Survey, Mimeographed Memorandum*, Oct. 30, 1935. The authors assign a thickness "in most places between 200 and 300 feet." (p. 1.)

are pumped with electric, gasoline, or natural gas power yield from 100 to 500 gallons per minute.

The water generally is of good quality, although rather hard. Of the 72 analyses reported in Table XII, 62 represent waters from wells thought, with reasonable certainty, to end in the Ogallala. In the samples analysed, total hardness ranges from 198 to 340 parts per million; chloride from 2 to 46 parts per million; sulphate from 8 to 165 parts per million; and bicarbonate from 158 to 347 parts per million.

The Ogallala of the Southern High Plains may be looked on as a vast reservoir that is only partly full of water. The upper part is dry because there is not enough rainfall to fill it, and because, as Johnson[77] has pointed out, such streams as the Beaver have cut deeply into the reservoir and, being supplied from it, have drawn the water table down to low levels. The part below the water table is known as the zone of saturation because the spaces between the pebbles in the gravels and between the grains of the sands are filled with water. The total amount of pore space and the amount of water may be as great in the clays as in the gravels and sands, but because each space is very small the water can move slowly if at all. Therefore the strongest wells are those which penetrate saturated gravels, but those in coarse sand may be nearly as good.

Reference to the well tables will show that in Texas County gravel is reported by owners or tenants as the water-bearing bed in about half of the wells. Out of 1,004 domestic and stock wells thought to be in the Ogallala for which reports were obtained, 52.5 per cent were reported to obtain water in gravel, 23 per cent in sand, 12.5 per cent in clay, and the rest in mixtures of gravel and clay or sand and clay.

In contrast with the reports of owners and tenants, the logs of deep water wells in Texas County and adjacent Kansas indicate that the water-bearing material generally is sand. In 12 wells which penetrate from 251 feet to 570 feet of the Ogallala[78], the thickness of all the beds penetrated below the water table varies from 66 feet to 440 feet, and averages 163 feet. The estimated total thickness of the saturated sands and gravels in these wells ranges from 21 feet to 218 feet. Gravel is reported in only 3 of these 12 wells, and the total thickness of the gravels amounts to only about 35 feet out of a total thickness of about 1,011 feet of water-bearing materials. In other words these logs indicate that only 3.5 feet out of 100 feet of water-bearing material will be gravel.

77. Johnson, W. D., *Op. cit.*, p. 644.

78. Figures quoted include the city well at Liberal, Kansas (log K-6), which shows no red beds to a depth of 502 feet, and the Hooker exploratory well, in which the red beds (Cloud Chief?) are supposed to have been reached at a depth of 570 feet.

Specific capacities of wells in the Ogallala. The specific capacity of a well is the number of gallons of water produced per minute for each foot of draw down, and it is obtained by dividing the yield in gallons per minute by the draw down measured in feet. It depends on the permeability of the water-bearing bed or beds and on the construction of the well. It should be higher for wells in gravel or clean coarse sand than for wells in fine sand, and higher for a properly constructed well than for one that is poorly constructed or is old and in poor condition. Table IX shows the specific capacities of a number of wells in the Ogallala, in relation to their depth and the thickness of the water-bearing beds in them. The figures are based on yields and

TABLE IX

SPECIFIC CAPACITIES OF WELLS IN THE OGALLALA FORMATION IN TEXAS COUNTY, OKLA.

Well No.	Depth of well	Thickness of water-bearing beds	Yield in Gal. per Minute	Drawdown (feet)	Specific Capacity
Irrigation and Municipal Wells:					
45	230	20	100	13	7.7
319-A	330	40	251	7	35.8
319-B	330	40	285	9	31.6
497	280	81	450	38	11.8
179	251	93	300	30	14.1
317-A	386	114	588	17½	33.6
181	298	173	680	27	25.2
181	298	173	960	60	16.0
317	385	194	628	10	62.8
Chicago, Rock Island and Pacific Railroad wells:					
Hooker 1	163	......	60	3	20.
Hooker 2	230	......	60	3	20
Optima	115	......	10	0?	?
Goodwell	200	......	123	5	24.3

draw-downs as reported to the writer, and indicate a range from 7.7 to 62.8 gallons per minute per foot of drawdown.

Mechanical analyses of sands and sandstones. Because the texture helps to determine the readiness with which a water-bearing bed will yield water to wells, and also has a bearing on the construction of wells, samples of water-bearing materials from wells, mostly saved by the drillers, were run through a set of sieves, and the results are given as cumulative percentage curves (figures 4 to 7). These curves show the percent of the sample by weight which passed each size screen opening.

Twenty of the samples came from wells drilled for the Panhandle Agricultural and Mechanical College at Goodwell, 2 are from the Wiggins No. 1 gas well (Hardendorf), 1 from the immediately adjacent well which supplied water for drilling the gas well, 10 from the Ferguson No. 2 gas well, and 1 from the Lester Sparks irrigation well. Except for the samples from the Wiggins water supply and Sparks irrigation wells, all the materials were washed up in the process of rotary drilling, and it is therefore likely that some of the finer fractions were carried away in the drilling water. As a check, the distribution of sizes among the sand grains was determined for a very arenaceous caliche (nearly a sandstone) and for a white, micaceous sandstone from the Jurassic (?), and the results from these rocks are shown on the same sheet as the analyses for the Wiggins (23) and Sparks (24) wells (fig. 6). It will be seen that the Jurassic (?) sandstone (26) is the finest-grained of the six, and that the caliche (25) falls near the middle of the group. According to the classification adopted by the United States Bureau of Chemistry and Soils, as quoted by Meinzer[79], the Jurassic (?) sandstone is composed of fine sand, and the caliche contains medium-grained sand. Of the 34 samples from wells, 3 are fine gravel, 8 are coarse sand and fine gravel, 1 is a mixture of gravel and clay, 2 are coarse sand, 1 is medium to coarse sand, 15 are medium sand, 2 are fine to medium sand, 1 is fine sand, and 1 is sandstone.

79. Meinzer, O. E., "The Occurrence of Ground Water in the United States": *U. S. Geol. Survey Water Supply Paper* 489, p. 17, 1923.

The permeability of sands and gravels depends not only on their coarseness of texture, but also on how completely they have been sorted into one size. In order to express the degree of sorting of different materials quantitatively so that they can be compared, an arbitrary value known as the uniformity coefficient[80] is used. This is defined as the ratio of the diameter of a grain that has 60 per cent (by weight) of the sample finer than itself, to the diameter of the grain that has 10 per cent finer than itself. Thus in curve 1, figure 4, the size having 60 per cent of the sample finer than itself is 1.4 millimeters, and the size having 10 per cent finer than itself is 0.32 millimeter. The uniformity coefficient for this sample is 1.4 divided by 0.32, or 3.56. If all the grains in a sand were of the same size, the uniformity coefficient would be 1, but with the ordinary even-grained materials it is likely to range from 2 to 3. Table X lists the uniformity coefficients of the Texas County materials that were tested, using the same identifying numbers as figures 4-7, and shows coefficients for materials from wells in the Ogallala ranging from 1.6 to 5.3 and averaging 2.8. Although some of the samples probably tested more nearly uniform than they really are in nature because of loss of fine materials that were washed away in drilling water, others may have tested less uniform than they really are because of the inclusion of materials from several beds of varying texture in the same sample. Thus the average may be somewhere near the truth, and indicates a good degree of uniformity and a correspondingly good average permeability for the sands in the Ogallala.

80. Meinzer, O. E., *Op. cit.*, p. 7.
Hazen, Allen, "Experiments Upon the Purification of Sewage and Water at the Lawrence Experiment Station": *Mass. State Board of Health 23d Ann. Rept.*, for 1891, pp. 429-431, 1892.

TABLE X.

UNIFORMITY COEFFICIENTS

Source and description of material	Depths Represented (feet)	Uniformity Coefficient
I. IRRIGATION WELL, EXPERIMENTAL FARM OF PANHANDLE A. & M. COLLEGE, GOODWELL.		
1. Fine gravel	116-153	3.6
2. Fine gravel	161-196	4.0
II. TEST WELL NO. 1, EXPERIMENTAL FARM OF PANHANDLE A. & M. COLLEGE, GOODWELL.		
3. Medium sand	135-172	1.7
4. Medium sand	187-194	1.8
5. Medium sand	197-200	2.0
6. Medium sand	210-264	1.9
7. Coarse sand	290-300	1.8
8. Medium sand	318-325	2.2
9. Medium sand	325-330	1.8
III. IRRIGATION WELL ON CAMPUS OF PANHANDLE A. & M. COLLEGE, GOODWELL.		
10. Medium sand	135-145	2.2
11. Coarse sand	145-148	5.3
12. Medium sand	148-155	3.9
13. Medium sand	155-170	1.9
14. Fine to medium sand	170-178	3.6
15. Medium sand	178-182	1.8
16. Medium sand	182-184	4.1
17. Fine sand	184-200	1.6
18. Medium sand	200	1.8
19. Medium sand	208	2.1
20. Medium sand	251	2.1
IV. WIGGINS GAS WELL SEC. 1, T. 2 N., R. 14 E.		
21. Medium sand	about 180	2.0
22. Fine gravel	about 200	3.3
V. WELL USED TO SUPPLY DRILLING WATER FOR WIGGINS GAS WELL, SEC. 1, T. 2 N., R. 14 E.		
23. Fine to medium sand	about 270	1.7
VI. LESTER SPARKS IRRIGATION WELL, SEC. 5, T. 3 N., R. 11 E.		
24. Water-bearing sand (may be in Cretaceous)	103-103½	2.1
VII. H. C. HITCH FARM, SEC. 6, T. 1 N., R. 16 E.		
25. Arenaceous caliche (after removal of carbonate)		2.3
VIII. RED POINT LOCALITY, JURASSIC (?) EXPOSURE.		
26. Calcareous sandstone (after removal of carbonate)		1.6
IX. FERGUSON NO. 2 GAS WELL, SEC. 14, T. 6 N., R. 16 E.		
27. Coarse sand and fine gravel	120-130	2.2
28. Fine gravel and coarse sand	130-140	2.7
29. Fine gravel and coarse sand	140-150	3.2
30. Fine gravel and coarse sand	150-160	2.9
31. Fine gravel and sand	160-170	4.5
32. Coarse calcareous sandstone	170-180	2.5
33. Fine gravel and coarse sand	190-200	4.3
34. Fine gravel and coarse sand, very calcareous	200-210	4.1
35. Fine gravel and coarse sand, very calcareous	210-220	4.4
36. Fine gravel with a little clay	350-360	3.0

CALICHE

Definition and character. "Caliche" is a Spanish word derived from the Latin "calx", meaning lime, and in the original sense was applied to a "crust of lime which flakes from a wall"[81], among other things. In Chile and Peru it has been used for efflorescent deposits of sodium nitrate mixed with calcium, magnesium and sodium sulphates.[82] In 1901 Blake[83] applied the name to calcareous deposits near the land surface in Arizona and Mexico, and in this sense it has been widely used by geologists and soil scientists working in the sub-humid to arid Southwest. This latter use is the last of eight widely divergent meanings for "caliche" listed in Fay's Glossary of the Mining and Mineral Industry.[84]

In discussing the caliche of the American Southwest, most writers restrict the term to deposits of calcium carbonate, or specify that the caliche is "calcareous", "ferruginous", etc., but they are not in complete agreement as to just what constitutes calcareous caliche. Most writers recognize a gradation from very soft to very hard varieties, but Price[85] appears to restrict it to "a porous, earthy calcium carbonate containing impurities of soil, sand, and gravel." He introduces the terms "young caliche" for incipient accumulations of soil-lime in grains, flakes, nodules, irregular aggregates, and unconsolidated beds of carbonates, and "mature caliche" for consolidated beds of calcium carbonate. Elias[86] would restrict the term "caliche" to efflorescent deposits, including the nitrates and other non-carbonate materials, and would rule out deposits which accumulate beneath the surface, for which he considers the name "hard pan" is applicable.

Sayre[87] restricts the name "caliche" to calcareous deposits,

81. Casares, J., "Novisimo Diccionario Ingles-Espanol y Espanol-Ingles," Madrid, p. 135.
82. Grabau, A. W., "Principles of Stratigraphy," 2d Ed. p. 365, 1924.
83. Blake, W. P., "The Caliche of Southern Arizona, An Example of Deposition by Vadose Circulation": *Am. Inst. Min. and Met. Eng. Trans. vol.* 31, pp. 220-226, 1901.
84. *U. S. Bur. Mines, Bull.* 95, p. 125, 1920.
85. Price, W. A., "Reynosa Problem of South Texas, and Origin of Caliche": *Bull. Amer. Assoc. Petro. Geol.* Vol. 17, pp. 500-501, 1933.
86. Elias, M. K., Oral communication.
87. Sayre, A. N., "Geology and Ground Water Resources of Duval County, Texas": *U. S. Geol. Survey Water Supply Paper* 776, p. 65-66, 1937.

and describes the caliche of Duval County, Texas, as "a dense layer of hard, resistant white calcium carbonate 1 to 4 inches thick, which grades downward into softer, less pure calcium carbonate and finally into calcareous sand or clay. The zone in which the calcium carbonate shows a concentration greater than that in the underlying bed rock should be termed 'caliche.' This zone appears to be about 4 to 8 feet thick in Duval County."

In this report "caliche" is used in the sense in which "gyp" is used locally in Texas County, i.e., for all the calcareous deposits which occur near the surface and somewhat below. This material fits Sayre's description in a general way, but both the hard and the soft types are much thicker than he indicates. The hardest and densest beds of calcium carbonate are generally found nearest the surface. They tend to be massive, but are broken by many irregular cracks which run from top to bottom of the bed, giving the rock a biscuit-like structure closely resembling freshwater limestone. They contain only a few scattered grains of sand, and commonly are gray or drab in color but become white after weathering. Immediately southwest of Guymon in sec. 36, T. 3 N., R. 14 E., a layer of such rock about 1.8 feet thick is exposed at the top of a cut bank on the east side of a tributary of South Fork, and 50 feet or more below the level of the upland. Above it the exposures are few and poor, but similar rock appears in scattered outcrops to the top of the bluff. At most other localities where this rock is present, it appears to be confined to the uppermost few feet, immediately below the upland level. Measured thicknesses for any single bed range from 1.8 to 5.5 feet. Obviously such thicknesses compare more closely with the algal limestone 2 to 3.5 feet thick which Elias[88] finds at the top of the Ogallala in Kansas than with the 1- to 4-inch beds of hard calcium carbonate reported in Duval County, Texas, by Sayre.

Another common type of caliche consists of loosely consolidated, irregular, nodular calcium carbonate. Although it appears to contain nearly as much calcium carbonate as the dense, hard beds described above, and although parts of it are hard, it does

88. Elias, M. K., "Geology of Wallace County, Kansas": *Kans. Geol. Survey Bull.* 18, p. 136, 1933.

not constitute a hard layer. It breaks down readily to form a sort of white, limestone "gravel", and where exposed in road cuts or on valley bluffs is generally between 5 and 10 feet thick.

The arenaceous type of caliche consists of a calcium carbonate matrix in which are embedded grains and granules of white, yellowish, gray, and colorless quartz and quartzite. The sand generally is more abundant in the lower part of an exposure than in the upper. Locally pebbles several inches across are included (see section, page 60), and on the east side of South Fork in sec. 2, T. 2 N., R. 14 E., a cut bank exposes a loosely cemented gravel which grades upward into rather well consolidated arenaceous caliche. This arenaceous variety occurs in ledges from 10 to 30 feet thick without well-defined bedding, weathers in irregular, rounded knobs and projections, responds with a dull thud when struck with a hammer, and in outward appearance and manner of breaking somewhat resembles igneous tuff. The prevailing color is light gray, faintly tinted buff or pink, and in places there are several ledges separated by unconsolidated or loosely consolidated materials. This kind of material is probably the rock type referred to by Hay[89] as "mortar beds."

The following analyses of samples of caliche from Texas County were made in the chemical laboratory of the Oklahoma Geological Survey by S. G. English, chemist. They illustrate the wide range in lime and silica in the different types.

TABLE XI

ANALYSES OF CALICHE FROM TEXAS COUNTY

Lab. No.	SiO_2	Al_2O_3	Fe_2O_3	MnO_2	P_2O_5	CaO	MgO	CO_2	SO_3	H_2O	Total
5014	7.88	0.45	0.36	none	none	49.31	1.88	39.00	none	0.99	99.84
5006	24.54	1.68	1.22	none	none	39.02	1.12	30.94	none	1.38	99.90
6017	27.28	2.62	1.36	trace	trace	36.81	0.80	28.74	none	2.35	99.96
5023[1]	31.02	1.00	1.14	trace	trace	35.57	1.00	28.40	none	1.43	99.56
6020	32.16	1.94	1.14	trace	trace	34.31	1.16	26.84	none	2.44	99.99
5021[1]	35.62	0.95	1.07	none	trace	20.41	13.40	27.20	none	1.54	100.19
5020[1]	42.24	2.03	1.29	trace	trace	27.22	2.18	22.62	none	1.90	99.48
6021	42.30	1.21	1.65	trace	none	29.41	0.88	23.24	none	1.40	100.09
5017[1]	47.80	1.25	1.29	none	trace	18.92	7.80	19.72	none	2.83	99.51
6023	50.54	1.21	1.57	trace	none	23.14	2.78	17.84	none	2.50	99.58

1. Tested and found satisfactory for rock wool in the Industrial Research Laboratory of the Oklahoma Geological Survey.

89. Hay, Robert, "Water Resources of a Portion of the Great Plains": *U. S. Geol. Survey, 16th Ann. Rept. Pt.* 2, p. 570, 1895.

Origin. The origin of caliche has been the subject of much scientific discussion, and several theories have been advanced to explain it. A summary of the existing literature was given by Gould and Lonsdale[90] in their discussion of the caliche in Texas County, and subsequently Price,[91] Weeks and Sayre have reviewed the subject in considerable detail.

The more important explanations mentioned by Gould and Lonsdale involve precipitation of calcium carbonate from descending rain water at the level of the water table, or rise of water from the water table as a result of capillary attraction. Under present conditions, however, the water table in Texas County is well below the caliche, to which it is not now related directly, and capillary attraction would be inadequate to draw the water up to a point where it could be evaporated.

Other explanations involve the downward percolation of rain or flood waters to relatively slight depths, where evaporation of the water and precipitation of calcium carbonate are thought to occur. Sayre[92] suggests that the caliche of the Reynosa Plateau results from the leaching of the soil by downward moving waters during wet seasons, followed in dry seasons by a capillary rise and evaporation of the water with precipitation of the contained calcium carbonate. The water need not descend to the water table. The thickness of the resulting caliche is limited by the thickness of the soil zone to be leached, which in turn is limited by the depth at which the calcium carbonate accumulates. Sayre finds three conditions necessary for the development of caliche, namely:

(1) A subhumid to arid climate;
(2) The underlying formation must be calcareous; and
(3) The underlying formation must be of such texture as to favor capillary movement of subsurface water.

90. Gould, C. N., and Lonsdale, J. T., *Op. cit.* pp. 31-33.
91. Price, W. A., *Op. cit.*, pp. 502-513.
Weeks, A. W., "Lissie, Reynosa and Upland Terrace Deposits of Coastal Plain of Texas Between Brazos River and Rio Grande": *Bull. Amer. Assoc. Petro. Geol.* Vol. XVII, pp. 472-476. 1933.
Sayre, A. N., *Op. cit.*, pp. 67-70.
92. Sayre, A. N., *Op. cit.*, pp. 69-70.

Sayre's explanation has much in common with that of Hawker[93], who attributes caliche to the progressive leaching of the upper soil zone (zone A) with a concentration of calcium carbonate in a zone of accumulation a short depth below the surface (zone B). In this connection, Harper[94] reports that near Stillwater, Oklahoma, there is a thick deposit of calcium carbonate at a depth of about 7 feet which he suggests may have accumulated during periods when rainfall is heavy and penetrates deeply, and a thin, discontinuous or nodular bed at a depth of about 2.5 feet, which may have accumulated in dry seasons. As quoted by Sayre[95], Meinzer is of the opinion that the calcium carbonate is introduced in flood waters from adjacent highland areas. These waters sink into the ground in regions of aggradation, and evaporate in the soil, leaving a calcareous deposit. All of these explanations call for the formation of caliche below the surface, and such deposits would be termed "hard pan" by Elias.[96]

The Texas County caliche probably is no thicker than that in other parts of the Southern High Plains, but it does appear to be thicker than most of that discussed in the literature referred to above, and this thickness constitutes a problem in itself. Price[97] explains the formation of thick beds of caliche by suggesting that "gradual leaching lowers the zone of accumulation and erosion lowers the upper surface of the soil", but the thickest caliche considered by him is about 20 feet, in contrast with the common occurrence of 30 feet or more in Texas County. White[98] holds that the caliche was deposited at or near the land surface, and that the buried caliche beds were deposited before the plains had been built up to their present level. Where caliche beds are separated by unconsolidated sands and gravels, this explanation implies that the formation of caliche was interrupted, perhaps because the supply of calcium carbonate was temporarily cut off; or because increased precipitation or the addition of coarser sedi-

93. Hawker, H. W., "A Study of the Soils of Hidalgo County, Texas, and the Stages of Their Soil-lime Accumulation": *Soil Science*, Vol. 23, pp. 478-482, 1927.
94. Harper, Horace J., Director of Agricultural Experiment Station, Stillwater, Oklahoma, Oral communication.
95. Sayre, A. N., *Op. cit.*, p. 69.
96. Elias, M. K., Oral communication.
97. Price, W. A., *Op. cit.*, p. 505.
98. White, W. N., Oral communication.

ments led to better soil drainage and removal of calcium carbonate instead of precipitation; or because sediments were deposited over the existing caliche so rapidly that caliche could not be formed throughout.

The dense, hard variety may prove to be the same as the layer of limestone at the top of the Ogallala formation of western Kansas, in which Elias[99] has found algal material and for which he assigns a lacustrine origin.

Age. In Texas County that part of the caliche which is still being formed as a secondary deposit in the present soil, or which has been formed in the soil since completion of the Ogallala deposits and of the High Plains surface, is clearly post-Ogallala in age. It is probable, however, that most of the caliche is contemporaneous with the upper part of the Ogallala. The present streams have cut through all types of the caliche to produce the best natural exposures of the material, and presumably they began to degrade near the end of the period of Ogallala deposition. Furthermore, the topmost bed is the dense, hard layer resembling fresh-water limestone, and where present this rock is a barrier to downward moving waters and to the secondary deposition of caliche in lower beds. Hence it appears to be the youngest of the thick and important calcareous deposits. On further examination it may prove to be of the same origin and age as the limestone at the top of the Ogallala of western Kansas, in which Elias[100] has identified the alga *Chlorellopsis,* together with fossil seeds[101] which he has also found in northern Ellis County, Oklahoma, where they are associated with Pliocene vertebrate remains. If it really is equivalent to the *Chlorellopsis* limestone, this bed marks the top of the Ogallala, and all underlying caliche beds must be considered a part of the Ogallala, and probably Pliocene in age.

Distribution. The caliche probably occurs under the soil in most parts of the county. It is widely exposed as a cliff-making

99. Elias, M. K., "Geology of Wallace County, Kansas:" *Kans. Geol. Survey Bull.* 18 pp. 137-141, 1931.
100. Elias, M. K., *Op. cit.*, pp. 137-141.
101. Elias, M. K., Oral communication.

unit along the valleys just below the upland level, and drillers[102] report that it is encountered in most wells.

Thickness. Thicknesses of the different types of caliche have been mentioned in the section on the character of the rock. A maximum thickness of about 30 feet of the arenaceous caliche was measured along South Fork, immediately west of Guymon, but the top of one 30-foot exposure is many feet below the level of the upland, and leaves open the possibility that the original maximum thickness was much greater. As reported by well drillers, the caliche is 50 feet thick or more (see logs 179, 319, 412).

WATER SUPPLY

No wells draw water from the caliche, first because it is relatively impermeable and second because it is above the water table. However, it is important in relation to recharge of the ground water reservoir because it retards the downward movement of rain water, either stopping the water entirely or causing it to follow a zig-zag course. Sayre[103] reports experiments by W. A. Lynch and J. C. Cumley on the relation of caliche to recharge to the Goliad sand, in which test holes near wells were made with a soil tube:

> "In certain test holes carried to a depth of 9 feet . . . . caliche was absent or was present only as chalky nodules. In adjacent test holes, however, the caliche was found to be present as a hard, impermeable layer either at the surface or within 9 feet of the surface. These wells showed fluctuations of water level from 5 to 34 feet during the period in which water-level measurements were made. Recharge was believed to occur in the areas where the test holes indicated that caliche was absent. Near wells . . . . which showed fluctuation of water level of less than 0.4 foot, every test hole encountered caliche at 2 to 8 feet below the surface."

102. Seawright, I. C., and Sanborn, G. C., Oral communications.
103. Sayre, A. N., *Op. cit.*, pp. 70-71.

QUATERNARY SYSTEM

ALLUVIUM

The alluvium consists of sands, gravels, silts and clays that have been deposited in the valley bottoms by the streams. The materials have been derived largely from the Ogallala formation, but debris from older rock formations is also included in the alluvium at places downstream from the outcrops of those formations. Gravels and sands are the sediments first deposited when streams lose velocity and carrying power, and so should occur in long, narrow, winding bands that represent former river channels. The silts and clays are deposited in quiet backwaters or on the flood plains, or may be left in the channel of the stream itself if the volume of water becomes very low. They should therefore surround the gravels and sands on all sides and be more or less intimately bedded or mixed with them.

These deposits are younger than the Ogallala formation, from which they have been largely derived, and they are still being shifted about by the streams, with additions and subtractions. Hence they are assigned to Quaternary age.

Thickness. The total thickness of the alluvium is largely a matter of conjecture because the streams do not cut completely through the alluvium to expose older rocks, and because the unconsolidated gravels, sands, and clays of the alluvium are so similar to the nearly unconsolidated Ogallala deposits that they cannot be distinguished with certainty in wells. However, well number 287, located approximately in SE cor. sec. 16, T. 3 N., R. 12 E., begins on a terrace less than 25 feet above the channel of Tepee Creek, and is reported to enter the red beds at a depth of 78 feet. It is probable that all of the 78 feet of material overlying the red beds is alluvium because nearby red bed exposures, located both upstream and downstream from the well, indicate the absence of the Ogallala from this part of the valley.

A thickness of at least 105 feet is indicated by a domestic well that was drilled on the flood plain of the Beaver due north of Guymon (well log 176-a). The red clay encountered in this well between depths of 40 feet and 70 feet is thought to be a

part of the alluvium because it is underlain by at least 35 feet of good water-bearing gravel. It could have been derived from the outcrop of Triassic (?) red beds located between 5 and 10 miles upstream.

From this meagre evidence, then, it appears that the thickness of alluvium in the valley of the Beaver may exceed 100 feet, and that it may reach 50 or 100 feet in parts of tributary valleys.

WATER SUPPLY

Most of the domestic and stock wells located in the valley bottoms are shallow, and draw water entirely from the alluvium. A 30-foot well located beside the Beaver due north of Guymon (number 176), has been used for irrigation since 1934, and a well about 60 feet deep, located on the flood plain of North Fork about 8 miles west of Goodwell, has been used for irrigation since 1932. Other irrigation developments are under way in the valley of Frisco Creek and on the flood plains of Paloduro Creek. The existing wells are reported to yield from 80 to 500 gallons per minute.

The saturated part of the alluvium is either a definitely restricted underground reservoir bounded by impervious materials, or it is part of a very extensive reservoir, depending on whether it is underlain by the Permian or so-called Triassic red beds or is underlain by the Ogallala. Three possible conditions are described on pages (136-138) and are illustrated in figure 10.

The quality of the water varies with the amount of soluble mineral matter in the sediments. Along Paloduro Creek, more or less gypsum and perhaps salt are mixed with the alluvial deposits, and cause the water to be high in sulphate and chloride (see analyses 113, 129, and 249, table XII). Even where the alluvium is apparently underlain by the Ogallala formation, the water is likely to be rather hard, as indicated by analysis 20. In the four waters from alluvium that were analyzed, the total hardness ranged from 444 to 1,305 parts per million; chloride ranged from 26 to 520 parts per million; sulphate ranged from 165 to 1,120 parts per million; and bicarbonate ranged from 152 to 345 parts per million. Locally the water from the alluvium is reported to have a "swampy" taste or odor, probably because it has come in contact with buried and partly decomposed vegetable matter.

DUNE SAND

Dune sand covers the Ogallala formation in the eastern and northern parts of the county, as described on pages 21 and 22. The deposits consist of fine- to medium-grained quartz sand heaped by the wind into small but steep hills, and attain a maximum thickness of about 25 feet. The sand is thin or even absent in the areas between the hills.

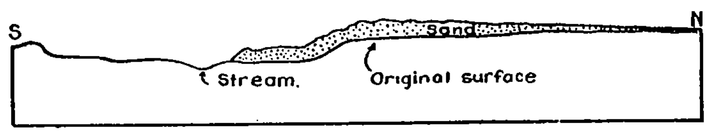


Fig. 9. Ideal cross-section showing relation of dunes to eastern part of Beaver Valley. (After Gould and Lonsdale.)

Most of the dunes rest on the Ogallala formation, from which they were derived in part, and must be somewhat younger, or post-Pliocene in age. They are younger than the alluvium to the extent that they have been derived from flood plain and channel deposits of the present valley bottom, and are contemporaneous with the alluvium to the extent that they were derived from such deposits before the flood plain reached its present form. In the eastern part of the county, some of the dunes mantle the north bluff of Beaver River valley, obviously having been deposited in their present position after the valley had attained essentially its present form (Fig. 9). This evidence indicates recency, and the dunes are therefore assigned to Quaternary age.

WATER SUPPLY

The sands are porous and loosely packed, with relatively large openings between the grains, and rain water sinks into them instead of accumulating in surface pools where it can evaporate. Its downward movement is probably more or less retarded

by underlying silty or loamy soils, and by the more dense and massive varieties of caliche, but sooner or later much of the water reaches the ground water reservoir. The actual route of downward movement may be very indirect, but the recharge which takes place through the dunes is probably significant.

At times of heavy precipitation the lower part of the dune sands may become saturated with water. The zone of saturation thus formed would constitute a perched and probably temporary reservoir, inadequate for perennially supplying water to wells. Information now available indicates that all wells in the dune areas penetrate far below the base of the sand to the main water table. The fact that the deposits vary greatly in thickness and diminish to a few feet or even disappear in the areas between the hills, strongly suggests that there is no reliable supply of water in the sands. Furthermore, no springs issuing at the base of the sand hills at the contact with the underlying, more impervious beds, are known to the writer. It is therefore apparent that the sand dunes as a rule do not furnish adequate water directly to wells.

GROUND WATER SUPPLIES AND DEVELOPMENT

Shape and Slope of the Water Table and Movement of the Ground Water

The shape and the slope of the water table in the northeastern quarter of Texas County are shown in the map, figure 8, by means of lines of equal elevation on the surface of the water table, all of which are referred to sea level. These lines are approximately level, and together they show the configuration of the water surface just as ordinary contour lines show the topography of the land surface. The direction of movement of the ground water is ordinarily at right angles to these lines in the direction of maximum slope.

The map shows that the general slope of the water table under the plains of the northeastern quarter of the county is southeastward, but that the amount of slope varies considerably because of irregularities of the water table. Where the lines are rather uniformly spaced, the slopes range from 10 to 17 feet to the mile.

Irregularities on the water table may be caused by unequal addition of water to the ground water reservoir at different places. Thus, water added to the reservoir tends to build up a mound or high area on the water table because the frictional resistance offered by the small passageways through the sands prevents it from spreading out as rapidly as it would on the surface of a lake. Such may be a partial explanation for the high areas of figure 8. Wildhorse Lake and adjacent low-lying areas may be places where water is taken into the ground, and the same may be true of the small lakes and ponds in the vicinity of Tyrone. The map shows domes on the water table at both of these localities. There is also a small nose on the water table, near Bakersburg which cannot be attributed to lakes or ponds, but which may be related to soils which are more sandy than elsewhere and which therefore take in more water, or it may be a place where water from some distant intake area finally reaches the water table after following a long and circuitous downward path.

Other high areas are to be expected along ephemeral streams—i.e., streams which flow only when there are storm waters to be carried away, commonly known as "dry streams" or "dry washes." The channels of such streams are above the water table and part of the storm water seeps into them and descending to the underground reservoir, builds up a long and narrow ridge on the water table. The slope of the water table is away from the valley rather than toward it. Such streams are termed "influent" with respect to ground water because water is added to the underground reservoir through them. Evidence of influent conditions is afforded by the dry upper part of Beaver River. At the bridge in SE¼ sec. 32, T. 2 N., R. 12 E. C. M., about 8 miles west of Goodwell, the water table is about 28 feet higher than in well 167, located 1.75 miles east of the bridge. No water table ridges appear on figure 8 because there are no ephemeral streams in the part of the county shown.

Discharge of ground water into perennial streams has the opposite effect. Where valleys have been cut below the general level of the water table, the water table slopes toward the stream as shown by figure 8 for Beaver River in the eastern part of the county. Water moving down this slope enters the stream channel, causing the flow of the stream to be perennial. Such a stream is said to be "effluent" with respect to ground water.

Water in a well located either on the flood plain or on the valley bluff adjacent to an effluent stream, will be actually higher than the water in the stream channel, and will be reached at a depth which is less than the height of the well above the stream. The slope of the water table toward the Beaver as measured with an aneroid barometer at several localities in the eastern half of the county averages about 13 feet to the mile.

Discharge of water through a well tends to depress the water table in the immediate vicinity, forming what is known as a cone of depression, the size of which depends partly on the rate at which water is being withdrawn. If withdrawal is stopped refilling will take place until the depression disappears. A well which flows or is pumped continuously will always be in a cone of depression. The cones of depression caused by the pumping of existing wells in Texas County probably are too small to appear on figure 8.

Other irregularities in the water table are due to differences in the permeability of the deposits. If there is a bed of impermeable material at the level where the water table otherwise would be, the continuity of the water table is broken. A well passing through the impermeable bed will be dry until it enters some underlying permeable bed, when the water will quickly rise.

Water table slopes steepen where materials become less permeable in the direction of ground water movement. There probably are many changes in permeability of the deposits of the Ogallala formation in Texas County, and some changes in the slope of the water table may be due to them. It is unlikely, however, that the variations shown on figure 8 are entirely due to such causes, because the variations are probably less than the contour interval used.

In summary, the water table under Texas County has a general southeastward slope averaging 10 or 15 feet to the mile. The shape of the water table depends on the uniformity of the subsurface materials, and the local conditions affecting recharge and discharge of the reservoir. The water table is depressed below the normal level along such perennial streams as Beaver River (eastern part), Coldwater, Hackberry, and Paloduro Creeks, and probably is elevated in ridge form under the dry part of the Beaver and the dry tributaries. The depth to water in a well depends on the balance of these several factors at the place where the well is drilled.

Chemical Character of the Water

The chemical character of the ground water in Texas County is indicated by partial analyses of samples from 72 wells, which are tabulated in table XII. Most of the samples are from wells thought to be in the Ogallala formation, but samples 113, 129, and 249 are from wells thought to be in the alluvium where it is underlain by the Cloud Chief formation along Paloduro Creek; number 20 is from alluvium where it is underlain by the Ogallala formation; numbers 287, 412, and 403 are from wells which penetrate red beds thought to represent the Triassic (?) and numbers 118, 126-a, and 242 are from wells that almost certainly draw all or part of their water from the Cloud Chief. Seven of the samples were taken from town supplies, 19 were from wells at rural schools or from wells that supply schools, 43 were from ordinary farm wells, and 1 was from a railroad well. Two analyses by an industrial company represent water from wells drilled for industrial purposes but not actually in use.

The analyses, which, with two exceptions, were made in the Water Resources Laboratory of the United States Geological Survey by Margaret D. Foster, include determinations of bicarbonate, sulphate, chloride, and total hardness. Fluoride also was determined on the 26 samples from town and schools wells. The analyses indicate the general chemical character of the waters and their suitability or unsuitability for industrial use, for irrigation, and for domestic use as far as this is affected by the dissolved mineral matter; they do not show the sanitary condition of the waters. Tests of the sanitary condition of the waters in the Panhandle are being made, however, by the Oklahoma Department of Public Health, through its district office at Guymon.

The analyses indicate that the waters in the Ogallala formation are very uniform in chemical character and mineral content. They are hard, calcium bicarbonate waters, usually with between 200 and 300 parts per million of bicarbonate and between 200 and 350 parts of total hardness. Most of the Ogallala waters examined contained moderate to low amounts of sulphate and chloride. In general, waters from the sands in the Ogallala are lower in mineral content than those from the older formations.

Waters from the Cloud Chief are likely to be very hard and to contain considerable sulphate and chloride, as a result of contact with gypsum and salt that occur in the formation. The three samples (118, 126-a, and 242), which are from wells thought to draw part or all of their water from the Cloud Chief, are very hard, calcium sulphate waters. They differ considerably however, in degree of concentration of calcium sulphate. They also differ greatly in chloride content. Another sample (132-a) from a well 100 feet deep and which should reach the Cloud Chief, is in chemical character a typical Ogallala water.

The waters from the so-called Triassic red beds that were analyzed (287, 412, and 403) were quite dissimilar in chemical character. One (287) was a water of mixed calcium-sodium, bicarbonate-sulphate type, with the sodium somewhat higher than the calcium and the bicarbonate somewhat higher than the sulphate; the other two samples were calcium sulphate waters, although no. 412 was about twice as high in sulphate as no. 403.

Waters from the alluvium differ greatly in mineral content depending upon local conditions, such as opportunities for mixing with waters from the red beds or for solution of salts concentrated in the soil. The three samples (113, 129, and 249) from wells in alluvium where it is underlain by the Cloud Chief were all very hard, calcium sulphate waters, but they differed considerably in the amount of mineral matter in solution. One of these samples was high in chloride as well. Sample 20, from a well in alluvium underlain by the Ogallala formation, was a calcium bicarbonate water and was much lower in dissolved mineral matter than the water from wells in alluvium where underlain by the Cloud Chief.

In Texas County, water is used chiefly for domestic purposes and for irrigation. There is little demand for water for industrial use. The quality of water that may be considered satisfactory for drinking and for other domestic uses depends on the locality and the individual. However, some of the ground waters in Texas County contain in excess of 250 parts per million of sulphate and of chloride, respectively, the upper limits of these constituents suggested by the United States Treasury Department as permissible in waters used for drinking on interstate carriers. Sulphate and chloride in excess of these limits tend to make the water unpalatable, although many waters exceeding these limits have been used for long periods without harmful effects. The only Texas County waters reported as being unpalatable are those from wells in the pre-Ogallala red beds, or in alluvium along streams where the red beds are exposed and locally in alluvium where the waters come in contact with buried vegetable

matter. The waters from the Ogallala formation are entirely satisfactory in this respect, but they are hard and require excessive amounts of soap when used for laundry purposes and form a scale in teakettles.

Attention should be called, however, to the fluoride content of the Ogallala waters. Of the 26 Texas County waters that were examined for fluoride, 17 contained more than 1.0 part per million. All but one of these waters were from wells thought to be in the Ogallala formation. The waters containing more than 2.0 parts per million (of which there were five) were all from wells in the southwestern quarter of the county. One of these waters contained 4.8 parts of fluoride. The waters containing less than 1.0 part per million were from wells in the northeastern part of the county.

The relation between fluoride in water and the dental defect known as mottled enamel has only recently been generally recognized. Dean[104] has found that:

"In surveys made of cities having the requisites for quantitative evaluation and even where these requisites are closely approximate, there is a definite quantitative relation between the flouride concentration and the clinical effect. Although a prognosis with respect to any one individual is obviously unwarranted, it is felt that a prognosis relative to the group response to waters of varying fluoride concentration may be tentatively made at this time. From the continuous use of water containing about 1 part per million, it is probable that the very mildest forms of mottled enamel may develop in about 10 percent of the group. In waters containing 1.7 or 1.8 parts per million, the incidence may be expected to rise to 40 or 50 percent, although the percentage distribution of severity would be largely of the 'mild' or 'very mild' types. At 2.5 parts per million an incidence of 75 to 80 percent may be expected, with possibly 20 to 25 percent of all cases falling into the 'moderate' or a severer type. A scattering few may show the 'moderately severe' type.

"At 4 parts per million the incidence is in the neighborhood of 90 percent, and as a rule 35 percent or more of the children are generally classified as 'moderate' or worse. In concentrations of 6 parts per million or higher an incidence of 100 percent is not unusual."

104. Dean, H. Trendly, "Chronic Endemic Dental Fluorosis": *Jour. Amer. Med. Assoc.* Vol. 107, pp. 1269-1272, Oct. 17, 1936.

The interference with the normal development of the enamel apparently takes place during the period of its formation. Once a tooth is mottled, it never loses the disfigurement, even though the cause is eliminated. On the other hand, normally formed teeth have never been known to become mottled later and persons moving into an endemic area after the second teeth have developed are not affected. It is important, therefore, that children should not use water containing more than 1.0 part per million of fluoride. Because of the undesirable effect of fluoride in water on the enamel of the teeth of children, the Oklahoma Department of Public Health is giving special attention to the fluoride content of the waters. The logical solution of the problem is to avoid the use by children of water containing fluoride in excess of 1.0 part per million. In some instances this can be done by using a nearby water that is free of toxic amounts of fluoride. Where this is not feasible it may be possible in some cases to provide distilled or cistern water for drinking and cooking purposes for the portion of the population (children between birth and 8 years) needing protection. At present no cheap and efficient method is in use for removing fluoride from water for domestic use.

The successful use of water for irrigation depends on a number of factors in addition to the mineral content of the water. Some of these factors are the character of the soil, the amount of water used, rainfall, and drainage. Scofield[105] in 1932 suggested limits for certain mineral constituents in waters used for irrigation. The suggested limits are shown in the following table:

SUGGESTED LIMITS FOR SAFE AND UNSAFE WATERS FOR IRRIGATION

Constituents	Safe Less than	Unsafe More than
Total dissolved solids (parts per million)	700	2,000
Sodium (Na) (percent)	50	60
Sulphate (SO_4) (parts per million)	192	480
Chloride (Cl) (parts per million)	142	355

The percentage of sodium is obtained by dividing 100 times the milligram equivalent of sodium in the water by the sum of

105. Scofield, C. S., "Quality of Irrigation Waters": *Calif. Dept. Public Works, Division of Water Resources*, Bull. 40, 1933.

TABLE XII.

PARTIAL ANALYSES OF WATER FROM WELLS IN TEXAS COUNTY, OKLAHOMA

ANALYZED BY MARGARET D. FOSTER

(except numbers 317 & 317a which were analyzed by General Atlas Carbon Company, Pampa, Texas)

(Parts per million. Numbers correspond to well numbers in table of well records, pp. 184 to 222.)

No.	Owner	Location Sec. T. R.	Depth (feet)	Date of collection	Bicarbonate (HCO_3)	Sulphate (SO_4)[a]	Chloride (Cl)	Fluoride (F)	Total hardness as $CaCO_3$	Geologic Formation
4	Land Company	17-1N.-10E.	214	Nov. 3, 1937	213	40	17	....	237	Ogallala
20	Sunnyside School	21-1N.-11E.		Nov. 8, 1937	345	165	50	2.0	444	Alluvium
45	Cimarron Utility Co. (Texhoma)	32-1N.-12E.	[b]230	Feb. 2, 1938	230	35	16	1.0	249	Ogallala
71	Mrs. R. Ritter (Frisco School)	10-1N.-14E.	[b]100	Jan. 25, 1938	218	30	7	1.8	246	Ogallala
87	George Reust	20-1N.-15E.	[b]168	Mar. 23, 1938	224	76	9	....	246	Ogallala
113	C. C. Smart	2-1N.-18E.	12	Nov. 23, 1937	343	1,120	520	....	938	Alluvium
118	Ezra Shorb	24-1N.-18E.	[b]207	Aug. 6, 1938	34	1,800	820	....	1,478	Cloud Chief
122	L. M. Cooper	30-1N.-18E.	26	Nov. 23, 1937	261	14	28	00	360	Ogallala
126-a	Archie Campbell	1-1N.-19E.	[b]50	Aug. 6, 1938	166	925	30	....	1,312	Cloud Chief
129	Robert Johnson	7-1N.-19E.	34.5	Nov. 23, 1937	152	920	28	....	1,305	Alluvium
132-a	M. B. Kile	22-1N.-19E.	[b]100	Aug. 6, 1938	234	132	38	....	321	Ogallala
136	L. Dillard	30-1N.-19E.	66	Nov. 22, 1937	224	66	13	....	276	Ogallala
146	Jackson and Johnson	33-2N.-10E.	186.5	Feb. 8, 1938	225	20	12	....	237	Ogallala
180	Town of Goodwell	35-2N.-13E.	[b]188	Feb. 2, 1938	223	50	11	1.8	255	Ogallala
202	M. N. Buford	27-2N.-15E.	186	Mar. 23, 1938	236	72	10	....	267	Ogallala
223	L. C. Webb	21-2N.-17E.	67	Nov. 26, 1937	341	34	5	....	282	Ogallala
226	Hardesty Townsite	26-2N.-17E.		Nov. 27, 1937	218	60	32	1.4	330	Ogallala
237	O. R. Bingley	19-2N.-18E.	145	Nov. 25, 1937	258	70	24	....	340	Ogallala
238	C. E. Martin	23-2N.-18E	131	Nov. 25, 1937	240	14	20	....	258	Ogallala
242	R. O. Mason	35-2N.-18E.	141	Aug. 6, 1938	52	2,600	1,440	....	2,400	Cloud Chief

TABLE XII. (Continued)

No.	Owner	Location Sec. T. R.	Depth (feet)	Date of collection	Bicarbonate (HCO_3)	Sulphate (SO_4)[a]	Chloride (Cl)	Fluoride (F)	Total hardness as $CaCO_3$	Geologic Formation
249	Harold L. Gibson	15-2N.-19E.	17	Nov. 25, 1937	279	330	26	....	682	Alluvium
264	C. E. Beaman	26-3N.-10E.	156	Nov. 4, 1937	217	8	2	....	198	Ogallala
277	Clem Huddleston	26-3N.-11E.	[b]140	Feb. 2, 1938	243	40	14	3.8	243	Ogallala
284	Sch. Dist. 93 (Liberty)	5-3N.-12E.		Nov. 10, 1937	294	40	12	4.8	282	Ogallala
287	Stonebraker—Zea Ranch	16-3N.-12E.	[b]207	Mar. 22, 1938	261	180	49	....	186	Triassic (?) Red Beds
305	Stonebraker—Zea Ranch	29-3N.-14E.	69.5	Jan. 31, 1938	237	40	9	....	252	Ogallala
317	General Atlas Carbon Co.	28-3N.-15E.	385		347	77	18	....	280	Ogallala
317-a	General Atlas Carbon Co.	28-3N.-15E.	386		327	78	30	....	300	Ogallala
319	Okla. Elect. & Water Co. (Guymon)	31-3N.-15E.	[b]330	Nov. 27, 1937	212	40	12	1.7	261	Ogallala
326	Town of Optima	5-3N.-16E.	[b]165	Nov. 27, 1937	234	40	34	1.8	270	Ogallala
343	S. Pleasant View School	10-3N.-17E.		Nov. 27, 1937	234	60	9	1.2	300	Ogallala
360	Charles Chittenden	16-3N.-18E.	139	Dec. 4, 1937	255	70	9	....	294	Ogallala
373	J. S. Houston	4-3N.-19E.	130	Dec. 3, 1937	296	14	16	....	294	Ogallala
387	C. Dencker, Supplies School	9-4N.-10E.	[b]200	Nov. 1, 1937	284	45	7	1.9	264	Ogallala
396	Center School, Dist. 147	17-4N.-11E.	225	Dec. 17, 1937	279	70	14	2.2	294	Ogallala
397	M. W. Wright	19-4N.-11E.	155	Nov. 14, 1937	270	64	9	....	273	Ogallala
399	A. Bender	26-2N.-14E.	142.5	Dec. 10, 1937	208	62	9	....	237	Ogallala
403	B. M. & E. R. R. (Eva)	19-4N.-11E.	[b]391	Aug. 6, 1938	262	250	16	....	428	?
411	L. H. Langston	17-4N.-12E.	157	Nov. 12, 1937	221	24	10	....	225	Ogallala
412	F. B. Buzzard	25-4N.-12E.	[b]453	Jan. 27, 1938	175	500	19	....	300	Triassic (?)
421	Renfrew Investment Co.	22-4N.-13E.	155	Jan. 27, 1938	255	66	10	....	279	Ogallala
431	Konecke Estate	15-4N.-14E.	180	Mar. 23, 1938	226	27	4	....	210	Ogallala
439	Friendship Sch. Dist. 80	4-4N.-13E.	[b]151	Jan. 26, 1938	225	40	9	1.1	264	Ogallala
454	G. F. Lundgrin	16-4N.-16E.	127	Dec. 22, 1937	214	120	14	....	297	Ogallala
470	F. E. Smith	15-4N.-17E.	125	Oct. 29, 1937	212	105	10	....	315	Ogallala
484	A. Balzer	27-4N.-18E.	105	Dec. 4, 1937	299	12	5	....	309	Ogallala
499	G. D. Mires	30-4N.-19E.	119.5	Dec. 28, 1937	244	44	26	....	306	Ogallala

TABLE XII. (Continued)

No.	Owner	Location Sec. T. R.	Depth	Date of collection	Bicarbonate (HCO_3)	Sulphate (SO_4)[a]	Chloride (Cl)	Fluoride (F)	Total hardness as $CaCO_3$	Geologic Formation
514	E. R. Oswald	10-5N.-11E.	201	Nov. 11, 1937	246	40	11	....	243	Ogallala
517	L. J. Guymon (Supplies Triumph School)	25-5N.-11E.	[b]150	Dec. 17, 1937	267	10	3	1.0	267	Ogallala
524	C. T. Fowler (Sup. Sch.)	9-5N.-12E.	[b]220	Dec. 17, 1937	242	25	11	2.1	219	Ogallala
537	Blake (Supplies School)	11-5N.-13E.	207+	Mar. 22, 1938	228	56	17	1.0	270	Ogallala
538	Henry Hiller (Supplies Brown's Corner & Comet Schools)	13-5N.-13E.	[b]240	Mar. 22, 1938	223	40	8	.6	204	Ogallala
550	W. A. Albers	32-5N.-14E.	164	Mar. 23, 1938	223	21	2	....	225	Ogallala
559	J. F. Gibson (Sup. Sch.)	15-5N.-15E.	[b]160	Dec. 18, 1937	214	140	17	.0	291	Ogallala
573	J. C. Eaton	20-5N.-16E.	140	Dec. 22, 1937	205	115	14	....	330	Ogallala
585	B. F. Huebener	17-5N.-16E.	145	Dec. 14, 1937	244	50	8	....	258	Ogallala
592	Town of Hooker	34-5N.-17E.	[b]200	Dec. 9, 1937	206	150	17	.3	306	Ogallala
603	J. M. Howell	22-3N.-18E.	105	Dec. 11, 1937	205	54	25	....	285	Ogallala
605	Phoenix School	35-5N.-18E.		Dec. 4, 1937	299	10	4	1.5	279	Ogallala
613	C. H. Morehouse	14-5N.-19E.	129.5	Dec. 6, 1937	251	60	46	....	327	Ogallala
628	Denny R. Brown	31-6N.-10E.	292	Mar. 3, 1938	237	35	13	....	228	Ogallala
637	Mrs. Grace Schuss	30-6N.-11E.	245	Nov. 11, 1937	259	110	25	....	327	Ogallala
644	C. L. Griffith	21-6N.-12E.	233	Mar. 22, 1938	289	84	15	....	324	Ogallala
651	C.E.Garrett (Sup.Dist.Sch. 68 Pleasant Plains)	22-6N.-13E.	230	Mar. 22, 1938	232	72	12	.7	279	Ogallala
662	J. Gribble	25-6N.-14E.	215	Jan. 26, 1938	216	46	18	....	243	Ogallala
671	Block School, Dist. 97	29-6N.-15E.	172	Dec. 18, 1937	206	165	14	.2	303	Ogallala
680	Dague School, Dist. 86	29-6N.-16E.	172	Dec. 15, 1937	158	125	39	.3	303	Ogallala
692	Lemon School	30-6N.-17E.	165	Dec. 14, 1937	185	35	27	.0	246	Ogallala
701	Buena Vista School	20-6N.-18E.	134	Dec. 23, 1937	255	65	27	.8	309	Ogallala
702	Albert Goos	22-6N.-18E.	135	Dec. 11, 1937	197	70	25	....	249	Ogallala
706	Town of Tyrone	25-6N.-18E.	[b]285	Aug. 6, 1938	232	60	23	.8	288	Ogallala
715	C. E. Butcher	33-6N.-19E.	115	Dec. 31, 1937	228	48	14	....	228	Ogallala

[a] Approximate determination by turbidity. [b] Reported.

the milligram equivalent of calcium, magnesium, and sodium in the water:

$$\frac{\text{Milligram equivalents Na x 100}}{\text{Milligram equivalents Ca + Mg + Na}} = \text{Percent Na}$$

Waters within the lower set of limits are not likely to be harmful when used in ordinary irrigation; waters above the upper limits, however, are very likely to be unfit for irrigation, either because of their effects on the plants or because of their effects on the soil. Waters between the lower and upper limits may or may not cause injury to crops or soil, depending on the composition of the water, the characteristics of the land, and the manner in which the water is used.

The waters in the Ogallala formation that were examined were all well within the lower limits suggested above. Similar waters have been used successfully in other parts of the High Plains. Waters from the Permian and Triassic (?) red beds and some of those from alluvium may, however, be above the upper limits.

Present Development of Water Supplies from Wells

Nearly all water used in Texas County for farm, municipal, industrial, railroad, and irrigation purposes is supplied from wells. A few farmers have constructed earth dams in some of the smaller drainage courses to catch run-off waters for stock use, and stock may also use more or less water from the temporary ponds and lakes on the upland and from the perennial streams, but surface waters so used probably are but a small fraction of the total volume of water that is required.

In the present ground water investigation, records of 542 wells in the county were obtained and tabulated. Of these, 226 are farm windmill wells used for domestic and stock purposes, 213 are windmill wells not in use, 55 are windmill wells used only for stock, 24 are wells used for public supplies including schools, 20 are wells used for irrigation, 3 are wells used for industrial purposes, and 1 is a railroad well. These wells are listed in order by townships in the well tables on pages 184-222, which give the location, the topographic situation, the depth of the well and the depth to the water, the diameter of the well, the type of pumping equipment, the use to which the water is put, and so far as available the names of the owners, the nature of the water-bearing material, the yield, and other details. The wells are discussed below according to the uses to which they are put.

Domestic and Stock Wells

Most of the farm wells used for domestic and stock purposes and the private wells used for domestic purposes in the towns, are of the drilled type and are from 4 to 6 inches in diameter. Except on the flood plains of the major streams and the adjacent lower slopes of the valley bluffs, they are nearly everywhere more than 100 feet deep. They are equipped with windmills capable of pumping a few gallons of water per minute, and some also are provided with pump jacks operated by small gasoline engines for use when there is no wind. In upland farming areas there is about one well on each section of land, but in the smaller towns where many people have their own windmills there are many wells in a section. On the other hand, the wells are very widely separated along the major valleys where much of the land is in large cattle ranches. There are fewer wells in use now than formerly. According to reports, wells originally were drilled on nearly every quarter section of farm land, but many were abandoned as the average size of the farms increased and the number of families diminished. A few windmill wells are described in the following paragraphs.

F. B. Buzzard. NW¼ NW¼ sec. 25, T. 4 N., R. 12 E. (Well 412) The well is on the upland plain and appears to have been drilled into the red beds. The Ogallala formation consists of impervious material and yields little or no water (see log 412, page 178). Several previous wells at or near this place had either failed or proved unsatisfactory. One well 300 feet deep is said to have yielded only about a barrel of water a day. The present well was drilled to a depth of 453 feet, and the first water and the red beds are reported by the driller[106] at 170 feet. When the well was 300 feet deep, the water level was 143 feet below the

106. Kauffman, C. F., Gruver, Texas, personal communication.

surface, but on completion of the hole in 1936 it was only 124 feet, and as measured by the writer in 1937, it was about 128 feet. The well was cased to a depth of 396 feet, a cylinder was set at a depth of 384 feet, and the well yielded about 6.5 gallons per minute. After 5 hours the yield dropped to about 4 gallons per minute, but the water did not become clear. Gravel was put in the well, extending 5 feet up into the casing (to the 391-foot level), and the annular space outside the casing was filled with coarse sand to within 25 feet of the land surface. This procedure is said to have eliminated the sediment in the water, but the yield dropped to about 3 gallons per minute, and the water has never been satisfactory for drinking (see analysis, page 98).

Stonebraker-Zea Ranch. NW¼ sec. 16, T. 3 N., R. 12 E. (Wells 287 and 288). In November 1937, well number 288 was drilled on the bluff north of Tepee Creek and about 85 feet above the creek channel. As reported by the driller,[107] the well entered red beds, probably the Triassic (?), at a depth of about 40 feet, or about 45 feet above the stream channel. When the well was 126 feet deep, the water level as measured by the writer was 111 feet below the surface. The well was abandoned as too weak, and well number 287 was then drilled about half a mile to the southeast on the floodplain of Tepee Creek and about 20 feet above the channel. The driller reported a total depth of 207 feet in the second well, and a yield of 6 gallons a minute from a 38-foot red sand. The static water level as measured by the writer on July 25, 1938, was 53 feet below the surface. Red beds were reported at a depth of 78 feet. Partial analysis of the water from this well is given in the table of analyses as number 287.

DISCHARGE OF WINDMILL WELLS

The Panhandle Experiment Station[108] at Goodwell has been making tests of wind velocity since 1925, and in connection with this work conducted tests on the amount of water pumped by a windmill used for irrigation of a garden. The windmill was a 12-foot mill on a 30-foot tower, with a 2¼-inch cylinder. It operated on a 6-inch direct stroke and the pumping lift was 140 feet. The water was measured with a meter as it passed through a 2-inch pipe. The published record is not continuous because the data for periods when the windmill was not in good condition were discarded.

107. Freeman, Frank, oral communication.
108. Finnell, H. H., "Agricultural Significance of Climatic Features at Goodwell Oklahoma": *Panhandle Agri. Exp. Sta., The Panhandle Bulletin*, No. 40, pp. 26-30, 1932.

AVERAGE NUMBER OF GALLONS OF WATER PUMPED PER DAY BY A WINDMILL

Month	Gallons of water per day
January	1,065
February	1,175
March	1,618
April	2,087
May	1,798
June	1,469
July	1,661
August	1,033
September	1,788
October	1,339
November	1,425
December	1,425

WELLS USED FOR PUBLIC SUPPLIES

The larger towns are supplied from wells through waterworks including power-driven pumps, elevated tanks, and distributing systems. The wells average deeper and are of larger size and yield than the farm and stock wells. The following paragraphs summarize the significant data regarding the wells in each of the towns.

Guymon is served by the Oklahoma Electric and Water Company, which has two wells about 60 feet apart located about a block northeast of the Chicago, Rock Island, and Pacific Railroad station. The newer well was drilled in 1929 and is 330 feet deep (see log 319). The other is old, and no log of it could be obtained. Both wells are cased with 14-inch iron casing perforated below the water table, are gravel packed, and are equipped with turbine pumps. The older well is operated by an electric motor rated at 40 horsepower, and yields 285 gallons per minute with a draw-down of 9 feet. The newer well is operated by an electric motor rated at 35 horsepower, and yields

251 gallons per minute with a drawdown of 7 feet. The wells are pumped alternately. The static water level is reported as 190 feet, which seems unusually deep as compared with that of wells located within 2 miles to the northeast, northwest and southwest. Thus wells 188, 304, and 317 are located at comparable elevations, and the water levels in them were measured as about 125 feet, 125 feet, and 134 feet, respectively. On the other hand, the measured water level in well 198, which is located 2.25 miles to the southeast, is about 179 feet. Partial analysis of water from the Guymon supply is given in table XII as number 319.

The city of Guymon also has a municipal well for pumping water to fill the swimming pool and irrigate trees in the park (no. 320). As reported by Hugh Willoughby,[109] this well was begun by digging and completed by drilling methods in 1936. It is on the flood plain of Beaver River, about 2 miles north of town, is 57 feet deep, and is cased between depths of 9 and 57 feet with 12½-inch perforated iron casing. It penetrates a total of about 40 feet of water-bearing sand and fine gravel, with most of the water coming from a coarse sand and pea gravel between depths of 48 and 57 feet. (See log 320). The water level as measured by the writer on August 11, 1938, was about 12.28 feet below the land surface. The well is equipped with a centrifugal pump of 480 gallons per minute capacity, driven by a 40-horsepower combine engine adapted for the use of natural gas. This power unit is larger than necessary, having been selected largely on the basis of availability. The well is reported to yield 225 gallons per minute, and the drawdown as measured August 11, 1938, was 20.5 feet. Mr. Willoughby estimates that this well could be duplicated, complete with pump, power plant, and concrete pit, for $750. A piston pump and an auxiliary 15-horsepower engine are used to pump the water through 2 miles of 6-inch pipe to the park.

Hooker supplies its own water from four closely spaced wells about a block southwest of the Chicago, Rock Island, and Pacific Railroad station. The first well was drilled in 1907 and the second in 1917. These two are 200 feet deep and are cased to

109. Willoughby, Hugh, City Engineer, Guymon, Oral communication.

the bottom with 6-inch iron casing, the lowermost 60 feet of which is perforated. Both are equipped with 4-inch cylinder pumps set between 140 and 150 feet deep, driven by 7½-horsepower electric motors. They are reported to yield 60 gallons per minute each. The third well was drilled in 1931 and the fourth one in 1933. These two are 260 feet deep and are cased with 8-inch iron casing, the lower 60 feet of which is perforated, and have a gravel wall 4 inches thick outside the casing. Both are pumped by the air-lift method. There are two electric motors rated at 50 and 75 horsepower each, and two air compressors. Either motor and compressor can be used to pump either well, and both wells are used chiefly when the load is too great for the cylinder wells. The yield of these wells could not be obtained. The static water level is reported to be about 140 feet below the land surface. Two booster pumps are used to raise the water into the water tower. Partial analysis of water from this supply is given in table XII as number 592.

Texhoma is served by the Cimarron Utilities Company. The well is 230 feet deep, with a static water level of 210 feet, and yields 100 gallons per minute with a drawdown of 13 feet. Analysis of water from this well is given in the table of analyses as number 45.

Goodwell supplies its own water from two closely spaced wells located across the street from the Panhandle Agricultural and Mechanical College. These wells are reported to be 188 feet deep, with a static water level of about 150 feet. Both are cased with iron casing, the lower 20 feet of which is perforated. One is 6 inches and the other 8 inches in diameter. The larger well is equipped with a turbine pump operated by an electric motor rated at 20 horsepower, and yields about 120 gallons per minute. The drawdown is not known. The other well is equipped with a lift pump operated by an electric motor rated at 5 horsepower. It is reported to yield 11 or 12 gallons per minute, and is used chiefly to supplement the larger well. Partial analyses of water from the larger well is given in the table of analyses as number 180.

Tyrone supplies its own water from two wells which are reported to be 285 feet deep. They are cased to the bottom with 14-inch steel casing, the lower part of which is perforated for each of five water-bearing beds. The wells are not gravel packed. They are equipped with cylinder pumps, and each is driven by an electric motor rated at 10 horsepower. They yield about 65 gallons per minute each. The first water is reported at a depth of 95 feet.[110] Partial analysis of water from the eastern well is given in table XII, as number 706.

Hardesty is partly supplied with water from a windmill that is owned and operated by the town. The depth and water level of the well are not known. Partial analysis of water from this well is given in the table of analyses as number 226. Some residents also use water from private windmill wells, but these were not sampled.

Optima is partly supplied with water from a windmill well owned and operated by the town. It is said to be 165 feet deep, and is cased to the bottom with 6-inch iron casing. The static water level is reported as 109 feet below the surface. Partial analysis of water from this well is given in the table of analyses as number 326. Some residents also use water from private windmill wells, but these were not sampled.

Bakersburg, Mouser, Hough, and Eva are supplied with water from private windmill wells, and were not sampled except for the M. W. Wright well at Eva, the analysis for which is reported as number 397.

WELLS USED FOR INDUSTRIAL AND RAILROAD PURPOSES

There are only a few wells in Texas County that are used exclusively for industrial purposes, even including the wells that are drilled to provide temporary supplies of water for the drilling of gas test wells. These few are described below, together with several railroad wells.

General Atlas Carbon Co. (Wells 317, 317-a). In January 1938, two wells were completed for the General Atlas Carbon Co. at the site of a proposed plant for the manufacture of carbon

110. Fraim, Dewey, pump superintendent, personal communication.

black about 1.5 miles northeast of Guymon, in the NW¼ NW¼ sec. 28, T. 3 N., R. 15 E. The wells were drilled by the rotary hydraulic method to depths of 385 and 386 feet, are cased with 12-inch iron casing perforated below the water level, and have gravel walls about 9 inches thick. The water level in the southern well was measured by the writer on March 21, 1938, as 133.92 feet below the surface. This well is shown on the map and is listed in the tables of well records and logs as number 317. The log shows it penetrated a total of about 192 feet of sands, gravels, and sandstone below the static water level. It is reported to have yielded 628 gallons a minute with a 10-foot drawdown (specific capacity 62.8).[111] The water level in the northern well was not measured, but it probably is very close to 134 feet below the surface,as the two wells are only 150 feet apart and there is little difference in elevation of the ground at the two wells. The log (number 317-a) shows about 114 feet of sands, gravels, and sandstones below the 134-foot level, but those below 300 feet are not as clean as those in well 317. This well is reported to have yielded 588 gallons a minute with a drawdown of 17.5 feet (specific capacity 33.6). Permanent pumping equipment had not been installed at the time of writing.

Hagy, Harrington and Marsh Company[112] (Well 63). In the fall of 1937 the Hagy, Harrington and Marsh Company had a water well drilled in the NE¼ sec. 5, T. 1 N., R. 13 E., to supply water for the drilling of two gas test wells. This well was originally 190 feet deep, and was cased to the bottom with 8-inch iron casing, of which the lower 15 feet was perforated. The water-bearing bed was reported as sand occurring between the depths 172 and 188 feet, and the water level was said to be 158 feet below the surface. However, the well proved inadequate to supply the water needed, and it was deepened to 203 feet, but no more casing was set. At this depth it penetrated between 1 and 2 feet of water-bearing gravel, and the water level is said to have risen to the 153-foot level.

111. Perry, Frank M., General Atlas Carbon Co., personal communication.
112. Wagner T. J., of the Hagy, Harrington and Marsh Co., and T. E. Butler, driller, oral communications.

Kuhn Brothers (Well 188). In January 1938 Kuhn Brothers had a water well drilled in the NW¼ sec. 1, T. 2 N., R. 14 E., to supply water for the drilling of a gas test well. According to the driller,[113] this well is 265 feet deep and draws at least part of the water from a sand at the bottom of the well. However, this sand did not show up in the drilling of the adjacent gas test well, which is reported to have entered the red beds beneath the Ogallala at a depth of 205 feet. The well was cased with 6⅝-inch iron casing, and was pumped by jetting with natural gas. The driller estimated the yield at 50 gallons per minute.

Chicago, Rock Island, and Pacific Railroad.[114] The Rock Island Railroad uses two wells at Hooker. One well is 163 feet deep and is cased with 12-inch casing. The water level is 138 feet below the surface, the yield 60 gallons per minute, and the drawdown 3 feet. The other well is 230 feet deep, and the 12-inch casing extends to a depth of 212 feet. It is equipped with a 10-inch by 30-foot Cook screen. The water level is 148 feet, the yield 60 gallons per minute, and the drawdown about 3 feet.

The railroad well at Optima is 115 feet deep. It is cased with 7-inch casing to a depth of 114 feet, and the water level is 83 feet below the land surface. It is pumped with a windmill and yields about 10 gallons per minute without appreciable drawdown.

The railroad well at Goodwell is reported to be 200 feet deep, and is cased with 12-inch casing to a depth of 182 feet. It is equipped with a 10-inch by 20-foot Cook screen, and is pumped with a double-acting cylinder driven by a semi-diesel engine rated at 15 horsepower. It yields a maximum of 123 gallons per minute, with 5 feet of drawdown.

Beaver, Meade and Englewood Railroad (No. 403). The well used by the Beaver, Meade and Engelwood (Missouri-Kansas-Texas) Railroad at Eva is of especial interest because it is exceptionally deep. If a log was kept, it has since been lost, but neighbors report that much shale or clay was encountered in the

113. Kilbourn, L. J., Oral Communication.
114. Information supplied from company files.

drilling, and that the driller had little hope of obtaining a good well. Louis A. Baker[115], of the company which backed the project, reports a total depth of 493 feet. The only clearly recognized water-bearing bed of which there is a record occurs at a depth of 205 feet. Yellow clay was encountered at 175 feet, and a very hard material whose nature was not recorded, at 275 feet. The hole was filled with gravel to the 300-foot level, and cased with 8-inch casing, a part of which was perforated. It was equipped with a 4-inch drop pipe and a ¾-inch by 36-inch brass cylinder, and is operated by a gasoline engine rated at 10 horsepower. In a 3-hour test it yielded 40 gallons per minute. The water level is reported as 194 feet, and is deeper than might be expected, for the water level in the M. W. Wright well, which is located only a quarter of a mile to the southeast, was measured as 152 feet, and the water level in well 390, which is a little over a mile to the west-southwest, is only 165.4 feet. However, the measured water levels in this general locality vary within wide limits, and one driller[116] reports that the distribution of water-bearing beds and the depths to water are erratic.

WELLS USED FOR IRRIGATION

As a result of the succession of dry years from 1931 through 1937 there has been increasing interest on the part of Texas County farmers in the possibilities of irrigating from deep wells. Their interest has been somewhat strengthened by the hope that development of the gas field in the central part of the county would supply fuel for pumping the water at a cost low enough to overcome the obvious disadvantage of high pumping lifts. Actual development of irrigation plants has been held back by the fact that the gas is not available for immediate use in most parts of the county and by a general lack of ready funds.

Only a small beginning has been made. About 1932 Thomas Chance and J. J. Kimball, Jr., fitted up an old well located on the flood plain of North Fork, and have been irrigating from it since. In 1934 W. N. Ballinger began irrigating a few acres of low-lying land near Beaver River, north of Guymon, and in

115. Baker, L. A., Hardtner, Kansas, personal communication.
116. Sanborn, G. C., driller, oral communication.

1936 R. M. Van Hyning and his son, T. M. Van Hyning, installed irrigation plants located on the upland about half way between Adams and Bakersburg. In 1937 the Panhandle Agricultural and Mechanical College began experimental irrigation from two wells at Goodwell, and a few relatively shallow wells in valley bottoms were in use or were being drilled. The available information on the existing irrigation wells is summarized below. The four wells that are located on upland plains are described first because they most nearly represent the conditions which prevail in about three-fourths of the county.

Dr. W. A. Hodges. NW¼ NW¼ NE¼ sec. 21, T. 4 N., R. 19 E., leased to T. M. Van Hyning. (Well 496). The well is on the upland plain, and is 262 feet deep. It is cased with 12½-inch iron casing from the surface to a depth of 200 feet, and with 8-inch casing from 200 feet to the bottom, and is not gravel packed. The casing is perforated from 100 feet to the bottom. The reported water level is 105 feet below the land surface. Between depths of 120 and 262 feet, the well penetrates 47 feet of saturated sands which are interbedded with clays. (See log, page 179) It is equipped with a number 10 turbine pump and a geared head, and is operated by a permanently-installed 8-cylinder gasoline engine. The yield is reported as 550 gallons per minute. The drawdown has not been measured. The contract price of this well equipped with the pump and geared head was $2,710. About 50 acres of land was irrigated in the fall of 1936, and in the spring of 1937 about 20 acres of wheat and 80 acres of feed were irrigated. It is estimated that this well produced about 37.5 acre-feet of water in 1938.

R. M. Van Hyning. NW¼ NW¼ SW¼ sec. 21, T. 4 N., R. 19 E. (Well 497). The well is on the upland plain and is 280 feet deep. It is cased with 12½-inch iron casing to a depth of 186 feet, and with 8-inch casing from 186 feet to the bottom, and is not gravel packed. The casing is perforated from a depth of 100 feet to the bottom. The first well drilled at this locality failed when the casing broke, and a second was drilled about 25 feet distant. The water level in the unused well as measured by the writer on September 13, 1937, was 104.8 feet below the top of the steel drum used to cover the hole. Between depths of 100 and 280 feet the driller's log shows 81 feet of saturated sands interbedded with clays. (See log, page 179). The well is equipped with a turbine pump of 800 gallons per minute capacity and is operated by a Model L Case tractor. It is reported to yield 450 gallons per minute, with a drawdown of 38 feet after 3 hours of operation. This well at first gave considerable trouble because sand entered it, but in September 1937 the owner reported that alterations in the installation had at least partly overcome this difficulty. In 1938 it was used to pump about 56 acre-feet of water. The contract price of the well, including the pump, was $2,300.

PANHANDLE AGRICULTURAL AND MECHANICAL COLLEGE, GOODWELL

The College has two experimental wells that are used to supply water for irrigation, both of which were drilled in 1937. One well is on the college campus, in the town of Goodwell, and the other and larger well is at the experimental farm a little over a mile east of Goodwell.

College Campus well, NE¼ NE¼ SE¼ sec. 34, T. 2 N., R. 13 E. (Well 179). The well is on top of a broad, gentle rise on the upland plain. The driller's log (page 175) shows a total depth of 251 feet, but this is the depth of the initial, small-diameter test well, and the president of the college[117] reported the depth of the completed irrigation well as about 238 feet. The well is cased to the bottom with 12-inch iron casing which is perforated below the water table, and is gravel packed. The water level is reported as 135 feet below the land surface in 1937. Between depths of 135 and 238 feet, the driller's log shows 80 feet of saturated sands, of which 40 feet is coarse enough to be considered good water sand. The well is equipped with a turbine pump of 500 gallons per minute capacity, and is operated by an electric motor rated at 20 horsepower. It was tested at 425 gallons per minute and found to have a drawdown of 30 feet, but normally yields about 300 gallons per minute. The temperature of the water as measured by the writer in September 1937 was 62° F. It was used to irrigate about 30 acres, part of which

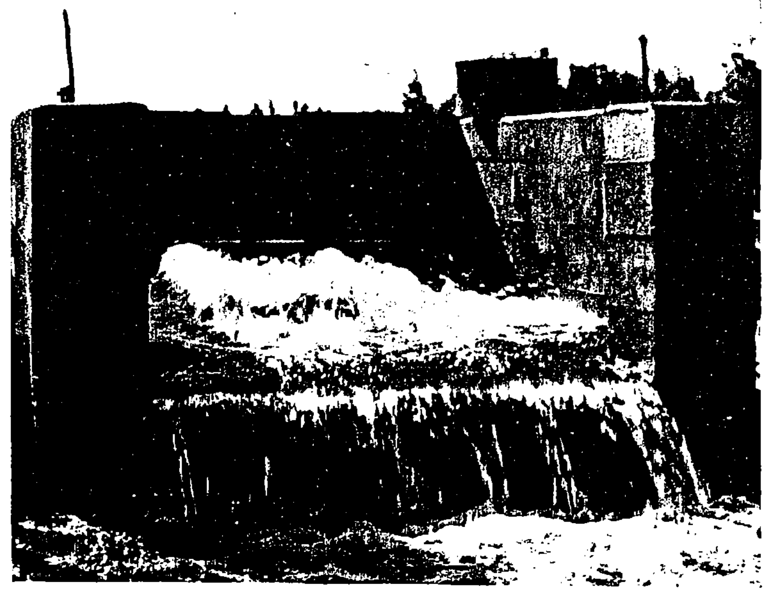
117. Morrison, E., oral communication.

was in row crop, during the last half of the summer of 1937, and also was used to supply water for college lawns and trees.

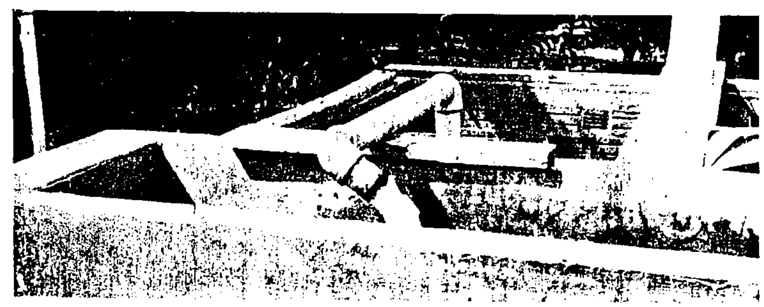
College Farm well, SE¼ NW¼ sec. 36, T. 2 N., R. 13 E. (Well 181). The well is on the upland plain and is 298 feet deep. It is cased with 18-inch iron casing, the lower 190 feet of which is perforated, and is gravel packed. The gravel walls are about 2 feet thick. The water level was measured as 118 feet below the land surface in November 1938. Between depths of 120 and 300 feet, the driller's log of the preliminary test well shows a total of 160 feet of saturated sand and gravel, and some sandstones from which water may be available. (See log, page 175). The well is equipped with a Deming-Mueller centrifugal pump with six 10-inch stages set at a depth of 230 feet, and a Johnson right-angle drive. It is operated by an Allis-Chalmers natural gas engine capable of producing 92 horsepower at 1,150 r. p. m. Initial tests with the driller's pumping equipment showed a yield of about 680 gallons per minute with a drawdown of 27 feet, but after installation of the permanent equipment described above, the yield was increased. Using a wier, W. L. Broadhurst measured the yield of the well in February 1939 as 960 gallons a minute.

The well is fitted with an air line and air pressure gage for making depth to water measurements. During the 1938 pumping season two measurements of the water level were made each time the pump was operated—one just before pumping was started and the other just before the pump was shut down. The difference between the water levels in these two measurements is called the drawdown. A summary of the data obtained by the College is shown in the following tables. The average drawdown was computed to be 35.8 feet.

The table shows that a total of about 191 acre-feet of water was pumped between April 4 and October 7. In addition some pumping was done during the first three months of the year, and the estimated pumpage for 1938 was about 288 acre-feet.



A. Irrigation well at Experimental Farm, Panhandle A. and M. College, Goodwell. (No. 181). A deep well on the upland flat. Measured discharge, 960 gallons of water a minute. (Photo courtesy of Pres. Morrison, Panhandle A. and M. College).

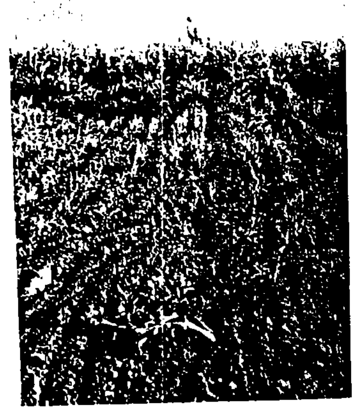


B. Irrigation well of W. N. Ballinger (No. 176). A 30-foot well on the Beaver River flood plain north of Guymon. Reported dicharge, 100 gallons of water a minute.

PLATE V

A. Sand blown off neglected fields accumulates around bushes. It also piles up around buildings and along fences, and drifts into roads. Picture taken about 12 miles north of Guymon, August 31, 1938.

B. Sweet Stalk Kaffir corn grown under irrigation with well water at Panhandle A. and M. College.



C. The difference water makes. The two crops were planted identically, but that in the background was irrigated. (B and C courtesy of Pres. Morrison, Panhandle A. and M. College).

DRAWDOWN IN RELATION TO THE LENGTH OF THE PUMPING PERIOD

Period of pumping (Hours)	Average drawdown (Feet)
0-5	32.9
5-10	35.8
10-24	36.7

MONTHLY PUMPAGE AND DRAWDOWN

	Hours of pumping	Quantity of water in acre-feet[1]		Average depth to water when pump was started[2] (feet)	Average drawdown[2] (feet)
		During Period	Total		
April 4 to 30	106	18.7	18.7	117	32.8
May 2 to 28	105.5	18.6	37.3	118	33.5
June 3 to 30	195.5	34.6	71.9	116	37.6
July 1 to 20	176.8	31.4	103.3	117	39.0
August 1 to 21	411.7	73.0	176.3	119[3]	34.6
September 1 to 30	44.0	7.8	184.1	117.5	36.9
October 3 to 7	40.2	7.1	191.2	116.5	36.4

[1] Figures based on discharge of 960 gallons a minute, as measured by W. L. Broadhurst, 1939.

[2] Measured by air line and pressure gage. The gage is about one foot above the land surface.

[3] Figure for August includes only measurements on days when pumping time for the preceding day was not more than 18 hours.

Lester Sparks. NW¼ NW¼ NE¼ sec. 5, T. 3 N., R. 11 E. (Well 281). This well is on the upland plain about 2.5 miles southeast of Eva, and is 118 feet deep. The static water level as measured by the writer on August 28, 1938, was about 87.6 feet below the land surface. At a depth of 101 feet the drill encountered a very fine-grained and very calcareous sandstone, and the water is said to come from a 6-inch layer of sand which is interbedded with this sandstone at a depth of 103 feet (see log 281). As tested with a bailer, the well yielded about 11 gallons per minute. It is cased with 15-inch iron casing to a depth of 15 feet only. At the time of writing, permanent pumping equipment had not been installed.

Thomas Chance and J. J. Kimball, Jr. NE¼ sec. 32, T. 2 N., R. 12 E. (Well 165). The well is on the flood plain of North Fork about half a mile from where the fork joins Beaver River, and is 59.5 feet deep. It was dug in 1920 by J. J. Kimball, Sr., who reports that it penetrates 36.8 feet of saturated gravel between depths of 22.7 and 59.5 feet. It is cased with 20-inch, perforated, galvanized iron casing between the depths of 21.5 and 59.5 feet.

The water level as measured by the writer on November 10, 1937, was about 22.75 feet below the land surface. It is equipped with a vertical centrifugal pump with a capacity of 500 gallons per minute, and is operated by a kerosene combine engine of about 15-horsepower. It is reported to yield 500 gallons per minute with a drawdown of 19 feet after 24 hours of pumping. Although the well was completed in 1920, it was not consistently used for irrigation until about 1932. The original cost for casing, pump, engine, and other equipment is reported to have been about $1,000,[118] but when regular irrigation was begun in 1932 another pump, engine, belt, and other equipment were installed at a cost of about $175. No charge for labor in digging the well is included in the above figures. In 1938 irrigation of 30 acres of alfalfa was begun on March 20, with expectations of increasing the total area irrigated by about 15 acres as the season advanced.

Louis Latham. NE¼ sec. 1, T. 1 N., R. 14 E., operated in 1937 by T. B. Terrell. (Wells 65 and 66). Two wells side by side are on a slope a few feet above the flood plain of Frisco Creek. One is 22 feet deep and is cased with iron casing, the lower 10 feet of which is perforated. The other is about 37 feet deep and is cased with 5-inch iron casing, part of which is perforated. The water-bearing bed was reported as quicksand. The water level as measured on September 3, 1937, was about 11.57 feet below the land surface. The wells are equipped with 2-inch centrifugal pumps reported to have a capacity of 200 gallons per minute, either of which can be operated by a 4-cylinder automobile engine rated at 20 horsepower. The deeper well is reported to yield about 100 gallons per minute, and the drawdown was measured as 4.64 feet after the well had been pumping about 3 hours. The temperature of the water was measured as 60.5° F. in September, 1937. The wells were drilled in 1935, and irrigation of a small tract on an experimental basis in 1937 produced a satisfactory crop. No irrigation from these wells was attempted in 1938.

Mrs. M. F. Douglas. NW¼ sec. 6, T. 1 N., R. 15 E., leased to Alfred Ritter. (Well 84). The well is on the bluff of a minor

118. Chance, T., personal communication.

gulley and is a few feet above the flood plain of Frisco Creek. It is 19.5 feet deep, and is said to have been dug to, but not into, the coarse sand from which the water comes. It is cased with 28-inch iron casing to a depth of 16 feet, the lower 3.5 feet being left as open hole. The water level was measured on September 2, 1937, as 12.13 feet below the southwest end of the frame which supports the engine. The well is equipped with a 2-inch centrifugal pump said to have a capacity of 220 gallons per minute, and is operated by a 4-cylinder gasoline engine rated at 17 horsepower. The yield is reported as 150 gallons per minute, and the drawdown was measured as 3.4 feet after the well had been pumping for half an hour. The temperature of the water was measured as 63° F. in September 1937. This well was completed in the winter of 1936-1937, and was used in the summer of 1937 to irrigate about 2 acres, although Ritter considered it adequate for a larger area. The original cost of this well was exceptionally low because Ritter did the work himself.

Robert Johnson. SE¼ NW¼ sec. 7, T. 1 N., R. 19 E. (No. 130). Two wells, about 40 feet apart, are on the flood plain of Paloduro Creek and 300 to 500 feet east of the channel, and are 29.5 and 34.5 feet deep. Both wells are cased with 20-inch, ring-type, concrete casing and are gravel-packed. The gravel wall is 8 inches thick. The water level as measured on November 24, 1937, was 2.22 feet below the edge of the casing in the northern well, or about 7.12 feet below the land surface. The wells are reported to penetrate saturated gravel and quicksand extending from a depth of 7.5 feet to their bottoms at 29.5 and 34.5 feet. Pumping equipment had not been installed when the writer visited the wells, but the plan was to operate both wells with one 5-inch centrifugal pump rated at 1,000 gallons per minute, driven by a combine engine. For partial analysis of water from a nearby well that probably is in essentially the same water-bearing bed, see number 129.

Harold L. Gibson. SW¼ SW¼ SE¼ sec. 15, T. 2 N., R. 19 E. (see no. 249). Four closely-spaced dug wells are on the flood plain of Paloduro Creek and range from 17 to 20 feet deep. They are cased with 20-inch, ring-type, concrete casing, and are gravel-packed. The gravel walls are 8 inches thick. The water level as measured in the easternmost well on November 24, 1937, was about 8.4 feet below the land surface. The deeper wells penetrate 12 feet of saturated gravel between depths of 8 and 20 feet. (See log 249, page 176). The wells are equipped with a centrifugal pump rated at 250 gallons per minute and are operated by a 4-cylinder automobile engine rated at 20 horsepower. The yield of three of the wells pumping together was measured as 86 gallons a minute on August 6, 1938. The drawdown is reported as 6 or 7 feet for each well after operating 1.5 hours. In 1937 three of the wells were used to irrigate 6 acres of land. The cost of putting the wells down was $6.50 per foot, including the gravel envelope and casing. The total cost of the plant is reported as between $550 and $600. For a partial analysis of water from an adjacent domestic well which is in the same water-bearing bed see number 249, page 98.

W. N. Ballinger. SW¼ SW¼ SW¼ sec. 18, T. 3 N., R. 15 E. (Well 176). The well is on the flood plain of Beaver River due north of Guymon, and is 30 feet deep. It is cased from a depth of 5.2 to 30 feet with 19-inch galvanized iron casing perforated with ¼-inch holes, which is set on a bed of clay. The water level as measured on September 4, 1937, was 3.71 feet below the edge of the casing, or about 8.9 feet below the land surface. Subsequent measurements of the water level are reported in the section on observation wells. The well penetrates 16 feet of saturated coarse gravel between depths of 14 and 30 feet. (See log 176-a, page 174. This log is the record of the immediately adjacent windmill well, which was deepened in 1937.) The well is equipped with a centrifugal pump rated at 300 gallons per minute and is operated by a combine engine adapted to use natural gas. The yield was measured as 100 gallons per minute, and the drawdown was measured as 12.8 feet after 5 hours of pumping. The temperature of the water was measured as 58° F. in August 1937. Irrigation was begun in 1934, and during the period from April to October this well is pumped about 8 hours per day. In 1937 an area of about 8 acres was irrigated and trees were watered. In 1938 the area under irrigation was increased to 11 or 12 acres,

and the well was pumped about 8 hours per day for a total of 90 days. It is estimated that about 13 acre-feet of water was pumped during the 1938 season.

Dr. Lee and McJ. Moore. SW¼ NE¼ sec. 15, T. 3 N., R. 15 E. (Well 314). The well is on the bluff of Beaver River a few feet above the flood plain, and is 70 feet deep. It is cased from a depth of 9 to 70 feet with 12½-inch iron casing, of which the lower 52 feet is perforated. As measured on September 16, 1937, the water level was about 11.4 feet below the land surface. The well penetrates 15 feet of saturated quicksand between depths of 12 and 27 feet, and 10 feet of coarse gravel between depths of 60 and 70 feet. It is equipped with a centrifugal pump of 200 gallons per minute capacity, and is operated by a gasoline engine. The yield is reported as 200 gallons per minute, and the drawdown is 20 feet. This well was completed in May 1937, and irrigation of 5 acres was begun, but was not successful for reasons not connected with the operation of the pumping plant.

M. A. Costner (two wells). Well 315, SW¼ NW¼ sec. 17, T. 3 N., R. 17 E. The well is on the bluff on the north side of Goff Creek about 10 feet above the channel, and is about 33 feet deep. It is cased with steel oil drums about 36 inches in diameter. The water level as measured on October 2, 1937, was 30.49 feet below the board cover over the pit. This well was completed in July 1936 and was used during the rest of that season, but when visited by the writer in 1937 was not equipped with pump or engine.

Well 316, SE¼ NE¼ sec. 18, T. 3 N., R. 15 E. This well is located on the flood plain of Goff Creek, and is 26 feet deep. Like well 315, it is cased with steel oil drums about 36 inches in diameter. The water level as measured on October 2, 1937, was 17 feet below the land surface. The well is equipped with a small pump and a gasoline engine of about 1½ horsepower. It was completed in April 1937, and was used to water a garden during the rest of the 1937 season.

C. A. Nash. NW¼ NW¼ sec. 18, T. 3 N., R. 16 E. (Well 350). The well is on the flood plain of Beaver River, and is 35 feet deep. It is cased from a depth of 4 to 35 feet with 19-inch galvanized iron casing, of which the lower 21 feet is perforated. The water level as measured October 2, 1937, was about 7.7 feet below the land surface. Subsequent measurements of the water level are reported in the section on observation wells. This well was drilled for irrigation purposes in 1934, and was equipped with a 4-inch centrifugal pump. However, it did not yield enough water, and therefore was equipped with a 5-inch cylinder and a windmill. In 1937 no irrigation was attempted.

POSSIBILITIES OF DEVELOPING ADDITIONAL WATER SUPPLIES FROM WELLS FOR IRRIGATION

The feasibility of developing additional water supplies from wells for irrigation in Texas County depends upon complex geologic, economic, and agricultural factors which can be considered here only in part. From the geologic point of view, successful irrigation from wells depends on (1) the depth to the water, (2) the permeability and thickness of the water-bearing materials, and (3) the amount of water that can be pumped from the underground reservoir without causing excessive depletion. The first factor—depth to water—largely determines the depth of wells and the costs of drilling, of pumping equipment, and of operation. The second factor—permeability and thickness of materials—also has a bearing on the depth and construction of wells and on installation and operating costs. These first two factors determine the success of the individual pumping plant. The third factor—safe yield of the reservoir—depends on the capacity of the reservoir and on the amount of annual recharge. It limits the total amount of development in a given area, and in the long run, it may also determine the success of the individual pumping plant.

Plate I shows that depths to water differ greatly in Texas County, even from one part of the uplands to another, and therefore that some parts of the area offer a much better opportunity for irrigation from wells than others, the best being an area of about 80 square miles between Optima, Tyrone, and Adams. Here the water table ranges from 70 to 100 feet below the sur-

face, the saturated part of the Ogallala appears to be thick, the land surface is relatively flat, and the soil is good.

On the flood plains of the major valleys, the water table is generally near the surface but such areas are second in importance because the soil is less favorable than that of the uplands and there is possibility of damage by flooding.

An area of upland near Eva has ground water that is nearer the surface than in the Optima-Tyrone-Adams locality, but there are indications that the amount of water is inadequate.

In the Range area, in the southeastern corner of the county, the water table is also near the surface, but much of the Ogallala formation which elsewhere supplies most of the ground water, has been removed by erosion, and in what remains the saturated part is thin. Many of the domestic and stock wells in this area yield highly mineralized water from the Permian red beds. There are considerable areas of poor soil and the topography is uneven.

The principal water-bearing formation in Texas County is the Ogallala, of Pliocene age. The formation is highly variable, and some wells are likely to encounter much more and better sands than others. The sands generally are unconsolidated, so that it is necessary to case the wells to the bottom to prevent caving, and in the larger wells a gravel wall outside the casing may be required. Where the sands are coarse enough, an appropriate screen may be adequate to keep the sand out. Sieve analyses of carefully selected samples of water-bearing sands obtained from preliminary test holes should indicate whether gravel packing is necessary, and if not, what type of screen should be used.

The thickness of the saturated portion of the Ogallala varies markedly, being greatest where the formation itself is thickest. Preliminary studies based on the logs of gas tests and deep water wells indicate that the Ogallala may be 500 or 600 feet thick in the northern and northeastern part of the county (see fig. 3). In part, the area of thick Ogallala is also an area of relatively shallow water levels, and the zone of saturation may range from 200 to 500 feet thick. Furthermore, coarse, water-bearing sands and gravels may be relatively abundant. The available information, however, is scanty, and test drilling should be done to verify it.

The permeability of the water-bearing beds as indicated by the yield of the existing large wells is good, but these wells represent a relatively small part of the county. When test drilling is undertaken, the depth, thickness, and character of all the beds encountered should be logged, the water-bearing beds should be carefully sampled, and laboratory tests should be made to determine the texture, permeability, and possible water-yielding capacity of each bed. Actual pumping tests might be made in the more favorable localities, such as the Optima-Tyrone-Adams shallow-water area.

WATER SUPPLIES FROM WELLS FOR IRRIGATION IN THE HIGH PLAINS IN TEXAS AND KANSAS

The following brief descriptions are offered of ground water developments for irrigation in the High Plains in Texas and Kansas. It should be understood, however, that the depths to the water level, the yield of wells, and the supply perennially available differ greatly from place to place within the High Plains, and that these differences affect the costs of installation and operation and otherwise limit the feasibility of irrigation developments.

High Plains of Texas. According to White, Broadhurst and Lang[119] irrigation of wheat and cotton with water from wells has been practiced in the vicinity of Plainview, Texas, since 1911. Until 1933 or 1934, there were relatively few wells in use, but the succession of dry years beginning about 1931, coupled with the known results from existing irrigation wells, brought increasing interest and activity. Beginning about 1934, many new pumping plants were installed, and the number was very greatly increased in 1937.

The present development is in 5 districts which center about Plainview, Lubbock, Muleshoe, Hereford, and Texline, and includes about 4,000 square miles in parts of 14 counties. Based on statements of owners, it is estimated that some 160,000 acres were irrigated in 1937 from about 1,150 wells, which pumped

119. White, W. N., Broadhurst, W. L., and Lang, J. W., "Ground Water in the High Plains in Texas," *Geol. Survey, U. S. Dept. Interior and Texas State Board of Water Engineers*, Mimeographed memorandum, July 1938; and oral communications.

about 129,000 acre-feet of water. This is an average of about 112 acre-feet per well.

The average water level in the irrigated areas is about 60 or 65 feet below the surface. Most of the wells are from 150 to 300 feet deep, from 14 to 26 inches in diameter, and are cased to the bottom with iron casing which is perforated below the water table. However, the water-bearing sands are somewhat consolidated, and some wells are cased only to the water table, some are cased only below the water table and some are uncased. Few wells are gravel-packed. The yield of the wells ranges from 500 to about 2,000 gallons per minute, and averages about 750. All of the newer wells are equipped with turbine pumps and most are operated by gasoline engines, commonly tractor engines. In the area around Plainview in 1937, about 75 percent of the wells were pumped by gasoline engines. In the Hereford district, also in 1937, there were 130 gasoline engines, 16 electric motors, 16 diesel or oil engines, and 11 natural gas engines in use, and at Muleshoe there were 100 gasoline engines, 8 diesel or oil engines, 3 or 4 natural gas engines and 1 electric motor.

The following estimate of the cost of drilling and casing a 200-foot well and providing pump and power plant has been made on the basis of prevailing costs in the Plainview district.

AVERAGE COST OF IRRIGATION WELL IN PLAINVIEW DISTRICT, TEXAS.

Drilling	200 feet at $1.60 per foot	$ 320
Casing	200 feet at $1.50 per foot	300
Pump	1000 gallons per minute, 100-foot setting	1,200
Power		430
	Total	$2,250

Dodge City, Kansas, and Vicinity. In the period November 15 to 20, 1937, the writer accompanied W. N. White and S. W. Lohman, both of the United States Geological Survey, on a preliminary investigation of recent developments in irrigation from wells in Ford County, Kansas, and vicinity. The results of this investigation have been reported by Lohman[120] in a publication of the Kansas Geological Survey. He summarizes the history

120. Lohman, S. W., "Water Supplies From Wells Available For Irrigation in the Uplands of Ford County, Kansas": *Kans. Geol. Survey, Mineral Resources Circ.* 9, 1938.

of previous developments of water supplies from wells for irrigation in western Kansas as follows:

"Pumping from wells for irrigation has been practiced for many years along the Arkansas Valley in and west of Ford County. However, very little attempt has been made heretofore to develop water from wells for irrigation on the uplands of the High Plains in Kansas, except in an area in Scott County and to a minor degree in an area in Meade County. In the so-called Scott County 'shallow water' area, about 5,000 acres of land are irrigated with water pumped from wells. The pumping lifts in the Scott County area range from about 20 to 70 feet and are less than in most parts of the High Plains. In Meade County several hundred artesian wells have been put down, in which the water either stands only a few feet below the surface or flows naturally at the surface. Most of the artesian wells are of small diameter, and in most of them the flows are less than 10 gallons a minute, but one was observed to flow about 75 gallons a minute. A small amount of land has been irrigated in the Meade basin by flowing wells, but there are at present only five pumped irrigation wells capable of delivering large quantities of water."

Lohman describes three wells in southwestern Ford County, Kansas, which were completed in October and November, 1937. The depths range from 149 to 211.5 feet, and the water levels were from 22 to 44 feet below the land surface in the latter part of 1937. Concerning the cost of these wells and costs generally, he writes that "they were put down at the rather low cost of about $750 each through an arrangement whereby one man rented his homemade drill rig to others practically at the cost of upkeep. Prices quoted by drillers equipped to put down gravel-walled wells of similar construction range from $8 to $12 a foot, including casing but not including pump or power. The cost of screened wells without artificial gravel packing would be proportionately less."

He further reports one recently completed 200-foot irrigation well on the upland at Ensign, in which the water level was measured as 165.5 feet below the land surface, and one well which

was being drilled northwest of Dodge City on the upland, where the water level in an exploratory test hole was about 112 feet below the land surface. Near Ford, Kansas, also, several irrigation wells have been drilled recently, one of which is reported to yield between 1,200 and 1,500 gallons a minute with a 50-foot lift.

The four well logs quoted by Lohman show rather coarse water-bearing materials in comparison with those reported in Texas County wells, with rather thick beds described as gravel. The water-bearing materials range from 35 to 124 feet thick in these wells.

Garden City, Kansas. The growing of sugar beets by means of irrigation has been practiced for 25 years or more in the vicinity of Garden City, Kansas. Both surface water from the Arkansas River and ground water from wells are used. Mr. Gillespie, of the Garden City Company, furnished the following information regarding the well owned by the company and operated by Refugio Gonzales, in the NW¼ NE¼ sec. 29, T. 23 S., R. 34 W. It is 350 feet deep, and is cased to a depth of 194 feet with 30-inch iron casing, of which 30 feet is slotted, and from 194 feet to the bottom with 12½-inch casing, all of which is slotted. The well penetrated a total of about 172 feet of sand and fine gravel between depths of 55 and 255 feet. The first water was encountered at 55 feet below the surface but rose to 52 feet, and is said to have been about 50 feet below the surface on May 1, 1937. The well is equipped with a turbine pump with a capacity of 1,400 gallons per minute and is driven by a 100-horsepower electric motor, and in ordinary use yields 1,350 gallons per minute. It is generally used for 12 hours every two weeks from May 1 to October 1, and irrigates 200 acres of sugar beets.

Liberal, Kansas. In August 1937 a well located on the C. M. Light farm about a mile north of Liberal, Kansas, was completed for the Liberal Deep Well Irrigation Company. This well is located on the upland flat, and the water level as measured by the writer on November 20, 1937, was 123 feet below the base of the pump, which was about 3 inches above the land surface.

The well is reported to be 357 feet deep,[121] but the chief water-bearing bed is a coarse sand between depths of 175 and 225 feet. The well is cased to the bottom with 16-inch steel casing perforated with shutter type apertures, and the gravel wall surrounding it is 12 inches thick. The pump is a 7-stage turbine with a capacity of 1,000 gallons per minute, and is driven by a natural gas engine rated at 90 horsepower. The bowls were first set at a depth of 220 feet and the well yielded about 450 gallons a minute with a 34-foot drawdown. Later the bowls were re-set at a depth of 260 feet in the hope of obtaining 650 gallons per minute. The well cost $3,000, including casing and the gravel envelope, the pump cost $2,100 and the engine cost $1,200, making the total cost of the plant $6,300.

WELL DRILLING METHODS

Most of the domestic and stock wells in Texas County have been drilled with cable tools operated from portable drilling rigs. The chief exceptions are dug wells located in the valley bottoms. The drilled wells range from 25 to 300 feet deep, and generally are from 4 to 6 inches in diameter, although some of the stock wells are 8 inches in diameter. Some of the first wells in the county are reported to have been drilled by hand or by horse-power, but the common source of power in present day drilling equipment is the second-hand automobile engine.

The unconsolidated character of the sands and gravels of the Ogallala formation makes it necessary to case most wells to the bottom to prevent caving. A common practice has been to drill through the water-bearing bed and set the casing on an under-lying clay. The galvanized iron casing that is widely used in small diameter wells has usually been perforated for 10 or 20 feet by means of hack-saw cuts, the length that is perforated depending on the thickness of the water-bearing bed. Although some of the galvanized iron casing in wells 20 or 30 years old is said to be in good condition, in other wells it has collapsed, caus-

ing difficulty in removing the cylinder for repairs, or retarding or stopping the flow of water into the well. Iron, steel, and oil well casing are also used. Some of the dug wells are walled with stone or wood.

The drop pipe is ordinarily held in place by a wooden clamp consisting of two 4x4-inch blocks bolted tightly to the pipe and resting on top of the casing. About half of the wells have an iron or steel cover over the casing and under the wooden clamp to prevent contamination from the surface. Burlap sacking stuffed into the space between the blocks of the wooden clamp is also used to plug the top of wells, and a few wells have an iron pump head with a wide flaring base which effectively seals the top of the well.

The irrigation and municipal wells range from 12 to 42 inches in diameter, and are cased with galvanized or wrought iron casing 12 to 18 inches in diameter, which usually is perforated from the first water-bearing bed to the bottom of the well. The larger wells are gravel-packed. Some have been drilled with cable tools, and others by the hydraulic-rotary method. For details regarding the types of pumps and kind of power used in the larger wells, see the descriptions of existing town, industrial, and irrigation wells, and the well tables.

GROUND WATER CONDITIONS DESCRIBED BY LOCALITIES

For purposes of detailed descriptions of the ground water conditions the county is divided into a number of areas based primarily on the depth to the static water level. Because these depths depend largely on distance from and the elevation of the land surface above the major streams, the subdivision can be made conveniently along topographic lines, and three main headings are possible, namely (1) upland areas, including the sand dune localities, (2) valleys, and (3) lands of intermediate elevation near Paloduro Creek. The "breaks" and the valley bluffs could be classed as lands of intermediate elevation, but in general the ground water conditions in such places are different from those in the intermediate lands near Paloduro Creek. These areas are not given special mention in the following descriptions because wells

121. Mayberry, Willard, Secretary-Treasurer of the irrigation company. Personal communication, Feb. 26, 1938. Also, statements made by Jack Doty, of the Well Works Manufacturing Company, Garden City, Kansas, who was in charge of drilling the well.

located in them are too few to supply the necessary information, their total area is relatively small, and their irregularity and steep slopes make them unfit for any use except grazing.

UPLAND AREAS

The uplands range from flat and featureless or gently undulating, where the High Plains surface has been little affected by erosion, to hilly in the sand dune areas. Although the soils near the main valleys and in the dune areas tend to be poor, much the larger part of the uplands is covered by the Richfield silt loam, the Pratt fine sandy loam, and loamy fine sand, or the Potter silt loam and sandy loam, all of which are excellent soils.[122]

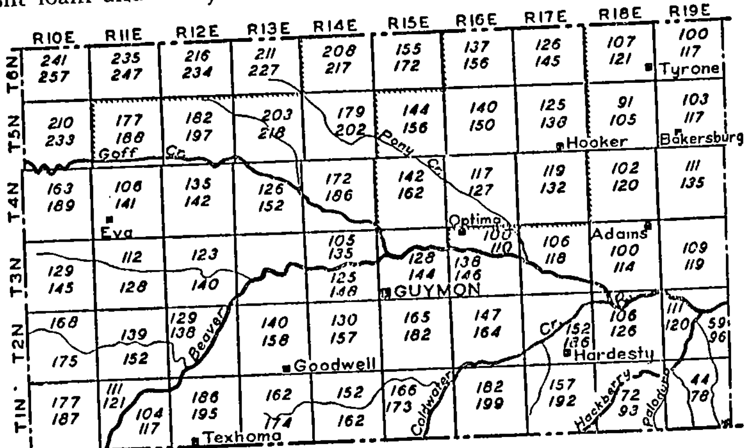


FIGURE 10. Average water levels and depths of wells on uplands, by townships. Upper figure is average depth to water below upland surface; lower figure is average depth of wells. Where a township is divided by a stream, averages for both parts are given, if data permit.

The table lands between the major streams (see page 20) have been made the basis for the following descriptions of upland areas. The tableland north of Beaver River in the eastern part of the county, and north of its tributary Goff Creek in the western part, comprises nearly half the county. It is unbroken except for Pony Creek, which has a moderately deep but narrow valley in the

122. Fitzpatrick, E. G., and Boatright, W. C., "Soil Survey of Texas County, Oklahoma": *U. S. Dept. Agri., Bur. Chem. and Soils Ser.* 1930, No. 28, pp. 13-20 and map.

lower 7 or 8 miles of its course. Water levels in this area range from 70 to 256 feet (the deepest for upland wells), and the total depths of the wells vary correspondingly. Because of this diversity, this tableland is subdivided into four smaller units based on depths to water as averaged by townships. The other tablelands show less diversity, and therefore are treated essentially as units. This scheme has resulted in the recognition of seven upland areas which, for convenience, are named for the principal town or towns located in them, or for former towns or post offices.

Figures on the map (Fig. 10) show the average depth to the static water levels in the recorded wells on the upland plain, by townships, and the average depth of these wells. Both averages are based on actual measurements by the writer. Where major streams cross the middle of a township, so that part of it falls in one upland area and part in another, separate figures are given for each upland area that is involved. Where there are so few well measurements in a township that the resulting averages probably are not representative, no figures are shown on the map.

Optima-Adams-Tyrone plain. T. 3 N., Rs. 16 to 19 E.; Tps. 4 to 6 N., Rs. 18 and 19 E.

The Optima-Adams-Tyrone plain as here defined is a roughly triangular area in the northeastern corner of the county. (Fig. 10) In it the water table is relatively near the surface, the zone of saturation in the Ogallala formation is probably thick, soils are excellent, and the surface is generally flat or undulating except for small areas of sand dunes.

The average depth to water in 9 wells measured in T. 5 N., R. 18 E. was 91 feet in 1937; in the other townships it ranged from 100 to 111 feet. There is an area of about 80 square miles in which the water table is less than 100 feet below the surface (see Plate I), and 20 wells were measured within this area. The water levels in about half these wells ranged from 70 to 90 feet, and the rest ranged from 90 to 100 feet.

Present information indicates that all the wells in this area draw water from the Ogallala formation. Logs of gas test wells are not available to show the thickness of the formation, but the logs of irrigation wells 496 and 497 (page 179) indicate thicknesses of at least 262 and 280 feet, respectively, and electrical resistivity data[123] indicate thicknesses ranging from 200 to 500 feet. The pre-Tertiary valley suggested on page 63 and figure 3 crosses this area. Along it the zone of saturation in the Ogallala should be exceptionally thick, and there should be an abundance of permeable, water-bearing beds.

Natural gas as a source of power for pumping water is available from adjacent areas if it cannot be obtained within the Optima-Adams-Tyrone plain. The area is crossed by three railroads and two main highways, includes four small towns which serve as shipping points, and is close to Hooker, the second largest town in the Oklahoma Panhandle. Liberal, Kansas, a larger town, is located just a few miles north in Kansas.

Records were obtained of 330 wells in this area, of which 81 were measured. In these 81 wells, the water levels ranged from 70 to 133 feet below the surface and averaged 103 feet. The depth of 79 of the wells ranged from 86 to 144 feet and averaged 118 feet. In 249 additional wells,[124] the reported depth ranged from 65 to 200 feet, and averaged 130 feet. The average depth of all the recorded wells was 127 feet. The water-bearing beds were reported as sand in 47 wells, gravel in 124, sand and gravel in 7, clay in 28, gravel and clay in 2, and sand and clay in 1.

Hooker-Mouser plain. T. 3 N., R. 15 E., Tps. 4 and 5 N., Rs. 15 to 17 E.; T. 6 N., Rs. 16 and 17 E.

The Hooker-Mouser plain is nearly rectangular (Fig. 10), and includes the larger part of the northern sand dune area. General conditions and possibilities for developing irrigation supplies from wells are similar to those of the Optima-Adams-Tyrone plain except that the water table averages deeper below the surface, and the zone of saturation in the Ogallala is perhaps somewhat thinner.

123. Unpublished cross-sections interpreting the electrical resistivity tests, in the files of the Oklahoma Geological Survey, at Norman.

124. From reports on rural wells which were gathered by workers on the State Mineral Survey, WPA project 65-65-538, sponsored and directed by Oklahoma Geological Survey, 1936.

The average measured depth to water in the eastern townships in 1937 ranged from 117 to 123 feet, and increased westward to a maximum of 144 feet in T. 5 N., R. 15 E. Present information indicates that all the wells in this plain draw water from the Ogallala formation. The Hooker exploratory water well (log page 180) indicates a thickness of 570 feet for the Ogallala. One gas test in the northwestern part of the area suggests a thickness of 675 feet for the Ogallala and the Kenny and Parker wells located a short distance to the west indicate thicknesses greater than 500 feet. Parts of the pre-Tertiary valleys suggested on page 63 and figure 3 cross this area, and along them the zone of saturation in the Ogallala should be thick, and there should be an abundance of permeable, water-bearing beds.

Records were obtained of 300 wells in this area of which 73 were measured. In these 73 wells the water levels ranged from 77 to 168 feet below the surface, and averaged 130 feet, and depths ranged from 95 to 190 feet, and averaged 145 feet. In 227 additional wells, the reported depths ranged from 90 to 247 feet, and averaged 153 feet. The average depth of all the recorded wells was 151 feet. The water-bearing beds were reported as sand in 75 wells, gravel in 152, sand and gravel in 14, clay in 6, and gravel and clay in 1.

Hough plain. T. 4 N., R. 14 E.; T. 5 N., Rs. 11 to 14 E.; T. 6 N., Rs. 14 and 15 E.

The Hough plain is irregular in shape and in T. 4 N., R. 14 E., and T. 5 N., Rs. 11 to 13 E., it includes only those uplands which lie north of Goff Creek (Fig. 10). It includes no dune areas, but there are some rolling lands along the north side of Goff Creek. By far the larger part of the flats in this plain are covered by the Richfield silt loam, which is the best soil recognized in the county.[125]

The depths to water are much greater than in the Optima-

125. Fitzpatrick, E. G., and Boatright, W. C., *Op. cit.*, pp. 13-15, and Map.

Adams-Tyrone and Hooker-Mouser plains, and the zone of saturation in the Ogallala is correspondingly thinner. The average measured water level ranged in 1937 from 155 feet in T. 6 N., R. 15 E., to 208 feet in T. 6 N., R. 14 E. (see Fig. 10). Present information indicates that all the wells in this plain draw water from the Ogallala formation. Logs of 9 gas test wells in T. 6 N., R. 14 and 15 E. suggest that the thickness of the formation may exceed 600 feet in places and that one of the pre-Tertiary valleys mentioned on page 63 crosses this area. Hence the saturated part of the Ogallala may be 300 feet thick locally, though it probably is much less in most parts of the plain, perhaps between 100 and 150 feet.

Natural gas as a source of power for pumping irrigation water is available within the area. The plain is crossed by one railroad which affords an outlet to the east, but there are no main state or federal highways.

Records were obtained of 154 wells in this area, of which 47 were measured. In these 47 wells the water levels ranged from 133 to 225 feet, and averaged 180 feet, and depths in 46 of them ranged from 139 to 240 feet; and averaged 196 feet. In 107 additional wells the reported depth ranged from 140 to 263 feet. The average depth of all the recorded wells was 198 feet. The water-bearing beds were reported as sand in 39 wells, gravel in 57, sand and gravel in 18, clay in 10, and gravel and clay in 1.

Carthage plain. T. 5 N., R. 10 E.; T. 6 N., Rs. 10 to 13 E. (Fig. 10).

The Carthage plain as here defined is an L-shaped area in the northwestern part of the county where the average measured depth to the water table by townships ranged in 1937 from 210 to 241 feet. It is named for the former town of Carthage, which was in sec. 10, T. 5 N., R. 10 E. The surface is flat, except along the north side of Goff Creek, where it is either rolling or broken, and the soils are similar to those of other parts of the uplands. This area was originally less thickly settled than the eastern part of Texas County, and it has lost population because of relatively greater damage by wind erosion.

The Carthage plain has the deepest water table and the deepest wells in the county. Water analyses indicate that all the wells probably draw water from the Ogallala formation, but supporting evidence from the logs of wells is not available. Gas test wells have not been drilled, and although water well 628 reaches a depth of 291 feet, the available information does not indicate whether it penetrated to the base of the Ogallala. If the formation is not over 300 feet thick, the saturated part may range from 50 to 100 feet in thickness.

Natural gas has not been discovered within the Carthage plain, but has been obtained in wells located only a few miles to the east and south of the eastern end. The northwestern corner of the plain is crossed by the Atchison, Topeka, and Santa Fe Railroad, and the nearest shipping point on it is Elkhart, Kansas, just north of the state line. To the south, Eva and Hough are shipping points on the Beaver, Meade, and Engelwood Railroad. No main state or federal highways cross the area.

Records were obtained of 61 wells in this area, of which 19 were measured. In these 19 wells the water levels ranged from 197 to 256 feet below the surface, and averaged 223 feet, and depths in 18 of them ranged from 209 to 291 feet, and averaged 240 feet. In 42 additional wells the reported depth ranged from 200 to 308 feet, and averaged 241 feet. The average depth of all the recorded wells was 241 feet. The water-bearing beds were reported as sand in 17 wells, gravel in 18, sand and gravel in 9, clay in 1, and gravel and clay in 2.

Eva plain. The Eva plain is a triangular area which includes all of the uplands between Beaver River and Goff Creek (Fig. 10). The base of the triangle is along the Cimarron County line, and its apex is near the junction of the two streams. The plain slopes eastward, and although the larger part of it is typical upland flat, there is considerable topographic diversity, both within the area and along its margins, because of partial dissection by tributary streams. Present information indicates that most of the wells in this plain draw water from the Ogallala formation, but some of the deeper ones appear to draw from Cretaceous, Triassic (?), or older rocks. Drillers[126] report erratic distribution of the water-bearing beds and uncertainty in obtaining good wells. These conditions exist either because locally the Ogallala is impervious below the level of the water table, or because the impervious red bed basement rises so near the surface that all the Ogallala is above the water table, or because the saturated part of the Ogallala is very thin. Well 412 (see page 101; log on page 178) appears to have been drilled into the red beds because the Ogallala is so impervious that it yields little or no water. The same may be true of the Beaver, Meade, and Engelwood Railroad well at Eva (page 108), which, however, yields a more adequate water supply than well 412. Well 281 encountered a hard, highly calcareous sandstone at a depth of 101 feet, which is quite unlike the sandstones in surface exposures of the Ogallala but similar to those found in the Dakota sandstone and underlying formations of northwestern Cimarron County.[127]

The thickness of the Ogallala appears to vary widely in this area. The Stonebraker-Zea Live Stock Co. gas test well indicates a thickness of only 69 feet, water well 281 indicates at the most about 100 feet, (log page 177), the Kugle gas test well indicates 160 feet, water well 389 is reported to have entered red beds at 160 feet[128], and water well 412 indicates 170 feet (log page 178). On the other hand, analyses of water from several wells about 200 feet deep are typical of waters from the Ogallala and imply that the formation is 200 feet or more thick. In places almost none of the Ogallala is saturated, and where the formation is thickest the water levels are deepest, so that the zone of saturation is probably thin in most parts of the Eva plain. Present information does not justify assuming a thickness greater than 50 feet for the saturated part of the Ogallala anywhere in this area.

So far as the depth to the water is concerned, the best place to develop irrigation supplies from wells in the Eva plain is the shallow water area between Eva and Tepee Creek. Here, the

126. Sanborn, G. C., and Freeman, Frank, oral communications.
127. Opinion of J. W. Stovall, to whom drill cuttings were submitted.
128. Wasson, Paul, driller, Oral communication.

water may be shallow because of perched ground water reservoir, or because the impervious red bed basement is near the surface. In either case, the water supply may be unreliable. Water is also obtainable at moderate depths in the extreme eastern part of the area, near the junction of Beaver River and Goff Creek, but the surface is uneven and much of the original upland soil may have been removed by erosion. In other parts of the Eva plain the depths to water are materially greater, the maximum being a little more than 200 feet in the western part of T. 1 N., R. 10 E. The Eva plain is crossed by the Beaver, Meade, and Engelwood Railroad, which affords an outlet to the east and west, and by Federal highway 64. Roads in the southwestern part of the area are generally poor.

Records were obtained of 211 wells in this area, of which 80 were measured. In these 80 wells the water levels ranged from 42 to 208 feet below the surface and averaged 134 feet, and the depth ranged from 47 to 234 feet and averaged 151 feet. In 131 additional wells the reported depth ranged from 46 to 304 feet and averaged 180 feet. The average depth of all the recorded wells was 169 feet. The water-bearing beds were reported as sand in 42 wells, gravel in 80, sand and gravel in 30, clay in 11, gravel and clay in 1, and sand and clay in 3.

Guymon-Texhoma plain. The Guymon-Texhoma plain as here defined includes all of the uplands between Beaver River and Coldwater Creek (Fig. 10). Its surface varies from very flat in parts of T. 2 N., Rs. 13, 14, and 16 E., to broadly undulating near Goodwell, and it has been dissected locally by Frisco Creek and South Fork. Present information indicates that all the wells in this area draw water from the Ogallala. Logs of gas test wells suggest that the thickness of the formation ranges from about 200 feet immediately southwest of Guymon to 385 feet southwest of Goodwell, and the log of water well 181 (page 175) suggests a thickness of 356 feet in the area east of Goodwell. On this basis, the zone of saturation in the Ogallala varies from about 80 feet thick near Guymon to between 200 and 250 feet near Goodwell. At the latter place it constitutes a ground water reservoir second in importance only to that in the Optima-Adams-Tyrone and Hooker-Mouser plains.

Depths to water in a small area near Goodwell range from 110 to 137 feet, but they increase to the east, west, and southwest, From the standpoint of depth to water and topography, the best part of the Guymon-Texhoma plain for developing irrigation supplies from wells is the upland of the eastern part of T. 1 N., R. 11 E., where the average measured depth to water in 1937 was 104 feet. Depths to water are also moderate in an area of a few square miles in the narrow strip of upland near the junction of Beaver River and Coldwater Creek in T. 2 N., R. 17 E., but the surface is rather broken. The greatest average measured depth to water in any township is 186 feet, in T. 1 N., R. 12 E., where the water levels in some wells near Texhoma are more than 200 feet below the surface. The water table is between 150 and 200 feet deep in a large area west of Goodwell, and also to the southeast of Guymon. Natural gas as a source of power for pumping water seems to be available throughout this plain. The area is crossed by the main line of the Chicago, Rock Island and Pacific Railroad, and by Federal highway 54.

Records were obtained of 212 wells in this area, of which 69 were measured. In these 69 wells the water levels ranged from 81 to 216 feet below the surface, and averaged 151 feet, and the depths of 68 of them ranged from 104 to 270 feet, and averaged 167 feet. In 143 additional wells the reported depths ranged from 100 to 250 feet, and averaged 168 feet. The water-bearing beds were reported as sand in 54 wells, gravel in 78, sand and gravel in 39, clay in 3, and gravel and clay in 1.

Hardesty plain. The Hardesty plain includes all the uplands between Coldwater Creek on the west, the Paloduro-Hackberry valley on the east, the Texas state line on the south, and Beaver River on the north (Fig. 10). The surface is very flat near the state line in T. 1 N., R. 16 E. and to the east of Hardesty, and undulating or mildly rolling in marginal areas near the streams which bound it. Present information indicates that nearly all the wells in this area draw water from the Ogallala. The log

of the Gailey gas test well, located about 1½ miles east of Hardesty, suggests a thickness of about 280 feet for the formation, and water well 227, located a mile southwest of Hardesty, is reported by A. Hughey[129] to have passed out of the Ogallala into the underlying red beds at a depth of about 190 feet. Comparison of these probable thicknesses with the depth to the water table indicates that the zone of saturation in the Ogallala ranges from about 25 to 160 feet in thickness.

From the standpoint of depth to the water and topography, the most favorable part of the Hardesty plain for developing irrigation supplies from wells lies to the east of Hardesty, where water levels ranged in 1937 from 100 to 150 feet below the land surface. There are also small local areas near the main valleys where depths to water are less than 100 feet and the land is flat enough and slopes are gentle enough to be suitable for irrigation. On the other hand there is a large area extending from Hardesty southwestward toward Hitchland, Texas, where depths to water range from 150 to 200 feet. Natural gas as a source of power for pumping water is available within the area of the Hardesty plain, which is crossed by a branch line of the Chicago, Rock Island, and Pacific Railroad, and by state highway 35.

Records were obtained of 66 wells in this area, of which 20 were measured. In these 20 wells the water levels ranged from 84 to 191 feet below the surface, and averaged 135 feet, and depths of 19 of them ranged from 97 to 205 feet, and averaged 157 feet. In 46 additional wells the reported depths ranged from 90 to 250 feet, and averaged 167 feet. The average depth of all the recorded wells was 164 feet. The water-bearing beds were reported as sand in 8 wells, gravel in 18, sand and gravel in 6, clay in 1, and sand and clay in 1.

VALLEYS

The broad, shallow valleys of the larger streams contain gently sloping lowland flats where water is obtainable in the alluvium at much shallower depths than in most upland areas. In a few

129. Hughey, A., Hardesty, ex-driller, oral communication.

places the flat flood plains between the stream channel and the base of the valley bluff are a mile wide, and in many places they range from a quarter of a mile to half a mile wide. Locally the streams have meandered considerably, leaving wide stretches of loose sand, and in other places the surface of the flood plain is so uneven that preparation of the land for irrigation might prove too costly, but in the aggregate there are many square miles of usable lowland flats.

The soils of these areas are classed by Fitzpatrick and Boatright[130] as Lincoln loams and sands, and in 1930 their value was estimated to range from 25 to 50 per cent of that of the best upland soil (Richfield).

Present information indicates that most of the wells in the valley bottoms—on the flood plains—draw water from the alluvium. The thickness of the zone of saturation in the alluvium varies from place to place in the valleys, and is greatest, of course, in the middle of each valley, where the total thickness of the alluvium itself is greatest and the water table is nearest the surface. The alluvium may be part of an extensive ground water reservoir, or may be definitely limited, depending on the character of the underlying and adjacent rock formations. Three main conditions are described as follows, and are illustrated in figure 11.

(1) In most parts of the main valleys the alluvium is entirely underlain by the Ogallala formation. The two are similar in lithologic character, and together they constitute an extensive ground water reservoir. The water table extends from the Ogallala into the alluvium without important changes in shape or slope, and the water can move from the one into the other with relative freedom. Where streams are intermittent, flood waters seep into the alluvium and move outward and downward into the general ground water reservoir of the Ogallala. Where the streams are perennial the alluvium receives contributions of water from the Ogallala. (Fig. 11, A).

130. Fitzpatrick, E. G., and Boatright, W. C., *Op. cit.*, pp. 20-21, and map.

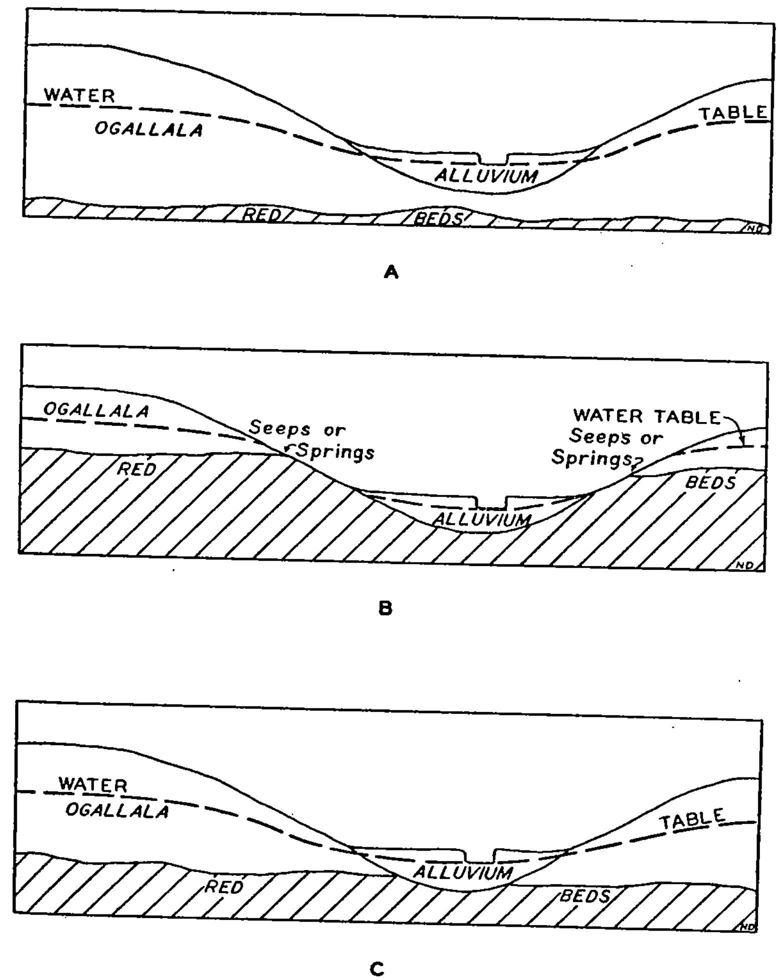


FIGURE 11. Three possible relationships between the alluvium and the underlying and adjacent formations where stream valleys are below the level of the water table.

A. Alluvium is underlain only by the lithologically similar Ogallala formation. The water table extends from the Ogallala into the alluvium, and the two formations constitute a single reservoir.

B. Alluvium is underlain only by impervious red beds. It can receive little water from the adjacent rocks and can lose little to them. It is a reservoir of limited capacity.

C. Intermediate situation. Alluvium underlain in part by red beds, and in part by Ogallala. It may receive water from the Ogallala, but the water may be contaminated by contact with soluble minerals in the red beds.

(2) Along Paloduro, Chiquita, and the lower part of Hackberry Creeks the alluvium is underlain by relatively impervious red clays of the Cloud Chief formation, and for a stretch of about 5 miles at the Red Point locality, west of Guymon, it is underlain by similarly impervious red beds of Triassic (?) and possibly Jurassic age. In these localities the alluvium is also separated from the Ogallala formation at the sides, and it therefore is an elongate bed of pervious deposits lying in a trough excavated in impervious materials. It can receive little water from the adjacent rock formations and can lose little to them. It is, therefore, a reservoir of definitely limited capacity, and the water in it must either seep into it from alluvium farther upstream in the same valley or from rainfall on its surface. (Fig. 11, B).

(3) Both upstream and downstream from the main outcrop of the Triassic (?) red beds on Beaver River and also upstream from the outcrop of the Cloud Chief formation on Paloduro Creek and its tributaries, the streams have probably channeled into the red beds. These channels have been filled more or less completely with alluvium, so that the red beds do not crop out. In such localities the ground water reservoir in the alluvium is definitely restricted at the bottom, but probably is continuous with that in the Ogallala at either side of the valley. This condition is intermediate between (1) and (2) above (Fig. 11, C).

The following paragraphs summarize the more important features of each valley.

Beaver Valley. The term Beaver Valley as used here includes all of the lowlands along Beaver River and its minor tributaries, but excludes the larger tributaries—Paloduro, Chiquita, Hackberry, Coldwater, Frisco, Pony, Goff, and Tepee Creeks—which will be discussed separately. The information now available indicates that most of the wells in the valley of the Beaver itself draw water from the alluvium. However, well 294 and a few other stock wells that are located on or near the pre-Ogallala inlier along Beaver River west of Guymon appear to end in red beds. Likewise, there is some possibility that a few of the flood plain wells in the extreme eastern part of the county, near the mouth of Paloduro Creek, may pass through the alluvium and enter the Cloud Chief formation, of Permian age.

The relation between the permanence of stream flow and the depth to water in valley wells has been outlined. Actual measurements of water levels in wells on the flat flood plains along Beaver River have shown that where the flow is permanent the depth to water ranges from less than 5 feet to a maximum of about 25 feet, and that even where the flow is intermittent and the channel is dry, as in the western part of the county, the depth to water in similar locations is not likely to be greater than 30 feet. Obviously those wells which are located on the valley bluffs, above the level of the true flood plain, will have to go deeper for water, and in general the water levels are deeper in the valleys of minor tributaries. For example, well 154 is located on a terrace some distance above the dry channel of North Fork, and the water level in it was 106 feet below the surface.

The thickness of the alluvium is uncertain because the unconsolidated alluvial deposits are so much like the nearly unconsolidated Ogallala deposits that the two cannot be readily distinguished in wells, but well log 176-a (page 174) appears to indicate a thickness of at least 105 feet. In most parts of the valley of the Beaver, and in the valleys of the tributaries here considered, the alluvium is essentially a part of the ground water reservoir in the Ogallala formation (see fig. 11, A). The volume of water available is likely to be relatively large, and the quality of the water is generally good. These factors, plus the shallow depths to water, make such areas rather desirable for the development of irrigation supplies from wells.

However, this condition does not exist in the area where the red beds crop out along the Beaver west of Guymon (see fig. 11, B). Here the volume of water in the alluvium probably is very definitely limited, and the quality may be poor if dissolved mineral matter from the red beds gets into the water. The intermediate condition, illustrated in figure 11, C, probably exists also, both upstream and downstream from the red bed locality, and perhaps likewise in the extreme eastern part of the county, near the outcrop of the Cloud Chief.

One well in the valley of the Beaver flows at the surface. It is reported[131] that it is 115 feet deep and once flowed a strong stream, but when visited by the writer on October 4, 1937, it barely overflowed. The well (number 329) is located in the NE¼ sec. 15, T. 3 N., R. 16 E., on the flood plain and at the base of a low cliff of caliche.

Records were obtained of 78 wells in the valleys of the Beaver and its minor tributaries, of which 44 were measured. In these 44 wells the water levels ranged from 2.2 feet below the surface in a well on the flood plain of the Beaver itself to 106 feet in a well located on a terrace above the channel of North Fork, and they averaged 28 feet. The depths of the measured wells ranged from 10 to 116 feet, and averaged 44 feet. In 34 additional wells, the reported depth ranged from 6 to 120 feet and averaged 41 feet. The average depth of all the recorded wells was 43 feet. The water-bearing beds were reported as sand in 2 wells, gravel in 7, and sand and gravel in 12.

Valleys of Tepee Creek and tributaries. Tepee Creek and one of its tributaries have cut through the Ogallala into the underlying red beds in some places (see Plate I), and the saturated alluvial fill in their valleys is a more or less definitely limited reservoir of the types illustrated by figure 11, B and C. These conditions probably exist in the valley of Tepee Creek all the way from the middle of T. 3 N., R. 11 E. downstream to the mouth of the creek. At other places the alluvium is entirely underlain by the Ogallala and for all practical purposes is a part of the ground water reservoir in that formation. It is probable that in general the alluvium in these valleys is thinner than in the valley of Beaver River, and the volume of water in the combined Ogallala-alluvium reservoir seems to be relatively small for reasons pointed out in the discussion of the Eva plain.

Shallow wells that are favorably situated may obtain good water supplies in the alluvium along these valleys, but where the

131. Sassin, L. O., oral communication.

alluvium is thin or barren of water the wells must be drilled into the red beds, where they generally obtain meager supplies of water which may be highly mineralized. Well 287 appears to have entered the red beds under the alluvium of Tepee Creek, but the water from it is not especially mineralized (see page 102 for details about the well, and table XII for analysis of the water). Wells drilled on the valley bluffs draw water from either the Ogallala or the red beds, depending on how near the red beds are to the surface (see well 288, page 102).

Records were obtained of 9 wells that are located in the bottoms of the valleys of Tepee Creek and its tributaries, of which 4 were measured. In these 4 wells the water levels ranged from 12 to 72 feet below the surface, and averaged 32 feet, and the depths ranged from 17 to 81 feet, and averaged 45 feet. In 4 additional wells the reported depths ranged from 39 to 84 feet, and averaged 58 feet. One flood plain well was reported to be 207 feet deep. The water-bearing beds were reported as sand in 4 wells, and gravel in 1.

Goff Creek Valley. Goff Creek is a dry wash which joins Beaver River from the north. The maximum width of the valley from the edge of the upland on one side to the edge of the upland on the other is between 1 and 1.5 miles, except locally, where mouths of tributary valleys may make it appear wider. Most of its width is in slopes, hence the low, flat flood plains are narrow, and irrigable areas are correspondingly small. The valley bottom is between 100 and 125 feet below the adjacent upland at the bridge 5 miles due north of Guymon, and is about 75 feet below the upland at the bridge on the Eva-Elkhart road in T. 5 N., R. 11 E. The creek is not known to have cut through the Ogallala into older rocks in any part of its course. The wells that are located near the channel in the downstream part of the valley may be entirely in the alluvium, but those on the valley bluffs or near the headwaters end in the Ogallala formation. Flood waters probably seep into the alluvium and migrate into the Ogallala, and the saturated parts of the two formations are essentially parts of the same underground reservoir (see figure 11, A). Measurements in wells indicate that on the flat bottoms in the lower 10 miles of the valley the water table ranges from 10 to 20 feet below the surface, but that in the upper part of the valley the depth to water may approach 100 feet even though wells are located close to the channel.

Five wells in this valley were measured. The water levels ranged from 11 feet below the surface in well number 433, which is about 9 miles upstream from the mouth of the creek, to 88 feet in well number 518, which is north of Eva and is less than 5 feet above the creek channel, and they averaged 44 feet. The depths of these wells ranged from 21 to 102 feet, and averaged 54 feet. In addition, well 541 may be considered as belonging in the Goff Creek valley, although it is located about 25 feet above the channel of a tributary and is considerably higher than the bottom of Goff Creek itself. However, it is also well below the upland, and in a sense its position is intermediate. In it the depth to water was 120 feet, and the total depth of the well was 128 feet. The water bearing beds are reported as sand in 1 well, and gravel in 1.

Pony Creek Valley. Pony Creek is like Goff Creek in many respects. It is usually dry, joins the Beaver from the north, has not cut through the Ogallala into the underlying rocks, and its valley has a maximum width ranging from 1 to 1.5 miles. The flood plains are narrow and the areas suitable for irrigation are small. The valley is about 100 feet deep in sec. 1, T. 3 N., R. 16 E., and roughly 50 feet deep where it is crossed by U. S. highways 54 and 64 about 1.5 miles northeast of Optima, but it rapidly becomes shallower upstream until it disappears entirely on the upland flat. Wells that are near the channel in the lower part of the valley may be entirely in alluvium, but those on the valley bluffs or near the headwaters probably end in the Ogallala formation. Flood waters probably seep into the alluvium and migrate into the Ogallala, and the saturated parts of the two formations are essentially parts of the same underground reservoir (see figure 11, A). Measurements in wells and reports by owners indicate that on the flat bottoms of the lower 10 miles of the valley the water table is nowhere more than 50 feet below the surface.

Records were obtained of five wells in this valley, of which two were measured. The water levels measured in wells 323 and 460 were 22 and 28 feet below the surface, and the depths were 25 and 43 feet, respectively. In three additional wells the reported depths were 65, 67, and 90 feet. The water-bearing beds were reported as sand in 1 well, and gravel in 1.

Coldwater and Frisco valleys. Coldwater Creek enters Texas County from the state of Texas, and its chief tributary in Texas County, Oklahoma, is Frisco Creek. Present information indicates that all the wells that are located on the flood plains of these streams draw water from the alluvium, and that the wells located on the bluffs of their valleys draw from the Ogallala. There are no exposures of pre-Tertiary red beds in these valleys, and it therefore seems probable that the alluvium is underlain by the Ogallala and is essentially a part of the ground water reservoir in the Ogallala (see Figure 11, A). The available ground water is probably comparable in volume and quality to that in the more favorable parts of Beaver Valley.

Coldwater Creek has cut its channel below the level of the water table, and therefore has a permanent flow. Frisco Creek channel, on the other hand, appears to lie somewhat above the water table, even in the lower part of its course, and the water table probably slopes away from the channel.

The flood plains in Frisco Valley and in the upper part of Coldwater Valley are narrower than those in the Beaver Valley, yet even in Frisco Valley as far upstream as the middle of T. 1 N., R. 14 E., there are small areas of flat, arable land. In addition to the present flood plains, there are also gently sloping lands at slightly higher elevations, some of which might be farmed. These really are the lower slopes of the valley bluffs, and they offer the advantage of relative freedom from flood damage, but the soil on them may not be very good. The largest areas of such lands appear to be along the west side of Coldwater Creek in the south central part of T. 1 N., R. 15 E.

Records were obtained of 46 wells in the valleys of Coldwater and Frisco Creeks, of which 23 were measured. In these 23 wells the water levels ranged from 4 to 78 feet below the surface, and averaged 32 feet, and the depths ranged from 15 to 144 feet, and averaged 49 feet. In 23 additional wells the reported depths ranged from 10 to 120 feet, and averaged 53 feet. The average depth of all the recorded wells was 51 feet. The water-bearing beds are reported as sand in 6 wells, gravel in 5, sand and gravel in 3, and clay in 1.

Valleys of Paloduro and Chiquita Creeks. The area here considered includes the valleys of Paloduro and Chiquita Creeks and minor tributaries, but excludes the valley of Hackberry Creek, which will be described separately. These valleys are broad and shallow, with rather gently sloping bluffs. The flood plain of Paloduro creek locally is a mile in width, and its flatness favors irrigation of relatively large areas, but the flood plains of Chiquita Creek and other tributaries are so narrow that they offer very little arable land.

Paloduro Creek has cut through the Ogallala formation into the underlying Cloud Chief formation (Permian) from its mouth to the Texas state line. Along this part of the valley the Ogallala has been removed from the bottom lands and lower slopes of the valley bluffs in a strip ranging from 1.5 to 3 miles wide. The same general condition is true of Chiquita Creek valley from its mouth as far south as secs. 26 and 27, T. 1 N., R. 19 E. The saturated materials capable of yielding water readily are therefore limited to the alluvium, which constitutes a definitely restricted reservoir (figure 11, B), because it is underlain by the relatively impervious red shales and clays of the Cloud Chief formation. Much of the water reaching this reservoir is probably rainfall which seeps into the thin capping of Ogallala on the higher divides, moves downward until it encounters the impervious red beds, thence moves laterally to issue in small springs or seeps at the Ogallala—red bed contact and then sinks into the alluvium. The part not used by flood plain plants, or evaporated, or withdrawn from wells on the flood plains, finally reaches the channels of the main streams. Any water entering the alluvium from the Cloud Chief is very likely to contain much dissolved mineral matter, and more or less soluble mineral matter is probably con-

tained in the alluvium itself. As a result, the water from the alluvium is generally very hard, high in chloride and sulphate, and commonly is described as salty or "gypy." The actual mineral content of the water probably varies widely from place to place in response to local conditions.

One well in the valley of Paloduro Creek flows about two-thirds of a gallon a minute from a water-bearing bed of unknown character at a reported depth of 207 feet. According to the owner, there was a slight rise in water level when the first water was reached. When the second water-bearing bed was penetrated, the water flowed out at the top of the well, but it did not rise appreciably above the ground until the third water-bearing bed was tapped. The original artesian head is reported as 7 or 8 feet above the surface, but it was only 1.8 feet in 1938. The water is reported to be salty. The well (number 118) is located in the SW¼ sec. 24, T. 1 N., R. 18 E., on the east bank of the creek.

Records were obtained of 20 wells in the valleys of Paloduro and Chiquita Creeks, of which 4 were measured. In these 4 wells, the water levels ranged from 7 to 24 feet below the surface, and averaged 18 feet, and the depths ranged from 26 to 39 feet, and averaged 32 feet. In 16 additional wells the reported depths ranged from 10 to 65 feet, and averaged 29 feet. The average depth of all the recorded wells was 29.5 feet. The water-bearing beds were reported as sand in 3 wells, gravel in 8, sand and gravel in 2, and clay in 6.

Hackberry Valley. Hackberry Creek has a rather broad and shallow valley. Locally there are moderate sized areas of flat, arable flood plain, but in most parts of the valley the total width of the flood plain probably does not exceed a quarter of a mile. Although the creek has cut deeply into the Ogallala formation, it has exposed the underlying Cloud Chief only in the lower 2 or 3 miles of its course. It is probable, however, that the Cloud Chief underlies the alluvium in the middle of the valley for several miles upstream from the known exposures of the formation. Thus the alluvium near the mouth of the stream is a ground water reservoir with a definitely limited capacity, underlain by impervious red beds and separated from the water-bearing Ogallala (see figure 11, B). Upstream for several miles more or less water may enter the alluvium from the Ogallala at the sides, but may be subject to contamination from soluble mineral matter in the underlying red beds (figure 11, C). Still farther upstream, either in Oklahoma or Texas, the alluvium is underlain by the Ogallala and is a part of the ground water reservoir in that formation (figure 11, A). Thus it is probable that both the volume and the quality of water available to wells in the alluvium of Hackberry Valley decreases downstream. Measurements in wells indicate that the water table in this valley is generally less than 25 feet below the flood plains and adjacent low-lying lands, but may be greater than 50 feet in the valleys of minor tributaries.

Records were obtained of 15 wells in Hackberry Valley, of which 6 were measured. In these 6 wells, the water levels ranged from 8 to 58 feet (in a tributary), and averaged 23 feet below the surface, and depths ranged from 10 to 70 feet, and averaged 29 feet. In 9 additional wells the reported depths ranged from 17 to 100 feet, and averaged 47 feet. The average depth of all the recorded wells was 40 feet. The water-bearing beds were reported as sand in 1 well, gravel in 2, sand and gravel in 2, and clay in 5.

LANDS OF INTERMEDIATE ELEVATION

Range Area. The name Range Area is used here for lands in the vicinity of old Range post office, formerly located in sec. 23, T. 1 N., R. 18 E., which are above the flood plain level but below the uplands. Erosion has cut away the original High Plains surface of this southeastern part of the county to produce a gently rolling topography between Paloduro, Chiquita, and Hackberry Creeks in T. 1 N., Rs. 18 and 19 E., and T. 2 N., R. 19 E. Minor tributaries have cut up the areas between the main streams so that few large, irrigable areas remain above the flood plain level. The soils are varied. Although there are several square miles of good Pratt fine sandy loam in the northwestern part of T. 1 N., R. 19 E., and smaller areas of Potter fine sandy loam (smooth phase) which is nearly as good, much of the soil

is so poor that it is of little value except for grazing.[132] The depth to the water table differs considerably from place to place because of the uneven topography, but measurements in wells show that it is less than 100 feet below the surface in all parts of the area except southwestern T. 1 N., R. 18 E., and that it is less than 50 feet in a large part of the area.

In the northern part of the area the Ogallala has been entirely stripped away so that wells must be drilled into the Cloud Chief formation (Permian), and are likely to obtain only small supplies of highly mineralized water. In the rest of the area a cap of the Ogallala remains on the interstream divides, but it is relatively thin, and the saturated part of it is a ground water reservoir of small capacity as compared with the saturated Ogallala in the Optima-Adams-Tyrone, Hooker-Mouser, or Guymon-Texhoma plains. Although wells in the Ogallala may obtain good water—as many appear to do in the area between Hackberry and Paloduro Creeks—it is probable that the volume of water is inadequate to supply large irrigation wells, and that it would soon be exhausted by many such wells.

Records were obtained of 64 wells in the Range Area, of which 19 were measured. In these 19 wells the water levels ranged from 26 to 117 feet below the surface, and averaged 55 feet, and the depths ranged from 43 to 194 feet, and averaged 93 feet. In 45 additional wells the reported depth ranged from 40 to 201 feet, and averaged 95 feet. The average depth of all the recorded wells was 94 feet. The water-bearing beds were reported as sand in 5 wells, gravel in 20, sand and gravel in 3, clay in 10, sand and clay in 3, and gravel and clay in 3.

Recharge of the Ground Water Reservoir

The addition of water to the underground reservoir is known as recharge, and the natural loss of water from the reservoir through seeps, springs, stream channels, evaporation, and use by plants, plus the amount withdrawn through wells, is known as discharge. As more water is pumped from a reservoir through wells, the natural discharge will decline, but because it usually is

132. Fitzpatrick, E. G., and Boatright, W. C., *Op. cit.*

not possible to salvage all of the natural discharge, some water will continue to escape through natural outlets after the safe yield of the reservoir has been exceeded. It follows, then, that the amount of water which can be pumped annually from the reservoir without causing a permanent and continuing decline of water levels is approximately the amount of the annual recharge, minus the part of the natural discharge that cannot be salvaged.

The ground water is derived from the water that falls as rain or snow, and the water table normally fluctuates in response to variations in rainfall, evaporation, and other climatic conditions. Once the water is in the reservoir it moves down the slope of the water table. Thus water which is added at a locality where it is of no immediate value may ultimately reach a place where it can be pumped profitably from the reservoir. The following paragraphs outline the ways in which recharge may be accomplished, with respect to Texas County.

Recharge from Local Rainfall. The amount of recharge over an area as large as Texas County is probably far from uniform because of variations in the amount of precipitation from one place to another, and because of variations in the disposal of the precipitation. The average annual precipitation of Texas County is about 18 inches. Of this amount, part is returned to the atmosphere through evaporation, part is used by plants, and part is lost through immediate run-off as flood waters. The remainder seeps downward through the soil and the underlying rocks into the zone of saturation. Most of the water in this zone eventually returns to the surface, either within the county or in outside areas, through seeps, springs, river channels, or wells, or is discharged by plants or by evaporation from the soil as it nears the surface.

The part of the precipitation that is lost by evaporation varies with the seasons, and is largest in the summer, when temperatures are highest (Table V). Finnell[133] states that 39 per cent of the water that falls during a wet period in the spring may become

133. Finell, H. H., "Agricultural significance of climatic features at Goodwell, Oklahoma": *Panhandle Agricultural Exp. Sta. The Panhandle Bulletin*, No. 40, pp. 22-23, 1929.

soil moisture, but as little as 22 per cent becomes soil moisture during the summer. Only a part of the soil moisture ever penetrates to the water table. On the average, a little more than half of the annual precipitation of Texas County comes in the four months from May through August, when temperatures are relatively high. Because there is also some loss by evaporation at other times, it is apparent that a rather large proportion of the annual precipitation must return to the atmosphere through evaporation.

The proportion of the precipitation used by plants is obviously greatest during the growing season, which again coincides rather closely with the season of maximum precipitation. Although the water used by plants cannot be considered entirely lost from the standpoint of human needs, it is lost so far as recharge of the ground water reservoir is concerned.

The part of the precipitation lost through immediate run-off depends on the rate at which the rain falls, the slope of the land, the porosity of the soil, and the amount of vegetation on the land. Other factors being equal, a much larger percentage of the water is lost through run-off during a heavy downpour than during a gentle rain. Moderate and steep slopes where soils are "tight" and there is little or no vegetation, favor a large loss through run-off, but in Texas County such slopes are limited to the breaks or the valley bluffs, and amount to less than a quarter of the total area. Hence the loss through immediate run-off is not excessive. Finnell[134] estimates that in the vicinity of Goodwell the average annual run-off is 2.43 inches, or about 13.5 per cent of the total annual precipitation.

The conditions which favor the downward percolation of water through the soil and into the underground reservoir are in general opposite to those which favor a large immediate run-off. The large areas of nearly flat plain in Texas County are areas where water will flow for only short distances. However, the soils generally are sandy or silty loams, or fine loamy sands, and water soaks into them slowly. Much of the rain that falls,

134. *Idem*, p. 41.

especially during heavy showers, must stand on the surface for a time, or drain off into the numerous depressions which dot the plains. In either case there may be considerable loss by evaporation, but some water will penetrate the soil. Once it is below the reach of plant roots and the zone where it can be evaporated from the soil, it will, in all probability, continue downward to the water table. The route followed is likely to be very circuitous because of the obstacles presented by impervious rock materials. Caliche underlies the soil nearly everywhere in the county, and the upper part of it is locally dense and impervious. On encountering such caliche, the water must move laterally or diagonally until it finds a crevice or joint leading downward, and because no single joint or crevice extends through the entire thickness of the caliche, the water must follow a zig-zag course downward. Below the caliche the route of movement is likely to be indirect because the impervious clays that are bedded with the sands force the water to move laterally for longer or shorter distances.

Some situations offer a much better opportunity for the water to begin this journey to the water table than others. The sand dune areas, the intermittent streams, and the temporary lakes are especially favorable.

The dune area east and southeast of Adams totals about 40 square miles, and the dunes along the Kansas state line, located mostly west of Tyrone, total about 32 square miles. In these areas a large percentage of the precipitation can enter the soil and move readily downward beyond the reach of plant roots and the influence of evaporation. Wells 761, 765, 770, and 842 are located in these dune areas, and have been selected for observation in an attempt to determine whether recharge takes place through the sand. Water level measurements have been repeated in these wells several times, and are summarized in the section on observation wells. Many more measurements over a long period of time will be necessary before the real importance of the dune areas can be estimated. In addition to the actual dunes, the soils in the southwestern corner of the county in T. 1 N., R.

10 E. are reported by the County Agricultural Agent[135] to be sandy, and recharge may also occur there.

The dry tributaries have cut through part or all of the caliche, particularly the denser, more impervious parts, and they are generally floored with rather coarse materials which will absorb part of the run-off waters. These waters will percolate downward and will make a high area—an elongate ridge—on the water table. Slopes on the water table are away from the dry streams rather than toward them. The amount of water that reaches the water table through any given stream channel may be small, but in the aggregate there are many square miles of dry stream channels. To the total of the tributaries, also, may be added the upper 13 or 14 miles of Beaver River Valley in southwestern Texas County.

The many shallow depressions which dot the upland plains often contain temporary lakes or ponds after heavy rains, and may be the sites of significant additions to the underground reservoir. Although some of the lakes are floored with clay,[136] the water generally stands in them long enough so that a considerable thickness of underlying beds can be saturated, or mud cracks which form when the lake is dry may lead the water downward to more pervious materials. Well 85 is located beside a lake which appears to have a maximum extent of about 115 acres. When the well was first measured, water covered several acres of land. Five months later the lake was dry, but the water level in the well was 0.58 foot higher. In August 1938, after a series of spring rains which were heavier than for several years previous, the water level was 1.21 feet higher than the original measurement of 12 months before, and the water level did not decline until November 1938.

Wild Horse Lake covers an area of about 160 acres in a broad, shallow, ill-defined depression in the northern part of the county, and may be the site of considerable additions to the ground water reservoir, as indicated by the fact that the water table stands at relatively high elevations for several miles to the east. The lines

135. Hyer, H. C., oral communication.
136. Randall clay. Fitzpatrick, E. G., and Boatright, W. C., *Op. cit.*, p. 24.

of equal elevation on the water table, which are shown on Fig. 8, bend sharply eastward in the vicinity of the lake, indicating a dome or "nose" extending eastward. A small pond covering some 5 or 10 acres is located near the lake and small additions of water may be made through it, but the well measurements are too few to show its effect. During the period of observation, the lake and the pond were dry, and observation well 354, located 2.5 miles northeast of the lake, showed only a very small rise of between 0.1 and 0.2 foot. This rise is too small to be conclusive, but might well have been greater if the well were closer to the lake, or if it were directly east of the lake, in the direction of the general slope of the water table.

Likewise, at Tyrone there is a small high area on the water table which may be attributed to recharge through several small lakes. However not all high areas indicated on the map of fig. 8 can be directly identified with lakes or ponds. At Bakersburg a strong eastward bend in the lines of elevation indicates a nose, but there are no lakes nearby. This nose may be related to looser and more permeable surface soils, or it may be a place where water finally reaches the water table after a circuitous journey from a rather distant point of intake.

In time the repeated measurements of water level in the observation wells in Texas County may show where recharge occurs and afford a measure of it, but at present the record is too short to justify any conclusive statement. However, the record of water-level measurements on the High Plains of Texas, south of Amarillo, is longer and includes periods of rather heavy rains, and it offers definite evidence that recharge does occur. White, Broadhurst, and Lang[137] report that the unused observation wells in this area which are out of the heavily pumped districts have shown clearly that recharge occurs along the dry washes and in the temporary lakes, and even in areas of ordinary upland plains. They conclude that: "In the aggregate the average amount of water that penetrates annually to the water table in the High

137. White, W. N., Broadhurst, W. L., and Lang, J. W., "Water in the High Plains in Texas": *U. S. Geol. Survey and Texas State Board of Water Engineers, Mimeographed Memorandum,* July 26, 1938, pp. 4-5.

Plains undoubtedly is very great. In depth over the entire area, however, the average recharge probably amounts to only a fraction of an inch." This statement can be applied to the High Plains in Texas County because general conditions are essentially the same as in the Texas area except that the average annual rainfall is somewhat less.

Recharge from precipitation on the Ogallala in outside areas. The intake area of a formation is generally about equivalent to its surface outcrop. The principal water-bearing formation of Texas County—the Ogallala—is widespread, and recharge in it can occur outside the county. The general slope of the land surface, the dip of the formation, the slope of the water table, and the direction of movement of the ground water are all southeastward. Hence, if exceptionally high recharge occurs to the west and northwest of Texas County, the water may ultimately move into Texas County and considerably increase the available supply.

The Ogallala formation of Texas County extends westward across Cimarron County and a few miles into New Mexico; northward into southwestern Kansas; and northwestward into southeastern Colorado. The effective recharge area so far as Texas County is concerned is limited on the northwest by the Cimarron River, which enters Oklahoma in the northwestern corner of Cimarron County, leaves again to enter Colorado about 12 miles west of the Texas County line, and flows thence through southern Kansas a few miles north of the Oklahoma State line. Most of the way across Cimarron County this river has cut through the Ogallala into the underlying Mesozoic rocks and there is no chance for ground water to move southward or southeastward into the Ogallala formation south of the valley. However, some ground water could possibly seep into the valley and go downstream into Colorado and Kansas, where the alluvium seems to be underlain by the Ogallala and southeastward movement of ground water may be possible. Here, also, ground water taken into the formation on the north side of the river may move southeastward under the valley and into Oklahoma.

To the west of Oklahoma erosion has cut through the Ogallala into older rocks, and there is no place where the outcrop here considered extends out of semi-arid country to a region of higher average precipitation. In general, topographic conditions and soils throughout the outcrop area are similar to those of Texas County, but the annual precipitation diminishes somewhat to the west and northwest. Any water which falls on the outcrop in outside areas and reaches Texas County by moving underground is probably offset by that which falls on the outcrop within the county and moves eastward or southward into Beaver County or Texas. Thus, in the absence of large additions of water from especially favored outside areas, it is safe to conclude that recharge through precipitation on the outcrop at adjacent places does not materially increase the total recharge of the ground water reservoir above that which normally takes place within the county.

Recharge by Beaver River. Streams which flow from regions of abundant precipitation, such as mountains, will either dwindle or disappear entirely as they cross arid and semi-arid regions because of evaporation of the water or seepage into their channels. The seepage goes to the ground water reservoir, and where the streams are large or numerous, the total recharge in the arid or semi-arid region may be many times greater than that which could normally come from local rainfall. In Texas County the only large stream that comes from a distance is the Beaver. Its headwaters are in northeastern New Mexico about 45 miles west of the Oklahoma line, at an elevation of about 6,500 feet, where the average annual precipitation as recorded by the Weather Bureau[138] is very similar to that of Texas County. Direct observation shows that in Texas County the upper part of the Beaver usually carries a stream for only a short time after a rain. Hence it appears unlikely that the Beaver receives enough water at or near its head to provide a flow reaching into Texas County, except occasionally after unusually heavy or long-continued rains.

Where Beaver River has a permanent flow the water is coming from the ground water reservoir rather than directly from precipitation in a distant locality.

Evidence for this conclusion is afforded by the fact that the

138. *U. S. Weather Bureau*, "Climatic Summary of the United States, Section 28, Northeastern New Mexico," 1930.

volume of water increases in a downstream direction, even before the contributions of Coldwater and Paloduro Creeks are received, and by the fact that the upper parts of the river are usually dry, not only in Texas County, but also in Cimarron County. Reference to Fig. 8 will show that in the eastern part of the county the slope of the water table near the Beaver is toward the river, not away from it. Because ground water moves in the direction of the maximum slope of the water table, it is clear that the permanent flow is coming from the ground water reservoir, not contributing to it.

From the foregoing discussion there can be only one conclusion, namely that the only water brought from outside areas by the Beaver and added to the ground water reservoir in Texas County is the percentage of the flood waters which can seep into the channel during the brief passage of a flood, as described on page, 151 but the looseness, permeability and thickness of the alluvium in the valley suggests that this percentage may be significant.

Recharge from Cimarron River. Cimarron River does not flow through Texas County, but it passes only a few miles north of the State line. Where it has cut its valley into the Mesozoic rocks, as along most of the stretch of river in Cimarron County, Oklahoma, the water cannot move out of the alluvium readily because adjacent and underlying rocks are relatively impervious. The alluvium is therefore nearly full of water, and the water table is approximately at the level of the stream bed. In places the water flows in the channel, and floods are frequent. Where the valley is partly or entirely in the Ogallala formation, as in northeastern Cimarron County, southeastern Colorado, and southwestern Kansas, the water may move laterally out of the alluvium and some may move southeastward through the Ogallala into Texas County. It is reported that little water flows in the 60-mile stretch of river downstream from the easternmost outcrop of pre-Ogallala rocks.[139] Hence it is possible that water reaches the ground water reservoir along this stretch.

139. Drainage Basin Committee's Reports for the Arkansas, Upper White, and St. Francis Basins, National Resources Committee, p. 17, December 1937.

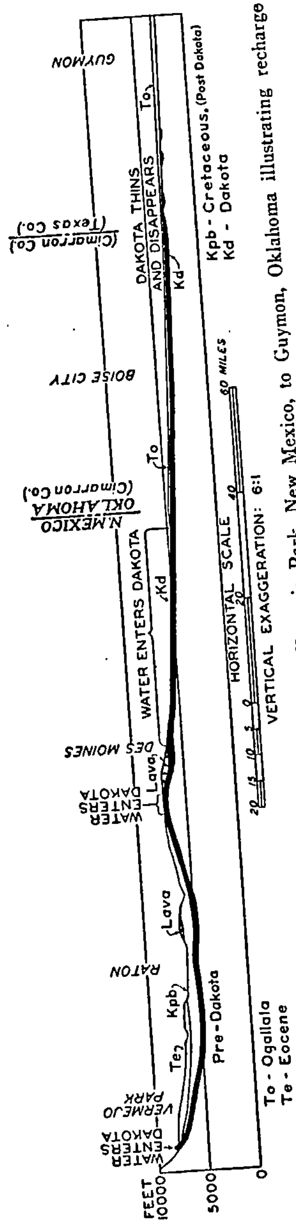


FIGURE 12. West-to-east cross section from the vicinity of Vermejo Park, New Mexico, to Guymon, Oklahoma illustrating recharge of the Ogallala formation from the Dakota sandstone.

Recharge from the Dakota Sandstone. There is a possibility that water which enters the Dakota sandstone in northeastern New Mexico or southeastern Colorado may travel down the dip into Oklahoma, and may migrate into the overlying Ogallala formation where the two formations are in contact and where the Dakota thins and finally disappears in eastern Cimarron County or western Texas County.[140] This method of recharge is illustrated by a west-to-east cross-section from the vicinity of Elizabethtown, New Mexico, to Guymon, Oklahoma[141] (Fig. 12). The Dakota sandstone is well known and widely used as a water-bearing formation, and it doubtless absorbs part of the precipitation that falls on it. Near Des Moines, New Mexico, the Dakota crops out at an elevation of about 6,500 feet, and is exposed for 50 miles to the east. It dips eastward, passing beneath the Ogallala formation a few miles west of the Oklahoma State line, at an elevation of about 4,700 feet. In Oklahoma it is exposed only along the valley of Cimarron River,[142] but presumably is present under the Ogallala in part of Cimarron County. In Texas County, however, it is absent at both of the two localities where rocks older than the Ogallala are exposed. Sandstones of Cretaceous age are exposed at the Red Point locality, west of Guymon, but are older than the Dakota. It is apparent, then, that the Dakota must thin and disappear somewhere between northeastern New Mexico and Red Point. As it becomes thinner, its capacity must become less until whatever water there is in it has to migrate into the lower beds of the Ogallala formation, and a similar movement of water into the Ogallala from Lower Cretaceous sandstones may also occur. Downward migration of water from the Cretaceous rocks is unlikely because the underlying beds are relatively impervious.

The possibility of recharging the Ogallala from the Dakota in this manner is limited by the scanty rainfall in the intake areas,

140. State Geologist R. H. Dott called the writer's attention to this possibility.
141. Geology and elevations for New Mexico are based on the Geologic Map of New Mexico, prepared by N. H. Darton, 1928. Some exposures of Cretaceous, Tertiary, and Quaternary igneous rocks have been omitted because they do not bear on the interpretation here offered.
142. Rothrock, E. P., "Geology of Cimarron County, Oklahoma": *Okla. Geol. Survey Bull.* 34, pp. 49-57, and Geologic Map, 1925.
Stovall, J. W., *Op. cit.*

by the probable discharge from the Dakota where it crops out, and by the capacity of the formation to transmit water laterally, especially near its eastern margin where it becomes thin. As shown by Fig. 12, the largest outcrop area which has any bearing on the present problem lies between the Oklahoma-New Mexico State line, and Des Moines, New Mexico. It is about 50 miles long from east to west, and 15 or 20 miles wide, and covers 800 or 900 square miles. Over an area of this size a considerable amount of water could be taken into the Dakota, but the average annual precipitation is relatively low, being very nearly the same as for Texas County, Oklahoma. The greatest precipitation on the Dakota probably occurs farther west along the front of the mountains, where the formation stands up as a hogback, but actual precipitation figures are not available for this locality. No estimate of the amount of water taken from the Dakota sandstone through wells in northeastern New Mexico is available. Some of the water in the formation seeps out at the contact of the Dakota on the underlying shales of the Purgatoire formation in Cimarron County, Oklahoma, and other losses doubtless occur along Cimarron River in New Mexico. Also, some water probably is discharged from the formation where it is exposed along the headwaters of Beaver River in New Mexico.

SUMMARY—AMOUNT OF ANNUAL RECHARGE

From the foregoing discussion it appears that much of the annual recharge to the ground water reservoir under Texas County comes from local precipitation which probably enters the ground through areas of sand dunes and sandy soils, through channels of dry washes, and through the temporary lakes. Probably only a small percentage of the 18 inches of precipitation which Texas County receives in an average year ever reaches the water table. There are no parts of the outcrop area of the Ogallala formation outside the county where exceptionally high precipitation and recharge occur. A significant part of the flood waters which come down Beaver River probably reaches the ground water reservoir through the dry channel in the upper part of the river. The Beaver, however, is not a mountain stream, but rises on the semi-arid plains in northeastern New Mexico. Floods on

Cimarron River are frequent and may contribute considerable water to the underground reservoir through seepage into alluvium. There is a possibility that some water that falls as rain on the outcrop of the Dakota or underlying sandstones ultimately gets into the Ogallala in Texas County. The amount of average annual recharge is a complex problem for the solution of which adequate data are not yet available.

It is probable that the recharge is approximately balanced by the discharge. Although some phases of the discharge can be estimated roughly, the tests necessary for estimating other phases have not been attempted. Thus tests of the amounts of water evaporated from the surfaces of the permanent streams and of the amounts removed from the underground reservoir by evaporation from the soil and by transpiration of plants where the water table is near the surface would be desirable. However, it is evident that the natural discharge of ground water through the perennial streams—Beaver River, Paloduro, Hackberry, and Coldwater Creeks—or by evaporation and transpiration in low-lying areas is not very large.

These considerations lead to the conclusion that the average annual recharge, although amounting to a considerable quantity of water in the aggregate, is equal to only a small part of the quantity of water that falls on the county as rain or snow. It is evident that the ground water supply of Texas County should be well husbanded, that the uses made of it should be carefully considered, and that a current inventory should be maintained of the withdrawals by pumping and of the resultant depletion of the supply as indicated by fluctuations in the water levels.

Observation Wells

In order to obtain a record of the fluctuations in water level which take place normally, about 45 wells in different parts of the county have been selected for observation. Measurements of the water levels in them are being made about every two months, and it is hoped that this program can be continued. The measurements may afford data for quantitative estimates of the amount of annual recharge, and will be especially valuable in showing the effects of heavy pumping and the probable amount of water that can be safely withdrawn through wells, either for irrigation or for other uses.

The wells selected represent a variety of topographic conditions. Including the wells which were abandoned for various reasons after several measurements had been made, 28 are located on upland flats, 3 are near temporary lakes, 4 are in or near sand dune areas, and 11 are located on the flood plains of Beaver River or its tributaries. Most of them draw water from the Ogallala formation, but several end in alluvium, and one (number 294) penetrates Triassic (?) red beds.

The period of observation is still too short to permit drawing any conclusions regarding the amount of annual recharge of the ground water reservoir, or even an adequate statement regarding the main annual trends. In general, the record indicates that the greatest fluctuation in water levels is in the alluvium of the valleys, and also that levels in wells so situated show the most direct response to periods of rainfall and drought. Under upland areas, where the water table is deep below the surface, water levels appear to fluctuate through a shorter range, and only slow general trends are recognizable.

The initial measurements in the observation wells were made in the course of routine field work, and accordingly were spread over a period of several months. Subsequent measurements have been bimonthly, and in some wells the autumn measurements for 1938 closely coincided in month and day, with the initial 1937 measurements. In other wells the 1938 measurements were about a month earlier or later than the initial 1937 measurements. The following paragraphs offer a comparison of the water levels in 1937 and 1938, so far as comparison is possible.

In well 85 the water level was 1.21 feet higher on August 28, 1938 than it was on August 27, 1937. This is a shallow well beside a large temporary pond. The soil of the bottom of the pond is rather loose and porous and is extensively cracked. The pond contained water in August 1937, but was generally dry beginning in January 1938. However, water probably stood in the pond for short periods after heavy rains, of which there were several in the spring and summer. The rise of water level in the well implies that recharge occurred through the pond.

Water level measurements in 14 wells were first made between September 7, and October 8, 1937, and were repeated on September 19, 20, and 28, 1938. In 11 of these wells the rise in water level ranged from 0.03 foot to 0.65 foot, but in 3 of the wells the water levels declined by amounts ranging from 0.14 to 0.7 foot. For the entire group of 14 wells there was an average rise of 0.18 foot. Of the wells showing a decline in water level, number 497 is about 25 feet from an irrigation well that was pumped somewhat more heavily in 1938 than in 1937, and number 172 is about 0.75 mile northeast of irrigation well 181 and about 2 miles northeast of irrigation well 179, both of which were pumped more heavily in 1938 than in 1937. If the records of these two wells are omitted, the average rise during the year was 0.29 foot for the other 12 wells.

Wells 120, 530, 551, and 552 were first measured October 20 and 23, 1937. In 1938 they were measured in September and again in November. To afford a basis for comparison, estimates of the probable positions of the water levels in October 1938 were made by interpolating between the actual measurements of September and November. In wells 120 and 551 these interpolated water levels were 0.81 foot and 0.21 foot respectively higher than in October 1937. In wells 530 and 552 the interpolated levels for 1938 were 0.06 and 0.16 foot lower than in October 1937. The average change for these four wells is a rise of 0.2 foot.

Water level measurements in 11 wells were first made between October 29 and December 19, 1937, and were repeated on November 19, 21, 22, and 24, 1938. One additional well (number 72) that was first measured on October 23, 1937 is included in this group because lack of a measurement for September 1938 makes it impossible to interpolate an October water level in the foregoing manner. The water levels in 8 of these wells were 0.02 foot to 0.35 foot lower in 1938 than in 1937, and in the other 4 wells they were 0.04 to 0.33 foot higher. The average change for this group of 12 wells was a decline of 0.01 foot.

Of the 31 wells for which comparisons between 1937 and 1938 measurements are possible, the water levels in 18 wells rose by amounts ranging from 0.03 foot to 1.21 foot. The water levels in 13 wells declined by amounts ranging from 0.02 foot to 0.7 foot. The average change in the 31 wells was a rise of 0.14 foot.

In the following descriptions, the significant data regarding the observation wells are summarized.[143] The wells are divided into east-west and north-south lines. The east-west line is given first, with wells listed in approximate order beginning with the eastern-most. The north-south line begins at the north. All water levels and depths are stated in feet below the measuring points.

EAST-WEST LINE OF OBSERVATION WELLS

765. Owner unknown, SW¼ sec. 26, T. 3 N., R. 19 E. Drilled stock well, diameter 6 inches, depth 120 feet; in use. Well is located in an area of sand dunes totaling several square miles. Measuring point, top north edge of tee, 3.25 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Dec. 3, 1937	107.20	July 27, 1938	107.35
Jan. 18, 1938	107.32	Sept. 20	107.30
March 21	107.31	Nov. 24	107.25
May 24	107.29		

770. A. C. DeHart, SW¼ NW¼ sec. 15, T. 3 N., R. 19 E. Drilled domestic well, diameter 4.5 inches, depth 125.7 feet; unused, no pump. Well is located in an area of sand dunes totaling several square miles. Measuring point, high point on south edge of casing, 0.1 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Dec. 3, 1937	123.89	July 27, 1938	123.91
Jan. 18, 1938	123.93	Sept. 20	123.88
March 21	123.33	Nov. 24	123.85
May 24	124.01		

143. Descriptions for most of the observation wells, and the 1937 water level measurements, have also been published in "Water Levels and Artesian Pressures in Observation Wells in the United States in 1937": *U. S. Geol. Survey, Water Supply Paper* 840, 1938. Subsequent water level measurements will be published in future papers in this series. The descriptions here are corrected and revised where necessary, and additional wells are given.

497. R. M. Van Hyning, NW¼ NW¼ SW¼ sec. 21, T. 4 N., R. 19 E. Drilled well, diameter 12.5 inches, depth 280 feet; unused, no pump. Well is located on upland flat about 25 feet west of irrigation well (same number) which is used during growing season. Measuring point, edge of smaller of two holes in head of oil drum used to cover the well, 1.0 foot above surface. Water levels, in feet, in 1937-38: Sept. 13, 1937, 104.80; Sept. 20, 1938, 105.06; Oct. 8, 104.90; Nov. 24, 104.72.

761. Mrs. Cordia Humble, NW¼ NW¼ sec. 7, T. 3 N., R. 19 E. Drilled domestic well, diameter 4.5 inches, depth 117 feet; used little if at all. Well is located on western edge of area of sand dunes totaling several square miles. Measuring point, top edge of iron pipe clamp, south side of pipe, 0.7 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Dec. 3, 1937	108.74	July 27, 1938	108.74
Jan. 18, 1938	108.67	Sept. 20	108.78
March 21	108.58	Nov. 24	108.84
May 24	108.68		

487. J. E. Friesen, SE¼ SE¼ sec. 34, T. 4 N., R. 18 E. Drilled stock well, diameter 5 inches, depth 120 feet; not used. Well is located on upland flat beside small temporary pond. Measuring point, top inside edge of west block of wooden pipe clamp, on north side of pipe, 1.5 foot above land surface. Water levels, in feet, in 1938: July 26, 101.31; Sept. 20, 101.29; Nov. 24, 101.51.

60. J. E. Friesen, SW¼ NW¼ sec. 3, T. 3 N., R. 18 E. Drilled domestic well, diameter 6 inches, depth 121 feet; in use. Well is located on upland flat. Measuring point, top east edge of tee, 2.5 feet above land surface, or 2.0 feet above concrete slab around the well.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Dec. 3, 1937	100.76	May 24, 1938	100.47
Jan. 18, 1938	100.33	July 27	100.37
March 21	100.32	Sept. 23	100.07

795. Herman Zable, NW¼ SW¼ sec. 30, T. 4 N., R. 18 E. Drilled domestic well, depth 124 feet; used a little. Well is located on upland flat. Measuring point, southeast top edge of tee, 3.7 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Dec. 7, 1937	116.88	July 26, 1938	116.84
Jan. 18, 1938	116.83	Sept. 20	116.81
March 21	116.78	Nov. 24	116.55
May 24	116.87		

589. August Lorenz, NW¼ NW¼ sec. 34, T. 4 N., R. 17 E. Drilled domestic well, depth 142 feet; in use. Well is located on upland flat. Measuring point, top edge of iron pipe clamp on east side of pipe, 0.5 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 29, 1937	120.00	May 24, 1938	120.10
Jan. 18, 1938	120.19	July 26	120.11
March 21	120.11	Sept. 23	120.12

40. August Lorenz, NE¼ NW¼ sec. 6, T. 3 N., R. 17 E. Drilled stock well, depth 97 feet; in use. Well is located on upland flat near tributary of Pony Creek. Measuring point, top inside edge of east block of wooden pipe clamp, on north side of pipe, 0.3 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Dec. 19, 1937	90.97	May 24, 1938	91.00
Jan. 15, 1938	90.93	July 27	90.96
March 21	90.93	Nov. 24	90.99

323. Mrs. Bostwick, SW¼ SE¼ sec. 1, T. 3 N., R. 16 E. Drilled domestic well, diameter 5 inches, depth 25 feet; not used. Well is located low in the valley of Pony Creek. Measuring point, edge of hole in tin cover through which pipe passes, 05 foot above land surface. Water levels, in feet, in 1937-38: Oct. 29, 1937, 21.90; July 27, 1938, 21.67; Sept. 20, 21.51; Nov. 24, 21.95.

324. Anna Calvert (?), SW¼ SW¼ sec. 2, T. 3 N., R. 16 E. Drilled domestic well, diameter 4 inches, depth 100 feet; not used. Well is located on upland flat. Measuring point, clamp bolt on north side of pipe, 0.3 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 29, 1937	95.67	May 24, 1938	95.68
Jan. 15, 1938	95.63	Sept. 20	95.72
March 21	95.65	Nov. 24	95.75

325. Mr. Ensten, NW¼ NW¼ sec. 2, T. 3 N., R. 16 E. Drilled stock well, diameter 4 inches, depth 121 feet; used little. Well is located on upland flat between Beaver River and Pony Creek. Measuring point, east edge of casing, 0.4 foot above land surface. Water levels, in feet, in 1938: Jan. 17, 105.03; July 27, 105.10; Sept. 20, 105.01; Nov. 24, 105.46.

350. C. A. Nash, NW¼ sec. 18, T. 3 N., R. 16 E. Drilled as an irrigation well, but found inadequate, diameter 19 inches, depth 35 feet, with 21 feet of perforated galvanized casing; used for domestic and stock purposes. Well is located on flood plain of Beaver River. Measuring point, south edge of casing, 4.0 feet below land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 2, 1937	3.69	July 27, 1938	3.62
Jan. 21, 1938	2.55	Sept. 20	3.29
March 21	2.54	Nov. 22	2.67
May 24	2.53		

187. John Gill, SE¼ NW¼ sec. 12, T. 3 N., R. 15 E. Drilled well, diameter 6 inches, depth 10 feet; unused, no pump. Well is located on flood plain of Beaver River. Measuring point, high point on north edge of casing, 1.4 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 7, 1937	5.50	May 24, 1938	4.48
Oct. 9	5.53	July 27	5.50
Jan. 21, 1938	4.84	Sept. 20	4.94
March 21	4.59	Nov. 22	4.84

295. E. O. Hobson, SW¼ NW¼ sec. 14, T. 3 N., R. 15 E. Dug well, diameter 30 inches, depth 14 feet; bucket and line, in

use. Well is located on flood plain of Beaver River. Measuring point, south edge of casing, 3.0 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 15, 1937	11.88	May 24, 1938	10.96
Oct. 9	11.98	July 27	11.76
Jan. 21, 1938	11.20	Sept. 20	11.23
March 21	10.90	Nov. 22	11.17

332. Owner unknown, SW¼ SE¼ sec. 17, T. 3 N., R. 15 E. Drilled domestic well, diameter 5 inches, depth 75 feet, not in use. Well is located in valley of Beaver River less than 0.5 mile south of channel, but on top of divide between two small tributaries, above flood plain level, unused. Measuring point, west edge of casing, 3.5 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 18, 1937	69.35	May 24, 1938	68.97
Oct. 9	69.78	July 26	69.09
Jan. 21, 1938	69.45	Sept. 20	69.06
March 21	69.20	Nov. 22	68.99

72. William L. Ziegler, SW¼ NW¼ sec. 33, T. 4 N., R. 14 E. Drilled domestic well, diameter 4 inches, depth 90 feet; in use. Well is located on slope near top of divide between Goff Creek and one of its tributaries. Measuring point, clamp bolt on west side of pipe, 2.0 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 23, 1937	74.37	May 26, 1938	74.45
Jan. 28, 1938	74.44	Nov. 22	74.47
March 22	74.50		

307. Henry Behne, NE¼ NE¼ NE¼ sec. 5, T. 3 N., R. 14 E. Drilled domestic well, depth 72 feet; unused. Well is located on a gentle slope, below the upland level. Measuring point, inside upper edge of west block of wooden pipe clamp, on south side of pipe, 0.3 foot above land surface. Water levels, in feet, in 1938: Aug. 17, 65.68; Sept. 19, 65.65.

294. Stonebraker-Zea ranch, NW¼ NW¼ sec. 25, T. 3 N., R. 13 E. Drilled well, diameter 5 inches, depth 57.5 feet; unused, no pump. Well is located on sloping bluff of Beaver River, and ends in Triassic (?) red beds. Measuring point, south edge of casing, 1.0 foot above land surface. Water levels, in feet, in 1937-38: Sept. 24, 1937, 43.47; Oct. 9, 43.47; Aug. 8, 1938, 43.13; Sept. 28, 43.08.

551. Owner unknown, SW¼ SW¼ sec. 19, T. 4 N., R. 13 E. Drilled well, diameter 5 inches, depth 214 feet; unused, no pump. Well is located on slightly undulating upland. Measuring point, south edge of casing, 1.0 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 23, 1937	146.69	July 25, 1938	146.42
Jan. 27, 1938	146.80	Sept. 19	146.53
March 22	146.57	Nov. 21	146.43
May 26	146.51		

552. B. G. Manwarren, NE¼ NE¼ sec. 1, T. 3 N., R. 12 E. Drilled domestic well, diameter 5 inches, depth 185 feet; in use. Well is located on upland flat. Measuring point, top west edge of tee, 3.0 feet above land surface. (0.62 foot above casing).

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 23, 1937	177.97	July 25, 1938	177.88
Jan. 27, 1938	178.13	Sept. 19	178.12
March 22	178.13	Nov. 21	178.14
May 26	177.90		

661. William Webb, SE¼ NE¼ sec. 8, T. 3 N., R. 12 E. Drilled domestic well, diameter 4 inches, depth 19 feet; in use. Well is located about 5 feet above channel of tributary to Tepee Creek. Measuring point, west edge of casing, 2.0 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Nov. 10, 1937	14.37	May 26, 1938	12.94
Jan. 27, 1938	14.77	July 25	11.87
March 22	14.83		

286. William Webb, SW¼ SW¼ sec. 9, T. 3 N., R. 12 E. Drilled stock well, diameter 5.5 inches, depth 56 feet; unused.

Well is located in bottom of intermittent tributary of Tepee Creek. Measuring point, east edge of casing, 0.3 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Nov. 10, 1937	23.91	Sept. 19, 1938	23.47
July 25, 1938	21.39	Nov. 21	23.97
Aug. 28	24.05		

85. George Dean, SE¼ NE¼ sec. 34, T. 4 N., R. 11 E. Drilled well, diameter 4.5 inches, depth 45.9 feet; unused, no pump. Well is located near shallow pond on upland. Measuring point, high point on southeast side of casing, 1.2 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Aug. 27, 1937	43.10	July 25, 1938	41.97
Jan. 27, 1938	42.53	Aug. 28	41.89
March 22	42.63	Sept. 19	41.80
May 26	42.57	Oct. 16	41.74
		Nov. 19	41.93

270. Owner unknown, NW¼ SW¼ sec. 7, T. 3 N., R. 11 E. Drilled domestic well, depth 82 feet; unused. Well is located low in valley of Tepee Creek. Measuring point, north clamp bolt, 0.6 foot above land surface. Water levels, in feet, in 1937-38: Nov. 5, 1937, 73.48; July 25, 1938, 73.57; Sept. 19, 73.58; Nov. 19, 73.38.

621. Owner unknown, NW¼ NW¼ sec. 2, T. 3 N., R. 10 E. Drilled domestic well, depth 165 feet; unused. Well is located on undulating upland, and appears to tap a lower aquifer than wells 618 and 626. Measuring point, top west edge of coupling, 1.6 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Nov. 5, 1937	151.25	July 25, 1938	151.01
Jan. 27, 1938	151.11	Sept. 19	151.17
March 22	150.81	Nov. 19	151.06
May 26	150.93		

618. Owner unknown, NW¼ NW¼ sec. 11, T. 3 N., R. 10 E. Drilled well, diameter 4.5 inches, depth 65 feet; unused, no pump. Well is located on sloping upland within 0.5 mile north of channel of Tepee Creek (intermittent). Measuring point, north edge of casing, level with land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Nov. 4, 1937	55.68	July 25, 1938	56.00
Jan. 27, 1938	55.97	Aug. 28	55.90
March 22	56.20	Sept. 19	Unmeasurable
May 26	56.14		

626. John Copeland, SW¼ NW¼ sec. 27, T. 4 N., R. 10 E. Drilled domestic well, diameter 5 inches, depth 112 feet; in use. Well is located on upland flat and is notable for shallow water level in such location. Measuring point, top inside edge of gear wheel used as pipe clamp, 0.6 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Nov. 6, 1937	91.72	May 26, 1938	91.68
Jan. 27, 1938	91.65	July 25	91.50
March 22	91.21		

NORTH-SOUTH LINE OF OBSERVATION WELLS

842. C. A. Rahm, NW¼ NE¼ sec. 22, T. 6 N., R. 16 E. Drilled domestic well, diameter 4.5 inches, depth 145 feet; unused, no pump. Well is located in sand dune area totaling several square miles. Measuring point, high point on west edge of casing, 1.7 feet above land surface on north side of well.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Dec. 15, 1937	123.80	July 26, 1938	123.75
Jan. 26, 1938	123.89	Sept. 19	123.96
March 23	123.72	Nov. 22	124.15
May 25	123.72		

369. Owner unknown, NE¼ NE¼ sec. 15, T. 6 N., R. 15 E. Drilled domestic well, depth 163.5 feet; unused. Well is located on upland. Measuring point, top inside edge of north

block of wooden pipe clamp, on east side of pipe, level with land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 22, 1937	156.10	May 25, 1938	156.03
Jan. 26, 1938	156.12	July 26	Unmeasurable
March 23	156.04		

354. A. M. Fankhauser, SE¼ SW¼ sec. 27, T. 6 N., R. 15 E. Drilled domestic well, diameter 5 inches, depth 167 feet; in use. Well is located at north end of depression containing Wild Horse Lake and a small pond. Measuring point, top inside edge of west block of wooden pipe clamp, on north side of pipe, 1.0 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 21, 1937	149.01	July 26, 1938	148.89
Jan. 26, 1938	149.00	Sept. 19	148.90
March 23	148.90	Nov. 22	Repaired.
May 25	148.91		Not measurable.

120. Joe Gribble, NE¼ NE¼ sec. 2, T. 5 N., R. 14 E. Drilled domestic well, diameter 6 inches, depth 200 feet; used a little. Well is located on upland flat. Measuring point, top north edge of coupling, 0.65 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 20, 1937	196.95	July 26, 1938	196.55
Jan. 26, 1938	196.45	Sept. 19	196.17
March 23	196.31	Nov. 21	196.10
May 25	197.11		

530. Owner unknown, NE¼ NE¼ sec. T. 5 N., R. 14 E. Drilled domestic well, depth 184 feet; unused. Well is located on upland flat. Measuring point, top east edge of tee, 1.0 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 20, 1937	178.50	July 26, 1938	178.46
Jan. 26, 1938	178.50	Sept. 19	178.48
March 23	178.43	Nov. 21	178.63
May 25	178.45		

507. J. H. Wells, SE¼ SW¼ sec. 1, T. 4 N., R. 14 E. Drilled domestic well, diameter 6 inches, depth 181 feet; in use. Well is located on upland flat. Measuring point, iron pipe clamp on east side of pipe, level with land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 8, 1937	165.87	May 25, 1938	165.44
Jan. 26, 1938	165.59	Sept. 19	165.56
March 23	165.38	Nov. 21	165.75

446. Owner unknown, NW¼ NE¼ NW¼ sec. 8, T. 4 N., R. 15 E. Drilled domestic well, depth 163 feet; unused. Well is located on upland flat beside temporary pond. Measuring point, upper edge of east block of wooden pipe clamp, on south side of pipe, 0.25 foot above land surface. Water levels, in feet, in 1938: July 26, 149.37; Sept. 19, 149.41; Nov. 21, 149.55.

235. John E. Bauer, SW¼ SW¼ sec. 18, T. 4 N., R. 15 E. Drilled domestic well, diameter 5 inches, depth 190 feet; unused. Well is located on upland flat. Measuring point, top inside edge of west block of wooden pipe clamp, north of pipe, 0.5 foot above land surface. Water levels, in feet, in 1937-38: Sept. 10, 1937, 168.59; Jan. 26, 1938, 168.96; March 23, 169.17; May 25, unmeasurable.

436. Leo Holtgraver, NE¼ NE¼ sec. 24, T. 4 N., R. 14 E. Drilled domestic well, diameter 4 inches, depth 198 feet; in use. Well is located on upland flat. Measuring point, top edge of coupling on north side of pipe, level with land surface. Established as observation well to replace number 235. Water levels, in feet, in 1938: May 26, 170.81; July 26, 171.01; Sept. 19, 171.05; Nov. 21, 171.12.

176. W. N. Ballinger, SW¼ SW¼ sec. 18, T. 3 N., R. 15 E. Drilled well, diameter 19 inches, depth 30 feet; used for irrigation. Well is located on Beaver River flood plain. Measuring point, southeast edge of casing, 5.22 feet below land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 4, 1937	3.71	May 26, 1938	1.79
Sept. 9	2.00	July 26	4.17
Oct. 9	3.07	Sept. 19	1.20
Jan. 22, 1938	2.17	Nov. 21	2.19
March 22	2.10		

386. Frank Roten, SE¼ SE¼ sec. 3, T. 2 N., R. 14 E. Drilled stock well, diameter 5 inches, depth 108.9 feet, probably little used. Well is located on upland flat near South Fork of Beaver River (intermittent). Measuring point, clamp bolt on south side of pipe, 0.5 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 24, 1937	102.12	July 25, 1938	101.98
Jan. 25, 1938	102.05	Sept. 20	101.95
March 23	102.10	Nov. 21	101.97
May 25	102.03		

399. Andrew Bender, NE¼ SE¼ sec. 26, T. 2 N., R. 14 E. Drilled domestic well, depth 142.5 feet; used a little. Well is located on upland flat. Measuring point, top west edge of coupling, level with land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 25, 1937	127.55	May 25, 1938	127.76
Jan. 25, 1938	127.79	July 25	127.71
March 23	127.79	Sept. 20	127.69

172. Owner unknown, SE¼ SE¼ NE¼ sec. 25, T. 2 N., R. 13 E. Drilled stock well, diameter 4 inches, depth 141 feet. Well is located on upland flat. Measuring point, edge of casing, 1.2 feet above land surface. Water levels, in feet, in 1937-38: Sept. 30, 1937, 119.74; Aug. 12, 1938, 120.63; Sept. 20, 120.44; Nov. 21, 120.34.

182. Panhandle Agricultural and Mechanical College, NE¼ NE¼ SE¼ sec. 34, T. 2 N., R. 13 E., about 100 feet E. of SE cor. Sewell-Loofburrow Hall and beside curb of driveway. Drilled well, diameter 6 inches, depth 151 feet; unused, no pump. Well is located on upland flat, near campus irrigation well (no. 179). Measuring point, edge of soil pipe where 6 inches in diameter, level with land surface. Water level, in feet, Nov. 22, 1938, 138.74.

404. Everett J. Ritter, NW¼ NE¼ sec. 4, T. 1 N., R. 14 E. Drilled domestic well, diameter 5 inches, depth 177.2 feet; in use. Well is located on undulating upland. Measuring point, top inside edge of west block of wooden pipe clamp, on north side of pipe, 1.3 feet above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Sept. 25, 1937	167.08	July 25, 1938	167.07
Jan. 25, 1938	167.20	Sept. 20	167.05
March 23	167.14	Nov. 21	167.28
May 25	167.11		

167. Owner unknown, SW¼ SE¼ SE¼ sec. 34, T. 2 N., R. 12 E. Drilled stock well, diameter 5 inches, depth 196 feet; unused, no pump. Well is located on upland flat 0.25 mile or less from breaks of Beaver River, and 1.75 miles east of river channel. Measuring point, south edge of casing, level with land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 11, 1937	190.77	Oct. 16, 1938	190.72
Aug. 12, 1938	190.79	Nov. 21	190.93
Sept. 20	190.97		

459. Owner unknown, NE¼ NW¼ sec. 21, T. 1 N., R. 14 E. Drilled domestic well, depth 71 feet; unused. Well is located about 45 feet above channel of Frisco Creek (intermittent). Measuring point, base of pump head on east side of well, 1.0 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 1, 1937	65.16	July 25, 1938	65.02
Jan. 25, 1938	65.40	Sept. 20	64.59
March 23	65.34	Nov. 21	65.04
May 25	65.24		

461. Owner unknown, NW¼ NW¼ sec. 31, T. 1 N., R. 14 E. Drilled domestic well, diameter 5 inches, depth 202.8 feet;

unused, no pump. Well is located on upland flat. Measuring point, north edge of casing, 0.5 foot above land surface.

WATER LEVEL, IN FEET, 1937-38

Date	Water level	Date	Water level
Oct. 1, 1937	192.13	July 25, 1938	191.92
Jan. 25, 1938	192.24	Sept. 20	191.98
March 23	192.16	Nov. 21	192.06
May 25	191.97		

WELL LOGS

In the following pages the logs of several Texas County water wells are given. The number of the well log corresponds with the number of the well as given in the well tables and on Plate I. In general these logs are essentially as recorded by the driller, but a few changes have been introduced to make the terminology agree with geologic usage. Beds reported by the driller as "gyp" are here interpreted as caliche, and "soapstone" is interpreted as shale or clay. True soapstone is a metamorphic rock which has no place among the sedimentary rocks of Texas County, but the name is commonly used to describe very fine shales or clays that become soapy or greasy when wet. In some logs the water-bearing sands reported as "fair" or "good" have been interpreted as "medium-grained" and "medium- to coarse-grained", in keeping with the known practice of the driller.

In addition to the logs of Texas County wells, the logs of six wells located just over the state line in Kansas are given (numbers K-1 to K-6). These all begin on the Ogallala formation and reach depths ranging from 277 feet to 502 feet, and some reach red beds which may be interpreted as Triassic (?) or Permian.

176-A. Domestic well of W. N. Ballinger, SW¼ SW¼ SW¼ sec. 18, T. 3 N., R. 15 E., within 25 feet of irrigation well 176. Originally 41 feet deep, it was deepened to 105 feet in 1937.

	Thickness (feet)	Depth (feet)
Alluvium		
Not reported. Static water level about 7 feet. First water, contains blue mud and has swampy taste, (cased out)	14	14
Coarse, water-bearing gravel (second water; supplies adjacent irrigation well; cased out)	16	30
Red clay	40	70
Coarse sand and fine gravel, water-bearing (third water)	35	105
Lower 10 feet of the 4.5-inch steel casing is perforated.		

179. Panhandle Agricultural and Mechanical College at Goodwell, NE¼ NE¼ SE¼ sec. 34, T. 2 N., R. 13 E.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Caliche	45	45
Soft rock	1	46
Shale or clay	23	69
White sand	23	92
Shale or clay	23	115
Fine sand, a little water. Static water level reported as 135 feet.	22	137
Hard shale or clay	11	148
Fine sand	26	174
Shale or clay	6	180
Fine sand	4	184
Soft rock	2	186
Shale or clay	4	190
Medium to coarse sand	15	205
Fine sand	8	213
Medium to coarse sand. Irrigation well developed at depth of 238 feet.	38	251

181. Panhandle Agricultural and Mechanical College, SE¼ NW¼ sec. 36, T. 2 N., R. 13 E.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil	2	2
White caliche	28	30
Shale or clay	10	40
White caliche	20	60
Dry sand	20	80
Shale or clay	20	100
Dry, coarse sand	16	116
Coarse sand, water-bearing. Static water level reported as 120 feet.	37	153
Soft sandstone	8	161
Coarse sand and gravel, water-bearing	35	196
Soft sandstone	5	201
Sand	1	202
Sandstone	1	203
Fine sand	27	230
Fine, dirty sand	43	273
Hard rock	5	278

	Thickness (feet)	Depth (feet)
Medium to coarse, clean sand. Main water-bearing bed. Irrigation well developed at depth of 298 feet.	22	300
Rock	3	303
Dirty sand	9	312
Shale or clay	7	319
Sand	9	328
Shale or clay	3	331
Sand	13	344
Red sand	12	356
Triassic (?) or Permian		
Shale and red beds	9.8	365.8

181-A. Panhandle Agricultural and Mechanical College at Goodwell, SE¼ NW¼ sec. 36, T. 2 N., R. 13 E. Domestic well located about 100 feet from irrigation well 181.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Not reported. Soil	2	2
Caliche	18	20
Light brown caliche	12	32
Ivory-colored, coarse-grained caliche	16	48
Caliche with some sand rock	4	52
Fine-grained sand rock	8	60
Sand and caliche	3	63
Sand rock with some caliche	5	68
Dry sand	12	80
Caliche	6	86
Dry sand, and caliche	6	92
Coarse, dry, quartz sand with pea gravel	28	120
Water-bearing flat gravel and quartz sand. Static water level reported as 120 feet.	25	145

249. H. L. Gibson, SW¼ SW¼ SE¼ sec. 15, T. 2 N., R. 19 E. Log represents four closely-spaced, dug irrigation wells.

	Thickness (feet)	Depth (feet)
Alluvium		
Soil and clay or silt	8	8
Water-bearing gravel. Static water level 8.39 feet.	12	20
Red clay	7½	27½
Water-bearing gravel; water rises to level of first water	?	27½

281. Lester Sparks. NW¼ NW¼ NE¼ sec. 5, T. 3 N., R. 11 E.

	Thickness (feet)	Depth (feet)
Gray-black soil. Fine to coarse sand with considerable clay.	3	3
Brown-gray calcareous sandstone. Sand is fine.	5	8
Light-brown, calcareous, sandy clay. Dense, compact	2	10
Light-brown, calcerous sandy clay	30	40
Light-red, calcareous sandstone	14	54
Pale-pink, calcareous sandstone	2	56
Red, calcareous sandstone	4	60
Red, sandy limestone	12	72
Greenish-gray clay. Slightly calcareous	29	101
Brown, compact, calcareous sandstone	2	103
Brown, loose, calcareous sand	½	103½
Brown, compact, calcareous sandstone	4	107½
Fine-grained, brown, calcareous clay.	5½	113

317. General Atlas Carbon Co., NW¼ NW¼ sec. 28, T. 3 N., R. 15 E.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil and caliche	6	6
White caliche rock	10	16
Sand with white limestone	20	36
Very coarse dry sand and gravel	56	92
Clay, dirty, sandy	23	115
Rock	1	116
Dirty sand	15	131
Rock	2	133
Static water level		134
Sand and caliche	17	159
Sand, dirty	21	171
Sand	39	210
Sand, dirty	75	285
Clay, sandy	30	315
Sand, good, clean	22	337
Sand, clean, with streaks of gravel	27	364
Clay, dirty, red, sandy	21	385
Triassic (?) or Permian		
Red bed		385

317-A. General Atlas Carbon Co., NW¼ NW¼ sec. 28, T. 3 N., R. 15 E. About 200 feet north of number 317.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil and caliche	6	6
White caliche rock	8	14
Sand and limestone	21	35
Sand, coarse	55	90
Clay	26	116
Clay, sandy	7	123
Hard shell	1	124
Sandstone, yellow	14	138
Sand, fine	13	151

	Thickness (feet)	Depth (feet)
Clay, sandy	15	166
Clay	37	203
Clay, sandy	28	231
Sandstone, yellow	9	240
Sand, fine	28	268
Clay	28	296
Clay, blue, tough	8	304
Dirty sand and gravel	60	364
Triassic (?) or Permian		
Clay, red	22	386

319. Oklahoma Electric and Water Company, Guymon, NW¼ NE¼ SE¼ sec. 31, T. 3 N., R. 15 E.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil	3	3
Clay and caliche	47	50
Limestone	11	61
Clay	11	72
Sand and clay	18	90
Hard clay	10	100
Clay and broken limestone	12	112
Hard, white caliche	9	121
Hard clay	14	135
Hard clay and gravel	11	146
Conglomerate	3	149
Sandy clay	11	160
Hard clay	15	175
Sticky yellow clay	15	190
Coarse sand and thin layers of yellow clay. Static water level reported as 190 feet.	30	220
Sand and clay	32	252
Red clay, sand, yellow sticky clay	24	276
Yellow clay, sandy yellow clay, muck or mud	26	302
Probably sand and gravel	28	330

320. Guymon municipal well, NW¼ NE¼ NW¼ sec. 19, T. 3 N., R. 15 E.

	Thickness (feet)	Depth (feet)
Alluvium		
Sand, very fine (static water level, 12 feet)	24	24
Clay	1	25
Fine plaster sand	9	34
Clay	1	35
Coarse plaster sand	10	45
Clay	3	48
Sand, coarse, estimated 35% pea-gravel	9	57

412. F. B. Buzzard, NW¼ NW¼ sec. 25, T. 4 N., R. 12 E.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil	8	8
Caliche	82	90
Clay with a little sand	80	170

	Thickness (feet)	Depth (feet)
First water encountered at 170 feet. Static water level reported as 143 feet when total depth of well was 300 feet. Static water level on completion of well reported as 124 feet.		
Triassic (?) or Permian		
Red beds, with a ¼-inch bed of blue shale at a depth of 425 feet. Last 28 feet harder than the rest.	283	453

496. Dr. W. A. Hodges, NW¼ NW¼ NE¼ sec. 21, T. 4 N., R. 19 E.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Not reported Struck water at 100 feet	100	100
White clay and sand	20	120
Soft sand rock	8	128
White clay	1	129
Red clay	15	144
Red clay and sand	4	148
Red clay	16	164
Red sand	7	171
Yellow clay	7	178
Light red sand	9	187
Red clay and sand	9	196
Red clay	6	202
Red sand	8	210
Yellow clay	3	213
Yellow sand	10	223
Yellow clay	13	236
Yellow sand	5	241
Blue clay	3	244
Yellow clay	4	248
Hard-packed sand	7	255
Blue clay	7	262

497. R. M. Van Hyning, NW¼ NW¼ SW¼ sec. 21, T. 4 N., R. 19 E.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Not reported Struck water at 100 feet	100	100
Yellow clay and sand	14	114
Yellow sand	10	124
Yellow clay	28	152
Yellow sand	8	160
Yellow clay and sand	5	165
Yellow sand	8	173
Yellow clay	2	175
Yellow sand	10	185
Yellow clay and sand	30	215

	Thickness (feet)	Depth (feet)
Yellow sand, water-bearing	10	225
Yellow clay	3	228
Yellow sand, water-bearing	31	259
White clay	3	262
White chalk gravel	4	266
Yellow clay	3	269
Blue clay	11	280

Hooker Exploration well, NW¼ sec. 34, T. 5 N., R. 17 E., Aug. 24, 1911.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil, drab, soft	10	10
Clay, drab, soft, sandy, water-bearing, static water level 130-140 feet.	125	135
Sand, brown, soft	20	155
Sandy clay and soft, drab sand	15	170
Gravel, black and yellow, water-bearing	10	180
Clay, drab, soft, sandy	47	227
Quicksand, white and brown, soft, water-bearing	53	280
Clay, red, soft	20	300
Clay, drab, soft, sandy	95	395
Quicksand, light-colored, soft, water-bearing	20	415
Clay, light blue, soft	15	430
Quicksand, light-colored, soft, water-bearing	15	445
Clay, drab, soft, sandy	15	460
Sand, light-colored, soft, water-bearing	25	485
Clay, red and yellow, soft, water-bearing	30	515
Gravel	3	518
Sand, light-colored, soft	32	550
Clay	20	570
Permian (?) Cloud Chief formation (?)		
Gypsum, white, soft	20	590
Clay, red, soft	50	640
Gypsum, white, hard	4	644
Shale, red, hard	10	654
Shale and gypsum, red and white, hard	18	672
Shale, red, hard	18	690
Clay, red, soft	77	767
Clay, red, granular, soft, water-bearing	13	780
Clay, red, soft	20	800
Gypsum, white, hard	10	810
Clay, red, soft	55	865
Gypsum, white, hard	3	868
Clay, red, soft	7	875
Gypsum, white, hard	25	900
Sandy clay, sandstone, and gravel, mixed	50	950
Clay, brown to red, soft	40	990
Clay, red, soft	63	1053

Ferguson No. 2 gas well, sec. 14, T. 6 N., R. 16 E. (compiled from samples submitted by Republic Natural Gas Company to Oklahoma Geological Survey).

	Thickness (feet)	Depth (feet)
Ogallala formation		
Sand, fine, light brown	10	10
Sand, fine, medium-brown	60	70
Sand, medium, light brown	10	80
Sand, fine, light brown	10	90
Sand, fine to medium, light brown	10	100
Sand, fine, light brown	20	120
Sand, gray (static water level probably in this unit)	10	130
Sand, coarse, and fine gravel, gray	10	140
Gravel, fine, and coarse sand, gray	30	170
Sandstone with grains of quartz and quartzite; highly calcareous	10	180
Sand, and fine gravel	10	190
Sand, fine to coarse, gray	10	200
Sandstone, very calcareous	20	220
Clay, brown, sandy	100	320
Clay, brown, and calcareous white clay	30	350
Sand, coarse, with some clay	10	360
Clay, brown, sandy	10	370
Sand, and sandy clay	20	390
Clay, brown, sandy	50	440

K-1. Kansas City Power and Light Company test number 1, Elkhart, Kansas, 100 feet north of the Oklahoma State Line, and 900 feet east of the southwest corner of sec. 21, T. 35 S., R. 42 W. Elevation of ground at well, 3621.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil	2	2
Sandy clay	18	20
Clay	5	25
Sandy clay	45	70
Sand	10	80
Sticky clay	5	85
Caliche and clay	45	130
Sand and clay	20	150
Clay	15	165
Sand and clay	17.5	182.5
Fine muddy sand	12.5	195
Clay and a little fine sand	7	202
Fine muddy sand, water-bearing	6	208
Sand, clay, and a little caliche	2	210
Clay and a little caliche. Static water level reported as 212 feet.	5	215
Clay with a little sand	2.5	217.5
Soft clay and sand	22.5	240
Fine muddy sand, water-bearing	15	255
Yellow clay	4	259
Fine brown sand, water-bearing	6	265
Yellow clay	34	299

K-2. Kansas City Power and Light Company test number 2, Elkhart, Kansas, 100 feet north of Oklahoma line, and 900 feet east of southwest corner of sec. 21, T. 35 S., R. 42 W. Elevation of ground at well 3614 feet.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil	2	2
Black gumbo	10	12
Clay	13	25
Sticky clay	5	30
Hard clay	25	55
Sandy clay	5	60
Hard sticky clay	42	102
Sandy clay	8	110
Caliche and clay	25	135
Soft sandy clay	30	165
Soft sticky clay	10	175
Soft sandy clay	25	200
Sticky clay and sand, in part water-bearing. Static water level reported as 202 feet.	32.5	232.5
Sticky clay and sand, water-bearing	7.5	240
Medium sand, water-bearing	8	248
Yellow sticky clay	11	259
Fine, muddy sand, water-bearing	25	284
Soft, muddy, sand rock, some water	4	288
Triassic (?) or Permian		
Red shale	2	290

K-3. Kansas City Power and Light Company test number 3, Elkhart, Kansas, 30 feet south and 15 feet west of NE corner sec. 21, T. 35 S., R. 42 W. Elevation of ground at well, 3631 feet.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Sand	50	50
Sandy clay	25	75
Sandy clay and sand	25	100
Clay	10	110
Sand and gravel	7	117
Clay	8	125
Sand, clay, and caliche	5	130
Caliche and clay	15	145
Sandy clay	35	180
Sand, caliche, and clay	10	190
Sandy clay. Static water level reported as 220 feet.	47.5	237.5
Clay	8.5	246
Sandy caliche or white clay	2	248
Fine muddy sand, water-bearing	27	275
Yellow sticky clay	13	288
Quicksand	12	300
Quicksand and joint clay	5	305
Triassic (?) or Permian		
Red shale	3	308

K-4. Kansas City Power and Light Company test number 4, Elkhart, Kansas, NW¼ NW¼ NW¼ sec. 21, T. 35 S., R. 42 W. Elevation of ground at well, 3608 feet.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Soil	2	2
Sand	23	25
Sandy clay	10	35
Sand	10	45
Sandy clay	55	100
Clay and caliche	8	108
Clay	12	120
Sandy clay	30	150
Sticky clay	10	160
Sandy clay	30	190
Fine, muddy sand. Static water level reported as 192.75 feet.	10	200
Sand and clay, with some caliche and pebbles	5	205
Clay with a little sand	2.5	207.5
Sticky clay	3.5	211
Sandy clay	4	215
Fine sand with a little clay	2.5	217.5
Sand with a little caliche	2.5	220
White clay	5	225
Clay	7.5	232.5
Fine sand, somewhat muddy, water-bearing	2.5	235
Medium sand, water-bearing	5	240
Sand and gravel, good water-bearing	3	243
Sand and clay balls, water-bearing	7	250
Clay balls and a little sand, water-bearing	2	252
Brown sand, water-bearing	1	253
Sand and clay, water-bearing	5	258
Hard brown clay	2	260
Layers of sand, rock, and clay	10	270
Hard sand rock, a little water	7	277
Triassic (?) or Permian		
Red bed	0.5	277.5

K-5. Santa Fe Railroad, Elkhart, Kansas, located a few hundred feet from the Kansas City Power and Light Company test number 4 (log K-4). Originally drilled in 1913 to a depth of about 200 feet, deepened to 277 feet in 1927, and still later deepened to 370 feet. No log was kept for the last 93 feet. Surface elevation 3621 feet.

	Thickness (feet)	Depth (feet)
Ogallala formation		
Brown clay	2	2
Marl	0.5	2.5
Light yellow clay	102.5	105
Marl	15	120
Light yellow clay	35	155
Marl	10	165

Red clay	17	182
Sandy clay	8	190
Red sand	4	194
Coarse sand, water-bearing. Static water level reported as 208 feet.	24	218
Caliche, clay, and clay or shale	25	243
Sand, water-bearing	5	248
Caliche, clay, and clay or shale	3	251
Sand, water-bearing	2	253
Caliche, sand, and shale or clay	1	254
Sand, water-bearing	1	255
Soft, yellow sand rock, water-bearing	16	271
Red sand	6	277

K-6. City of Liberal, Kansas; located in park.

Ogallala formation		
Static water level reported as 157 feet.		
Soil, clay, loam, and dry sand	200	200
Medium to coarse sand	17	217
Sandy clay	62	279
Hard shell	2	281
Medium to coarse sand	18	299
Rock	1	300
Tough clay	5	305
Hard shell	1	306
Sand	18	324
Sandy clay	31	355
Very hard rock	3	358
Sticky clay and sand	20	378
Tough clay	21	399
Coarse sand	7	406
Clay	19	425
Sand	8	433
Clay	15	448
Medium to coarse sand	48	496
Clay	5	502

TABLES OF WELL RECORDS

The tables on the following pages summarize the information that was obtained regarding wells of all kinds. The number in the first column is the same as the one appearing on the map (plate I) beside the well symbol. The depths of the wells are given to the nearest even foot as measured below the land surface. They may be different from the original depth obtained by the driller if the well has partly filled with sand or if some obstacle prevented the measuring tape from reaching the bottom. The water levels are given as measured below some definite and reasonably permanent object which usually was above the surface of the land. To determine the depth to which the water stands in a well, subtract the figure for water level from that for depth and add the height of the measuring point above the surface, unless this last figure is preceded by a negative sign, when it should be subtracted. The symbol (±) following the figure for water level indicates some uncertainty as to the exact position of the water table and an accuracy of a few tenths of a foot. If a question mark (?) follows the figure for water level, there was greater uncertainty, and the figure given may be accurate only within a few feet. Depths and water levels that were reported rather than measured are indicated by reference to a foot note. Where there was some doubt as to the accuracy of some of the other information, such as well diameters or the nature of water-bearing materials, a question mark (?) has been used.

Altitudes for the land surface at the wells were determined in part by aneroid barometer. The nature of the water-bearing materials is based on reports by owners and tenants, part of which were obtained by the State Mineral Survey. The water has been reported to be of good quality unless otherwise noted in the remarks column, and the temperature of the water as it is brought to the surface by most of the domestic wells ranges from 58° to 65° F. Many farm windmills are used to pump water for irrigating small gardens, in addition to the usual supplies for domestic and stock purposes.

WELL TABLES

Records of Wells in Texas County, Oklahoma

(All wells are drilled unless otherwise stated under "Remarks")

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M.P. (feet)[1]	Water level: Below M.P. (feet)	Water level: Date measured	Method of lift[2]	Use of water[3]	Remarks
	T. 1 N., R. 10 E.												
1	SW¼SW¼ sec. 2	Lem Moss	Old	Low hill on upland	....	187	....	1.0	175.41	11- 3-37	C,W	D,S	
2	SE¼SW¼ sec. 5	S. H. Stevenson	do	Upland flat	....	199	....	0.5	197.42	11- 2-37	C,W	N	Water in sand.
3	NE¼NE¼ sec. 12	F. F. Lint	1925	Low hill on upland	....	167	....	0.75	144.87	11- 3-37	C,W	D,S	Water in sand and gravel.
4	SE¼SE¼ sec. 17	Land Company	Old	Gentle slope	....	214	....	0.4	206.92	11- 2-37	C,W	D,S	Water in gravel. Temp. 62° F.
5	NW¼NW¼NE¼ sec. 18	....	....	Upland flat	....	230	....	0.3	218.8	do	C,W	D,S	Water rose 1.21 ft. in 15 min. after pumping stopped.
6	SE¼NE¼SE¼ sec. 22	....	....	Low hill on upland	....	179	....	0.5	173.1	11- 3-37	C,W	N	
7	NW¼NW¼NW¼ sec. 25	E. Hill	....	Hill	....	167	5?	1.0	156.84	do	C,W	N	Water in gravel.
8	SE¼SW¼ sec. 35	A. E. Harvey	1914	Gentle slope	....	149	5?	0.6	146.62	11- 2-37	C,W	D,S	Water in sand.
9	SE¼SE¼ sec. 36	....	....	Flood plain	....	37	....	1.6	26.29	do	C,W	S	
10	SW¼SW¼ sec. 18	....	....	Upland flat	....	236	8	....	233.6	8-25-38	None	N	Uncased hole.
	T. 1 N., R. 11 E.												
13	NE¼NE¼NE¼ sec. 5	S. W. Hanby	1906	Upland flat	3485	147	6	2.0	141.96	11- 8-37	C,W	D,S	
14	SW¼SW¼NW¼ sec. 10	G. W. McDaniel	1907	do	....	122	Large	1.0	113.76	11- 9-37	C,W	D,S	Water in coarse gravel. Uncased hole. Supplies 50 head of stock.
15	NW¼SW¼NW¼ sec. 12	F. O. Reid	....	do	....	122	....	0.6	104.53	11- 8-37	C,W	D,S	Water in gravel.
16	NE¼NE¼NE¼ sec. 14	G. W. McDaniel	....	Flood plain	3322	25	5	0.2	22.35	do	C,W	N	15 ft. above channel. Water in sand and gravel.
17	SW¼SW¼ sec. 16	....	....	do	....	32	5	0.7	19.45	do	C,W	N	15 ft. above channel.
18	NE¼NE¼ sec. 18	A. C. Fleming	....	Upland flat	....	162	....	0.5	149.21	do	C,W	N	Water in gravel.
19	NE¼SE¼ sec. 20	M. A. Huff	Old	Flood plain	....	37	6	1.5	19.63	do	C,W	S	15 ft. above channel.
20[4]	NE¼NE¼NE¼ sec. 21	Sunnyside School	....	do	....	......	....	....	....	....	H	P	Probably shallow.
21	SE¼NE¼ sec. 21	Bert Mann	....	Bench on river bluff	....	67	....	4.15	65.23	11- 8-37	C,W	D,S	Water in coarse gravel.
22	SW¼SE¼SW¼ sec. 23	N. American Life Insurance Co.	Old	Upland flat	....	134	....	....	122.11	do	C,W	D,S	Water in coarse sand and gravel.
23	SE¼SE¼SW¼ sec. 24	....	....	Gentle slope	....	111	....	0.25	92.38	do	C,W	N	
24	SE¼SE¼ sec. 28	J. C. Bergner	Old	Upland flat	....	140	....	0.4	124.89	do	C,W	D,S	Water in sand and gravel.
25	NE¼NE¼ sec. 30	Potts	....	Slope	....	89	....	0.75	84.63	do	C,W	D,S	Water in sand. Yield diminishes with pumping.
26	NW¼NE¼ sec. 31	George Walter		do	....	82	5	0.4	78.25	do	C,W	N	Water in sand and gravel.
27	NE¼NE¼SE¼ sec. 34	W. H. Walker	Old	Upland flat	....	133	6	0.3	119.62	do	C,W	D,S	Water in gravel.
	T. 1 N., R. 12 E.												
31	SE¼SE¼ sec. 5	Wilmer Allison	....	Flood plain	....	31	....	0.5	20.03	10-11-37	C,W	D,S	15 ft. above Beaver R. channel. Water in sand and gravel.
32	SW¼SE¼SE¼ sec. 7	Mrs. S. J. Johnson	Old	Ridge top	....	104	....	1.0	82.5	10- 7-37	C,W	D,S	
33	NW¼SE¼ sec. 8	....	....	Flood plain	....	54	....	....	28.56	do	C,W	S	25 ft. above Beaver R. channel.

1 Height of Measuring Point (M. P.) above ground. Usually top of casing, water pipe clamp, coupling, or tee discharge pipe.
2 Pumps: C, cylinder; T, turbine; Cent., centrifugal. Power: W, windmill; H, hand; G, natural gas engine; Gs, gasoline engine; K, kerosene engine. E, electric motor. Number indicates horse power.
3 Use: D, domestic; S, stock; I, irrigation (number indicates acres); Ind., industrial; P, public; RR, railroad; N, not used.
4 For analysis of water, see table on pp........
5 Reported.
6 Estimate based on measurements of nearby wells.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL: Height of M.P. (feet)[1]	WATER LEVEL: Below M.P. (feet)	WATER LEVEL: Date measured	Method of lift[2]	Use of water[3]	Remarks
	T. 1 N., R. 12 E. (Cont'd)												
34	NW¼NW¼SE¼ sec. 11	....	——	Undulating upland	....	221	....	0.5	216.92	10-11-37	C,W	N	
35	SW¼NW¼ sec. 15	H. & E. Cunningham	....	do	....	191?	....	1.0	189.1	do	C,W	N	Water in sand and gravel.
36	SW¼SW¼SE¼ sec. 16	....	....	do	....	175	....	0.7	173.08	do	C,W	N	
37	SE¼NW¼ sec. 19	Emma Cook	....	Slope	....	80	....	....	68.1	10- 5-37	C,W	S	Water in sand and gravel.
38	SW¼SE¼SE¼ sec. 21	....	——	Hill	....	192	....	....	191.5	10-11-37	C,W	S	
39	SE¼SW¼SW¼ sec. 21	T. W. Harvey	Old	Undulating upland	....	175	5	1.0	163.95	do	C,W	D,S	
40	See sec. 6, T. 3 N., R. 17 E.												
41	SE¼SE¼ sec. 25	W. P. Lusk	1929	Upland flat	....	205	6	1.8	197.35	10- 6-37	C,W	D,S	Water in coarse sand.
42	SW¼SW¼SW¼ sec. 26	C. E. Johnson	Old	do	....	201	....	0.5	198	10- 7-37	C,W	D,S	Water in gravel?
43	SW¼SW¼ sec. 28	W. E. Eslinger	1922	Upland flat	....	211	....	—	202	10- 7-37	C,W	D,S	
44	NW¼NE¼ sec. 30	....	....	Cr. bottom	....	90	6	1.0	63.5	do	C,W	N	15 ft. above channel.
45[4]	SE¼ sec. 32	Cimarron Utilities Co. (Texhoma)	....	Upland flat	....	230[5]	....	....	210[5]	....	——	P	Reported 100 gal. a min., drawdown 13 ft.
46	SW¼SW¼ sec. 32	W. E. Bradley	Old	do	....	206	5	0.5	195.78	10- 7-37	C,W	D	
47	NW¼NW¼SW¼ sec. 34	George Woods	do	do	....	230	5	0.65	216.4	do	C,W	N	
	T. 1 N., R. 13 E.												
50	SW¼SW¼SE¼ sec. 1	W. H. Wacker	....	Upland flat	....	163	....	1.0	149	10- 6-37	C,W	N	Water in gravel.
51	NW¼NE¼ sec. 6	R. A. Peek	Old	do	....	215	4	....	181.28	9-29-37	None	N	Water in gravel.
52	SE¼SE¼NE¼ sec. 7	....	——	Undulating upland	....	183	4	2.0	175.63	10- 6-37	None	N	

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Height of M.P. (feet)	Below M.P. (feet)	Date measured	Method of lift	Use of water	Remarks
	T. 1 N., R. 13 E. (Cont'd)												
53	NE¼NE¼ sec. 10	Mae Flannigan	——	Upland flat	——	150	....	0.5	136.98	10- 5-37	C,W	D,S	Water in gravel.
54	NE¼NE¼SE¼ sec. 13	W. W. Kennedy	——	Cr. bank	....	43	5	1.3	38.36	10- 6-37	C,W	N	Water in gravel. 25 ft. above channel.
55	SW¼SW¼ sec. 19	....	——	Slope	....	136	4	0.8	133.4	10- 7-37	C	N	
56	NE¼NE¼ sec. 22	....	——	Flood plain	....	57	....	2.5	53.1	10- 5-37	C,W	D,S	Water rose 0.9 ft. in 10 min. after pumping stopped.
57	SW¼SW¼ sec. 24	....	——	Upland flat	....	148	....	...	142.5	do	C,W	N	
58	SW¼SW¼SW¼ sec. 25	O. Cooksey	Old	do	....	182	5	3.0	170.9	10- 6-37	C,W	D,S	Water in gravel. Water rose 10.15 ft. in 40 min. after pumping stopped.
59	SW¼NW¼ sec. 29	Mrs. N. W. Draper	....	Gentle slope	....	195	....	....	180.95	do	C,W	D,S	
60	See sec. 3, T. 3 N., R. 18 E.												
61	NE¼NW¼ sec. 30	....	....	Upland flat	....	184	....	0.8	178.98	10- 7-37	C,W	S	
62	SE¼NW¼ sec. 32	....	....	Undulating upland	....	189	....	6.5	188	10- 6-37	C,W	N	
63	NE¼NE¼ sec. 5	Hagy, Harrington and Marsh	1937	Upland flat	....	203[5]	8	....	153[5]	....	C,Gs, 7½	Ind.	Water in sand, 172-188 ft. and gravel 201.5-203 ft. Casing perforated 175-190 ft., open hole 190-203 ft. Supplied water for drilling gas wells.
	T. 1 N., R. 14 E.												
65	NE¼ sec. 1	L. Latham	1935	Flood plain	....	22	....	—10.1	1.47	9- 2-37	Cent., Gs	I	65 and 66 operated by same pumping plant. Water in quicksand. Reported yield 100 gal. a min. each. Measured drawdown No. 66, 4.64 ft.
66	NE¼ sec. 1	do	do	do	....	37	5	—10.1	1.46	9- 3-37	do	I	
67	SW¼SE¼ sec. 1	do	——	do	....	29	4	0.6	23.5	10- 1-37	C,W	S	
404	NW¼NE¼ sec. 4	E. J. Ritter	Old	Hill on upland	....	176	5	1.3	167.08	9-25-37	C,W	D,S	
68	NW¼NW¼NE¼ sec. 7	G. S. Gaither	....	Upland flat	....	169	5?	0.75	154.1	9-30-37	C,W	N	Water in gravel.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL: Height of M.P. (feet)[1]	WATER LEVEL: Below M. P. (feet)	WATER LEVEL: Date Measured	Method of lift[2]	Use of water[3]	Remarks
						T. 1 N., R. 14 E. (Cont'd)							
69	SE¼SE¼ sec. 8	F. Shoup	....	Slope	....	111	....	0.8	101.38	do	C,W	N	
70	NE¼SE¼NE¼ sec. 9	Renfrew Investment Co.	1906	do	....	79	5	0.6	78.88	10- 1-37	C,W	N	
71[4]	SE¼NE¼NE¼ sec. 10	Rosie Ritter	....	do	....	100[5]	4	....	....	....	C,W	D,S,P	Reported little water in well. Supplies Frisco School. Dist. 57.
72	See sec. 33, T. 4 N., R. 14 E.	....	....										
73	NE¼NE¼ sec. 15	B. A. Stamps	Old	Slope	....	58	5	1.0	51.14	9-30-37	C,W	D,S	Water in gravel.
159	NE¼NE¼NW¼ sec. 21	....	....	do	....	70	....	1.0	65.16	10- 1-37	C,W	N	45 ft. above Frisco Cr. channel.
74	SW¼ sec. 22	....	....	Flood plain	....	44	5	2.9	36.22	do	C,W	N	
75	SW¼SW¼ sec. 27	Chris Neilson	....	Slope	....	85	4	1.0	63	do	C,W	S	
161	NW¼NW¼NW¼ sec. 31	....	....	Upland flat	....	202	5	0.5	192.13	do	None	N	
78	SE¼NW¼ sec. 34	Chris Neilson	....	Flood plain	....	38	—	—	31.88	do	C,W	N	Water in sand. Beside channel.
79	NW¼NW¼NE¼ sec. 35	J. Peterson	1907	Upland flat	....	215	5	1.0	206.31	3-23-38	C,W	D,S	Water in sand?
						T. 1 N., R. 15 E.							
83	SE¼NE¼ sec. 4	....	——	Edge of terrace	....	31	5	1.5	30.62	9-17-37	C,W	N	
84	NW¼ sec. 6	Mrs. M. F. Douglas	1935-1936	Small Cr.	....	20	28	....	12.13	9- 2-37	Cent. Gs.17	I,2	Dug well. Water in coarse sand 19.5 ft.—. Iron casing to 16 ft., rest open hole. Reported yield 150 gal. a min., measured drawdown 3.4 ft.
85	See sec. 34, T. 4 N., R. 11 E.												
86	NE¼NW¼NW¼ sec. 18	T. Kerr	——	Undulating upland	....	178	....	1.5	169.92	3-23-38	C,W	N	
87[4]	W. cent. NW¼ sec. 20	G. W. Reust	1936	Upland flat	....	168[5]	4.5	....	164[5]	....	C,W	D,S	Water in sand.
						T. 1 N., R. 16 E.							
93	NE¼NE¼NW¼ sec. 23	J. W. Rhoads	1919	Upland flat	....	198	6	1.5	178.58	10-25-37	C,W	D,S	Water in gravel. Water rose 1.11 ft. in 10 min. after pumping stopped.
94	SE¼SE¼SW¼ sec. 29	....	....	do	....	205	5	1.0	192.32	do	None	N	
95	NW¼NW¼SE¼ sec. 36	Wagner Bros.	....	do	....	195	4.5	3.25	179.96	do	C,W	S	Water in gravel.
						T. 1 N., R. 17 E.							
100	NW¼NW¼SW¼ sec. 2	R. L. Hayter	Old	Upland flat	....	207	5	0.5	167.75	10-26-37	C,W	D	Water in gravel. Water rose very slowly 10.25 feet after pumping stopped.
101	SW¼SW¼ sec. 8	C. J. Westmorland	....	Undulating upland	....	166	5	0.7	155	10-26-37	C,W	D,S	Water in quicksand, 155-160 ft.
102	SW¼SW¼SW¼ sec. 10	....	——	Upland flat	....	180[5]	4	3.0	147.22	do	C,W	N	
103	SE¼SE¼SE¼ sec. 13	Ollie Smith	1915	do	....	73	5	2.3	48.42	do	C,W	D,S	Water in sand.
104	SE¼SE¼ sec. 20	C. R. Gum	1916	do	....	191	5	1.6	160.88	10-25-37	C,W	D,S	Water in coarse sand. 163-198 ft. Water rose 19.92 ft. in 40 min. after pumping stopped.
105	SE¼NE¼SE¼ sec. 23	....	....	Flood plain	....	25	6	0.6	23.79	10-26-37	C,W	N	20-25 ft. above channel.
106	SE¼SE¼SE¼ sec. 27	....	....	do	....	25	6?	....	14.58	do	C,W	N	
107	NW¼NW¼ sec. 30	E. I. Wagner	1930	Upland flat	....	204	5	2.0	161.08	10-25-37	C,W	D,S	Water in gravel. First at 160 ft.
108	SW¼NE¼ sec. 36	....	....	Slope	....	70	5.5	0.25	58.3	10-26-37	C,W	N	
						T. 1 N., R. 18 E.							
112	SE¼NW¼SE¼ sec. 1	J. L. Stump	....	Slope	....	30[5]	7	....	23.96	11-23-37	None	N	Not fit to drink—salty.
113[4]	NW¼NW¼SE¼ sec. 2	C. C. Smart	1929	Flood plain	....	10	4	2.0	9.67	do	H	D	Dug well. Water in sand and gravel. Salty, not used for drinking.
114	SE¼NE¼ sec. 4	C. Robinson	Old	do	....	71	....	3.0	37.51	11-25-37	C,W	D	
115	NW¼NE¼ sec. 10	Curtis Ross	1930	do	....	19	4	0.85	15.04	do	C,W	D	12 ft. above Cr. Water in gravel.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M.P. (feet)[1]	Water level: Below M. P. (feet)	Water level: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 1 N., R. 18 E. (Cont'd)												
116	SE¼SW¼SE¼ sec. 14	Paul Johnson	1925	Flood plain	....	26	7	2.0	21.73	11-23-37	C,W	D,S	Cased to 13 ft., rest is open hole. Water rose 5.5 ft. in 45 min. after pumping stopped. Yield diminishes until well "pumps air".
117	NW¼NW¼ sec. 15	S. J. Prewett	1929	Slope	....	73	4	1.0	66.0	do	C,W	D,S	Water in gravel. Water rose 1.25 ft. in 20 min. after pumping stopped.
118[4]	NW¼SW¼ sec. 24	Ezra Shorb	1911	Flood plain	....	207[5]	4.5	....	+1.8	....	Flows	D,S	Cased to 183 ft., rest is open hole. 3d water at 183 ft. Measured yield, 2/3 gal. a min. Salty. Reported initial water level 7 ft. above land surface.
119	NE¼SE¼NE¼ sec. 28	....	....	Gentle slope	....	101	4	1.7	70.1	11-23-37	C,W	N	
120	See sec. 2, T. 5 N., R. 14 E.												
121	NW¼SE¼ sec. 29	....	....	Upland flat	....	142	5	3.4	120.67	do	C,W	N	
122[4]	NW¼NW¼ sec. 30	L. M. Cooper	Old	Creek bottom	....	26	6	0.3	23.38	do	C,W	D,S	Dug well. Water in sand 26-34 ft. Water temp. 60° F.
123	NW¼NW¼ sec. 34	John Driscoll	1907	Undulating upland	....	78	3	1.5	77.95	do	C,W	D,S	Water in fine gravel, 84-85? ft.
	T. 1 N., R. 19 E.												
126[4]	SW¼NW¼ sec. 1	A. Campbell	1930	Slope	....	157	5	0.6	50.36	11-22-37	None	N	30 ft. above channel of cr. exposing red beds of Cloud Chief formation. Water in red shell rock. Analysis for sample from adjacent well in use.
	T. 1 N., R. 19 E. (Cont'd)												
127	SE¼SE¼SE¼ sec. 3	....	....	Gentle slope	....	89	....	2.3	40.75	do	C,W	N	
128	SW¼SE¼ sec. 4	H. Perry	Old	Undulating upland	....	72	....	0.5	42.5	11-22-37	C,W	D,S	Water in gravel?
129[4]	NW¼NE¼NE¼ sec. 7	R. Johnson	Old	Flood plain	....	34	....	0.4	20.93	do	C,W.	D,S	Water in sand. Gyppy or salty. Water temp. 61° F.
130	SE¼NW¼ sec. 7	do	1937	do	....	29.5[5] 34.5[5]	20	—5.0	2.12	11-24-37	Cent., Gs.	I	Two dug wells, 40 ft. apart, operated by one pump and engine. Concrete ring casing, gravel walls 8 inches thick. Water in gravel and quicksand 7.5-34.5 ft. Measured northern well.
131	SE¼SW¼ sec. 12	E. J. Kruse	....	Slope	....	51	5	0.7	27.19	11-22-37	C,W	N	Water in red shale.
132[4]	SW¼SW¼ sec. 15	M. B. Kile	....	do	....	43+	5	2.0	44.7	do	C,W	N	Analysis for sample from well in use across road to south.
133	NW¼NW¼ sec. 20	T. W. Silsby	1912	Hill	....	46	6	3.0	31.7	do	C,W	N	Water in hard red clay. Not good for house use.
134	SW¼NW¼ sec. 25	....	....	Creek bottom	....	39	....	1.0	8.0	do	C,W	N	5 ft. above channel.
135	NE¼SW¼SE¼ sec. 27	....	....	Slope	....	111	5?	2.0	97.22	do	C,W	N	
136[4]	SE¼SE¼SE¼ sec. 30	L. Dillard	....	do	....	65	5	0.6	42.68	do	C,W	D,S	Water in gravel.
137	NE¼NE¼ sec. 32	J. R. Phelps	....	do	....	67	....	0.3	35.79	do	C,W	N	25 ft. above cr. channel.
	T. 2 N., R. 10 E.												
141	NW¼SW¼NW¼ sec. 12	E. E. Rickti	....	Upland flat	....	161	....	1.0	152.8	11- 4-37	C,W	N	Water in gravel.
142	SE¼SW¼SW¼ sec. 14	F. M. Hollis Estate	....	Upland flat	....	169	5	1.3	166.59	11- 4-37	C,W	N	Water in gravel.
143	NE¼SW¼ sec. 15	....	....	Slope	....	107	5	1.25	81.89	do	C,W	N	
144	SW¼SE¼SW¼ sec. 20	J. M. Elliott	....	Hill	....	234	4	1.1	209.18	11- 3-37	C,W	D,S	Water in sand.
145	NE¼SE¼SE¼ sec. 28	R. R. Harris	....	Upland flat	....	151	....	1.0	142.23	do	C,W	N	Water in fine gravel.
146[4]	SW¼SW¼SE¼ sec. 33	Jackson and Johnson	....	do	....	185	....	1.0	184.27	11- 2-37	C,W	D,S	
147	NW¼NW¼NE¼ sec. 35	....	....	Gentle slope	....	160	6	....	156.03	do	None	N	

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M.P. (feet)[1]	Water level: Below M.P. (feet)	Water level: Date measured	Method of lift[2]	Use of water[3]	Remarks
					T. 2 N., R. 11 E.								
151	SE¼SE¼NE¼ sec. 1	J. L. Thrasher	1912	Gentle slope	....	148	3.5	1.0	145±	11- 9-37	C,W	D,S	Water in coarse gravel at 160 ft.
152	SE¼NE¼SE¼ sec. 6	L. Flanagan	....	Slope	....	59	....	3.3	57.68	11- 6-37	C,W	N	Water in gravel and sand.
153	SE¼SE¼ sec. 9	G. A. Jones	1918	Upland flat	....	212	5	0.5	191.84	11- 9-37	C,W	D,S	Reported depth 286 ft. Water in sand 260-286 ft.
154	NW¼NW¼NW¼ sec. 10	S. K. McCall Est.	....	Creek bottom	....	116	....	....	105.84	do	C,W	N	Water in gravel.
155	SW¼SW¼ sec. 13	A. Panek	....	Slope	....	133	....	1.0	121.34	11- 8-37	C,W	S	Water in sand and gravel.
156	SE¼SE¼SE¼ sec. 17	George Fry	....	Upland flat	....	204	....	0.5	171.88	11- 9-37	C,W	D,S	Water in gravel.
157	NE¼NW¼NW¼ sec. 18	Sam Jackson	Old	Upland flat	....	171	....	1.0	158.64	11- 4-37	C,W	D,S	Water in gravel?
158	NE¼SE¼ sec. 20	....	....	Hill	....	107	5	0.5	95.66	11- 9-37	C,W	N	
159	SE¼SE¼SW¼ sec. 24	A. G. Bertlen	1908	Slope	....	86	5	1.25	76.65	do	C,W	D,S	
					T. 2 N., R. 12 E.								
163	NW¼NW¼NW¼ sec. 29	....	....	Gentle slope	....	127	5	....	123.38	11- 9-37	None	N	
164	SW¼SW¼NW¼ sec. 31	O. L. Shaeffer	....	Upland flat	3399	148	....	1.5	137.24	11-10-37	C,W	S	
165	NE¼NE¼ sec. 32	J. J. Kimball, Jr. and T. Chance	1920	Flood plain	....	59.5s	20	—18.51	4.25	do	Cent.,K 15	I	Dug well, cased with perforated galvanized casing, 21.5-59.5 ft. Water in gravel, 22.-75-59.5 ft. Reported yield 500 gal. a min. with 19 ft. drawdown. Irrigation since 1932.
166	NW¼NW¼NW¼ sec. 32	Geo. Walker	....	Slope	....	40	4	0.8	39.98	do	C,W	D	Water in sand
167	SE¼SE¼ sec. 34	....	....	Upland flat	3425	196	5	....	190.77	10-11-37	None	N	

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M.P. (feet)	Water level: Below M.P. (feet)	Water level: Date measured	Method of lift	Use of water	Remarks
					T. 2 N., R. 13 E.								
171	NE¼NE¼NE¼ sec. 15	Earhart	....	Upland flat	....	199	5?	0.5	177.28	9-27-37	C,W	N	
172	SE¼NE¼ sec. 25	....	....	do	....	139	4	1.5	120	9-30-37	C,W	N	
173	NW¼NW¼NE¼ sec. 26	R. D. Hall	Old	Upland flat	....	139	5	1.0	124.88	9-28-37	C,W	N	Water in gravel?
174	SW¼SE¼ sec. 26	do	Old	do	....	113?	5	1.5	109.38	do	C,W	D,S	Water in gravel.
175	NW¼NW¼ sec. 28	H. J. Jefferis	Old	do	....	173	5	0.5	159.6	do	C,W	S	Water in gravel?
176	See sec. 18, T. 3 N., R. 15 E.												
177	NW¼NW¼ sec. 31	Con Dearback	....	do	....	185	....	2.0	170±	do	C,W	D,S	Water in gravel.
178	SE¼NE¼ sec. 34	J. O'Donnell	Old	do	....	144	....	3.35	131.82	9-30-37	C,W	D,S	Water in gravel.
179	NE¼NE¼SE¼ sec. 34	Panhandle A. & M. College	1937	do	3300	238s	12	....	135s	....	T,E 20	I,30	See log. Reported yield 300 gal. a min., with 30 ft. drawdown.
180a	NW¼SW¼ sec. 35	Town of Goodwell	1926	Upland flat	3300	188s	8	....	150?s	....	T,E 20	P	Gravel packed. Water in sand. Reported yield, 120 gal. a min. with little drawdown.
180	Do	do	1930	do	3300	do	6	....	do	....	C,E,5	P	Supplements 8-in. well. Reported yield, 11-12 gal. a min.
181	SE¼SE¼NW¼ sec. 36	Panhandle A. & M. College	1937	do	....	300s	18	1.0	118.7	11-22-38	T,G 92	I, 180	See log. 18-in. casing, perforated 110-300 ft. Reported yield 680 gal. a min. on test with 27 ft. drawdown. Later operated at about 960 gal. a min. with 35.8 ft. drawdown (average for 1938).
182	NE¼NE¼SE¼ sec. 34	do	....	do	3300	151	6	....	137.74	11-22-38	None	N	
187	See sec. 12, T. 3 N., R. 15 E.												

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M.P. (feet)[1]	Water level: Below M. P. (feet)	Water level: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 2 N., R. 14 E.												
188	NW¼ sec. 1	Kuhn Bros.	1938	Slope	3108	265[5]	6.75	1.8	124.92	1-31-38	Jet,G	Ind.	Water in sand. Used to supply drilling water for gas well.
386	SE¼SE¼ sec. 3	Frank Roten	....	Upland flat	....	108	5	0.5	102.12	9-24-37	C,W	S	
189	NE¼SW¼ sec. 5	State of Okla.	....	do	....	138	....	0.4	128.77	2- 3-38	C,W	N	Water in sand and gravel.
190	NE¼SE¼ sec. 21	Chas. Bowen	....	Low hill	....	146	5?	0.5	134.55	9-25-37	C,W	N	
191	SE¼SE¼SE¼ sec. 21	Plainview School	....	Upland flat	....	148	5	0.7	135.6	do	C,W	N	
399[4]	NE¼NE¼SE¼ sec. 26	Andrew Bender	....	do	....	142	4.5	—	127.55	do	C,W	S	Water in coarse gravel. Measured yield, 1.3 gal. a min. Water temp. 60° F.
192	NW¼NW¼NW¼ sec. 30	A. M. Camp	1906	Hill	....	130	6	—	118.91	9-30-37	C,W	D,S	Water in sand? Reported 155 ft. deep.
193	SW¼SW¼SW¼ sec. 33	Chas. Cresswell	------	Upland flat	....	175	5	—	171.5?	9-25-37	C,W	N	Water in sand and gravel.
	T. 2 N., R. 15 E.												
198	SE¼SE¼NE¼ sec. 8	Mrs. F. Patrick	....	Upland flat	....	194	4	0.5	178.63	9-17-37	C,W	N	Reported 204 ft. deep. Water in sand and gravel, 200-204 ft.
199	SW¼SE¼SE¼ sec. 11	....	....	do	3065	179	5	1.0	163.45	9-16-37	C,W	N	
200	SE¼SE¼SW¼ sec. 18	Perkins School	1922	do	....	167	6	1.25	142.15	3-23-38	C,W	N	
201	SW¼SW¼NW¼ sec. 26	C. Bridgman	Old	do	....	184	5	—	173.9	9-16-37	C,W	S	Water in gravel?
202[4]	NE¼NE¼ sec. 27	M. N. Buford	1925	Upland flat	....	186	4	0.5	170.79	9-16-37	C,W	D,S	Water in sand.
	T. 2 N., R. 16 E.												
207	NW¼NW¼NW¼ sec. 9	....	....	Upland flat	....	159	....	0.75	143.32	10-27-37	C,W	N	
208	SE¼SE¼NE¼ sec. 11	Ed. Weatherford	....	do	....	153	....	0.5	131.97	do	C,W	D	Water in sand.
209	NW¼NW¼NE¼ sec. 13	C. Rothgeber	....	do	....	179	5	1.0	169±	do	C,W	N	Water in gravel.
210	NW¼SW¼ sec. 25	C. R. Miller	1920	Slope	....	144[5]	5	1.15	12.62	do	None	N	First water at 56 ft. Main supply in 2d "sheet", sand and gravel.
211	SW¼NE¼ sec. 34	M. B. Davidson	....	Flood plain	....	15	....	0.6	9.78	10-25-37	H	D,S	Water in sand.
212	SW¼SW¼SW¼ sec. 35	....	....	Gentle slope	....	47	4	1.0	43.46	do	None	N	
213	SW¼NW¼ sec. 35	....	....	Flood plain	....	20	4.5	3.0	19.62	do	None	N	
	T. 2 N., R. 17 E.												
217	NW¼NW¼NE¼ sec. 7	....	....	Upland flat	....	151	5	1.7	150±	11-26-37	C,W	N	
218	SE¼NW¼ sec. 11	Geo. W. Oller	1931	Gentle slope	....	17	4	4.1	13.81	do	C,W	N	Dug well. Water in gravel, 9.8-17 ft.
219	NW¼SW¼ sec. 12	Mrs. F. M. Johnson	....	Slope	....	44	4.5	2.75	33.45	11-26-37	C,W	S	Dug well? Water in sand and gravel.
220	NW¼NE¼ sec. 14	....	....	Flood plain	....	35	4.5	0.9	31.33	do	H	N	
221	SW¼SW¼SW¼ sec. 15	Alta Grimmer	1927	do	....	15	4.5	2.0	6.0	do	H	D	Dug well. Water in gravel, alkaline.
222	SE¼NW¼SW¼ sec. 19	C. R. Miller	1920	Slope	....	65	5	1.5	24.82	10-27-37	C,W	S	
223[4]	SE¼SW¼ sec. 21	L. C. Webb	1926	Flood plain	....	66	5	0.5	44.0	11-26-37	C,W	D,S	Dug well. Water in sand. Water temp. 61° F.
224	NW¼NW¼ sec. 23	....	....	Gentle slope	....	105	4.5	3.3	72.89	do	C,W	S	
225	SW¼NW¼ sec. 24	Mrs. F. M. Johnson	1925	Upland flat	....	166	4.5	4.0	142.67	do	C,W	D,S	Water in gravel, first at 164 ft.
226[4]	NE¼ sec. 26	Hardesty Town Site Co.	....	do	....	......	....	----	....	....	C,W	P	
227	NW¼NW¼ sec. 35	W. M. Hughey	....	Low hill on upland	....	207	4	1.0	166.64	11-25-37	C,W	N	Water in fine red sand.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL Height of M.P. (feet)	WATER LEVEL Below M.P. (feet)	WATER LEVEL Date Measured	Method of lift	Use of water	Remarks
	T. 2 N., R. 18 E.												
231	NE¼SE¼ sec. 10	E. R. Mock	1908	Creek bottom	....	-----	48	3.4	21.93	do	C,W	S	Dug well, open hole. Water in clayey caliche.
232	SE¼SE¼ sec. 11	O. M. McBride	1928	Slope	....	99	5	3.0	98.35	do	C,W	N	
233	NW¼NE¼NE¼ sec. 13	Mrs. H. Bailey	....	Hill	....	97	5?	2.75	97.34	11-24-37	C,W	N	30 ft. above cr. channel. Water in gravel.
234	SW¼SW¼NW¼ sec. 15	Kans. City Life Ins. Co.	Old	Slope	....	55	4.5	3.7	45.95	11-25-37	C,W	D,S	
235	See sec. 18, T 4 N., R. 15 E.												
236	NE¼SE¼ sec. 17	James Randles	....	Upland flat	....	84	5	4.6	63.53	11-25-37	C,W	D,S	
237a	SE¼SE¼SE¼ sec. 19	O. R. Bingley	1917	do	....	142	5	2.9	122.9	do	C,W	D,S	Water in coarse sand.
238a	SE¼SE¼ sec. 23	C. E. Martin	Old	do	....	128	3.5	3.25	122.93	do	C,W	D,S	Water in sand.
239	NW¼NE¼NE¼ sec. 28	E. C. Richards	1925	Upland flat	....	139	5	1.0	108.9	do	C,W	D,S	Second water, in gravel. Waters 40-50 head of stock.
240	NE¼NE¼SE¼ sec. 31	D. R. Rhodes	1914	do	....	153	5	4.0	121.82	11-23-37	C,W	D,S	Water in coarse gravel.
241	NW¼NW¼SW¼ sec. 34	....	....	do	....	113	....	4.77	112.29	11-25-37	C,W	N	
242a	SE¼SW¼SE¼ sec. 35	R. O. Mason	Old	do	....	140	4.5	1.25	84.86	11-23-37	C,W	D,S	Water in coarse gravel. Poor water.
	T. 2 N., R. 19 E.												
246	SW¼NW¼NW¼ sec. 8	....	....	Upland flat	....	100	5	3.5	99.42	2- 5-38	C,W	S	At edge of breaks.
247	SW¼SW¼SE¼ sec. 13	....	....	Low hill	....	66	4?	3.4	60.21	11-24-37	C,W	N	
248	NE¼NE¼SE¼ sec. 15	Grand Valley School Dist. 122	....	Flood plain	....	9	5	0.3	6.85	11-25-37	None	N	Dug well?

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL Height of M.P. (feet)	WATER LEVEL Below M.P. (feet)	WATER LEVEL Date Measured	Method of lift	Use of water	Remarks
	T. 2 N., R. 19 E. (Cont'd)												
249a	SW¼SW¼SE¼ sec. 15	H. L. Gibson	1936-1937	do	....	17s 20s	20	—1.0	7.39	11-24-37	Cent., Gs.,20	I,6	4 dug wells. Concrete ring casing to bottom, with gravel walls 8-in. thick. Water in gravel, 8-20 ft. 3 wells pumped simultaneously yield 85 gal. a min.
250	SW¼SW¼NW¼ sec. 19	Sam Washburn	....	Upland flat	....	140	....	4.0	131.22	11-24-37	C,W	N	
251	SE¼SW¼SE¼ sec. 21	M. P. Wouldridge	....	Flood plain	....	20	5	1.4	16.27	do	C,W	N	Dug well?
252	NW¼NE¼ sec. 23	Bill Johnson	Old	Creek bottom	....	......	....	2.5	32.18	do	C,W	S	Dug well. Water in red clay. Tastes "gyppy." Hauls drinking water.
253	NE¼NW¼NE¼ sec. 26	....	....	Hill	....	64	4	0.75	56.9	do	C,W	N	
254	E. cent. SE¼ sec. 27	Kans. City Life Ins. Co.	....	Undulating upland	....	59	....	2.4	52.69	do	C,W	N	
255	SE¼NW¼ sec. 32	Risky	....	Flood plain	....	8	4.5	0.9	4.75	do	C,W	N	Dug well?
256	NW¼NW¼SW¼ sec. 34	———......	....	do	....	16	5?	2.2	15.5	do	C,W	N	Dug well?
257	SE¼SE¼SW¼ sec. 36	School Dist.	....	Hill	....	194	5	0.6	74.56	11-22-37	None	N	
	T. 3 N., R. 10 E.												
261	NW¼NW¼NW¼ sec. 1	Mrs. J. C. Wells	Old	Hill on upland	3612	201	....	1.5	174.17	11- 5-37	C,W	D,S	
621	SW¼NW¼NW¼ sec. 2	....	——	do	....	163	....	1.6	151.25	do	C,W	N	
618	NW¼NW¼ sec. 11	....	....	Upland flat	....	65	4.5	....	55.68	11- 4-37	None	N	
262	SW¼NW¼ sec. 12	W. E. Metz	Old	Slope	....	119	....	0.75	116.65	11- 5-37	C,W	D,S	First water in gravel.
263	NW¼NW¼NE¼ sec. 17	Clara Baudry	....	do	....	169	4	0.85	136.21	do	C,W	N	
264a	SW¼SW¼SW¼ sec. 26	C. E. Beaman	1915	Upland flat	....	152	4	4.4	147.45	11- 4-37	C,W	D,S	Water in sand. Water temp. 61° F.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M.P. (feet)[1]	Water level: Below M.P. (feet)	Water level: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 3 N., R. 11 E.												
269	NW¼NE¼ sec. 6	J. E. Jordan	....	Upland flat	....	182	5	0.7	127.25	11- 6-37	None	N	
270	NW¼NW¼SW¼ sec. 7	....	....	Flood plain	....	81	....	0.6	73.48	11- 5-37	C,W	N	
271	NE¼NW¼ sec. 11	....	....	Upland flat	....	89	....	0.5	69.48	11- 6-37	C,W	N	Water in sand.
272	SE¼SE¼ sec. 13	J. Huddleston	....	20-30 ft. above cr.	....	28	....	2.25	22.82	do	C,W	D,S	Water in sand.
273	SE¼NE¼ sec. 15	....	....	Slope	....	90	....	0.25	88.54	do	C,W	S	
274	NW¼NW¼NW¼ sec. 16	V. Norris	1925	Upland flat	3495	74	4.5	3.5	71.06	do	C,W	D,S	Water in sand and gravel.
275	SE¼SE¼SE¼ sec. 19	Miss Rutenbaugh	....	do	....	127	....	1.0	125.25	do	C,W	D,S	
276	NE¼NE¼ sec. 20	Geo. O. Wilson	....	Slope	....	78	....	3.25	88.75±	do	C,W	D,S	Water in gravel.
277[4]	NW¼NW¼SW¼ sec. 26	C. Huddleston	....	Upland flat	....	140[5]	....	—	130[5]	....	C,W	D,S,P	Water in gravel. Supplies James School, Dist. 26.
278	SE¼NE¼ sec. 28	J. H. Keylon	1925	Gentle slope on upland	....	209	4.5	0.6	151.38	11- 8-37	C,W	D,S	Water in sand and gravel.
279	NE¼NE¼SE¼ sec. 29	E. C. Burns	1927	Upland flat	3537	154	5	1.0	150.42	11- 6-37	C,W	D?	Water in sand.
280	SW¼SW¼SW¼ sec. 32	....	....	do	....	126	....	1.0	121.7	do	C,W	N	
281	NW¼NW¼NE¼ sec. 5	Lester Sparks	1938	do	3536	118	15	3.25	90.84	8-28-38	None	...	Intended for Irr. Report 11 gal. a min. with slush bucket. Cased 15 ft.; rest open hole.
	T. 3 N., R. 12 E.												
552	NE¼NE¼NE¼ sec. 1	B. G. Manwarren	....	Upland flat	3367	182	5	3.0	177.97	10-23-37	C,W	D,S	
284[4]	NE¼NE¼NE¼ sec. 5	Liberty School Dist. 93	....	do	3424	113	4	0.5	102.45	5-23-39	None	N	Abandoned.
285	SW¼SW¼ sec. 7	E. A. Walters	....	Undulating upland	....	112	....	0.25	84.3±	11- 6-37	C,W	D,S	Water in sand.
	T. 3 N., R. 12 E. (Cont'd)												
661	SE¼NE¼ sec. 8	William Webb	1915	Creek bottom	....	17	4	2.0	14.37	11-10-37	C,W	D,S	5 ft. above channel. Water in gravel.
286	SW¼SW¼ sec. 9	do	....	do	....	55	5.5	0.75	23.91	do	C,W	N	45 ft. below upland.
287[4]	NE¼SE¼ sec. 16	Stonebraker-Zea Ranch	1938	Flood plain	....	207[5]	5	1.0	54	7-25-38	C,W	S	20 ft. above Tepee cr. channel. Water in red sand. Reported yield, 6 gal. a min.
288	SE¼NW¼ sec. 16	do	1937	Slope	....	126	5	—	111±	11-14-37	None	N	85 ft. above Tepee cr. channel. Red beds reported at 40 ft. Abandoned as too weak.
	T. 3 N., R. 13 E.												
293	NW¼NE¼NW¼ sec. 4	Guy Speakman	Old	Upland flat	....	150	5	0.5	143.8?	10-23-37	C,W	N	Water in sand? A poor well.
294	NW¼NW¼ sec. 25	Sonebraker-Zea Ranch	....	Slope	....	56	5	1.0	43.47	9-24-37	None	N	
295	See sec. 14, T. 3 N., R. 15 E.												
	T. 3 N., R. 14 E.												
300	SW¼SE¼ sec. 4	L. O. Schwenke	Old	Slope	....	111	6	3.0	109.81	1-29-38	C,W	N	Water in sand?
301	NE¼NW¼ sec. 6	Central Life Ins. Co.	Old	Flood plain	....	58	....	1.0	55.61	1-28-38	C,W	N	10 ft. above cr.
302	NE¼NW¼ sec. 11	M. M. Chenault	Old	Slope	....	59	6	2.0	54.42	do	C,W	N	Water in coarse gravel.
303	NE¼NE¼ sec. 17	Stonebraker-Zea Ranch	....	do	....	159	....	—2.0	102	do	C,W	S	
304	SE¼SE¼ sec. 25	1st Nat. Bank, Guymon	....	Upland flat	....	167	5	—2.6	122.55	9-18-37	C,W	D	Water in sand and gravel.
305[4]	SW¼SE¼ sec. 29	Stonebraker-Zea Ranch	....	Slope	....	68	8	1.0	23.18	9-24-37	C,W	D,S	Water in sand. Water rose 0.1 ft. in 20 min. after pumping stopped.
306	SE¼SE¼ sec. 34	M. Costner	....	Undulating upland	....	130	....	—	127.67	do	C,W	N	Water in sand.
307	NE¼NE¼NE¼ sec. 5	....	....	Gentle slope	3164	72	....	0.3	65.68	8-17-38	C,W	S	

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M.P. (feet)[1]	Water level: Below M.P. (feet)	Water level: Date Measured	Method of lift[2]	Use of water	Remarks
	T. 3 N., R. 15 E.												
310	SW¼NE¼ sec. 10	....	1930	Flood plain	....	32	5	1.3	24.17	10- 2-37	H	N	Dug well.
311	SE¼NE¼ sec. 11	Geo. M. Fowler	....	do	....	26?	6 ft. x 8 ft.	0.7	14.9	do	H	N	Dug well. Water in sand.
312	SW¼SE¼ sec. 12	Steve Barner	1933	do	....	9	5	1.1	7.1	10- 1-37	H	D,S	Dug well.
187	NW¼NE¼SW¼ sec. 12	John Gill	....	do	....	9	6	1.4	5.5	9- 7-37	None	N	Water in sand.
313	SW¼NE¼ sec. 14	Kans. City Life Ins. Co.	Old	do	....	22	4	2.2	19.39	10- 2-37	C,W	D,S	Water in sand.
295	NE¼SW¼NW¼ sec. 14	E. O. Hobson	....	do	....	14s	30	3	11.88	9-15-37	Bucket & line	D	Dug well.
314	SW¼SW¼NE¼ sec. 15	Lee & Moore	1937	do	....	70s	12.5	—9	2.42	9-16-37	Cent. Gs	I,S	Water in quicksand, 12-27 ft., coarse gravel 60-70 ft., casing perforated 18-70 ft. Reported yield 200 gal. a min. with 20 ft. drawdown.
332	SW¼SW¼SE¼ sec. 17	....	....	Hill	....	72	5	3.5	69.35	9-18-37	C,W	N	
315	SW¼NW¼ sec. 17	M. A. Costner	1936	Slope	....	33	36	....	30.49	10- 2-37	None	N	Dug well. Water in sand and gravel?
316	SE¼NE¼ sec. 18	do	1937	Flood plain	....	25?	36	1.0	18	do	Gs, 1.5	I	Dug well, water in sand?
176	SW¼SW¼SW¼ sec. 18	W. N. Ballinger	1934	do	....	30s	19	—5.22	3.71	9- 4-37	Cent,G	I,S	Water in coarse gravel, 14-30 ft. (Log 176-a). Measured yield 100 gal. a min. with measured drawdown of 12.8 ft.
317	NW¼NW¼ sec. 28	Gen'l. Atlas Carbon Co.	1938	Upland flat	3077	385s	12	....	133.92	3-21-38	None	N	Water in sand. (See log) Reported yield 628 gal. a min. with 10 ft. drawdown. Gravel wall 9-in. thick.
318	NW¼NW¼ sec. 29	Loan Co.	Old	Slope	....	144	5	1.0	123.23	9-18-37	C,W	N	Water in quicksand. Muddy.
	T. 3 N., R. 15 E. (Cont'd)												
319a	NW¼NE¼SE¼ sec. 31	Okla. Elec. & Water Co. (Guymon)	1929	Upland flat	3121	330s	14	....	190s	....	T.E. 35	P	Reported yield 251 gal. a min. with 7 ft. drawdown; second well similar, with 40 h.p. motor, yields 285 gal. a min. with 9 ft. drawdown. Both wells gravel-packed. See log.
320	NW¼NE¼NW¼ sec. 19	City of Guymon	1936	Flood plain	....	57s	12.5	—9.0	3.23	8-12-38	Cent., G	P	Water in sand and gravel. Partly dug, partly drilled. Reported yield 225 gal. a min. with 21 ft. drawdown.
	T. 3 N., R. 16 E.												
323	SW¼SE¼ sec. 1	Mrs. Bostwick	....	Flood plain	....	25	5	0.5	21.9	10-29-37	C,W	N	
324	SE¼SW¼SW¼ sec. 2	Anna Calvert	1912	Upland flat	....	100	4	0.3	95.67	do	C,W	N	Water in sand and gravel.
325	SW¼NW¼NW¼ sec. 2	Ensten?	....	do	....	121	4	0.4	105.03	1-17-38	C,W	S	
326a	NW¼NE¼ sec. 5	Town of Optima	Old	do	....	165s	6	....	105s	....	C,W	P	Water in sand.
327	NE¼SW¼ sec. 7	Blanche Hinchey	1937	Flood plain	....	19	large	....	15.9	10- 4-37	None	N	Dug for irrigation, but not completed. Uncased.
328	SW¼SW¼SW¼ sec. 10	Letha Sassin	1934	do	....	40s	4	0.5	26	do	C,W	D,S	Dug well, water in coarse gravel, 36-40 ft.
329	NW¼NE¼ sec. 15	F. H. Dale	....	do	....	115s	5	....	Flows	do	None	N	Water in sand or gravel. Feeble flow.
350	NW¼NW¼ sec. 18	C. A. Nash	1934	do	....	35s	19	—4	3.69	10- 2-37	C,W	D,S	Cased 4-35 ft., perforated 14-35 ft. Water in sand. Reported yield 50 gal. a min.
330	NW¼NE¼ sec. 22	....	....	Creek bottom	....	82	....	0.5	41.23	1-20-38	C,W	S	
331	NE¼NE¼NE¼ sec. 23	....	....	Flood plain	....	12	7	2.6	4.82	do	C,W	S	Dug well?
332	See sec. 17, T. 3 N., R. 15 E.												

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL: Height of M. P. (feet)[1]	WATER LEVEL: Below M. P. (feet)	WATER LEVEL: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 3 N., R. 16 E. (Cont'd)												
333	NE¼NE¼ sec. 28	....	....	Upland flat	....	146	4	2.0	131.61	10-27-37	C,W	N	
334	SE¼SE¼NE¼ sec. 30	Percy Thomason	....	do	....	141	....	0.6	136.86	do	C,W	S	
335	SW¼SW¼ sec. 31	....	....	Undulating upland	....	152	....	....	147 ±	do	C,W	N	
336	SW¼SW¼SW¼ sec. 33	New Bethel School Dist. 152	....	Upland flat	....	144	....	0.75	140.21	10-30-37	C,W	N	Water in sand?
	T. 3 N., R. 17 E.												
340	NW¼SW¼ sec. 3	J. F. Balzer	Old	Upland flat	2921	140	5	3.5	128.3	11-27-37	C,W	D,S	
341	NW¼NE¼NE¼ sec. 5	J. F. Hansen	1907	Slope on upland	2928	119	6	....	108.88	do	C,W	D,S	Water in sand and gravel.
.40	NW¼NE¼NW¼ sec. 6	August Lorenz	....	Upland flat	2931	97	....	0.3	90.97	12-19-37	C,W	S	Water in clay.
342	NE¼NW¼NW¼ sec. 8	Heath Estate	....	do	....	117	....	3.3	100.61	1-18-38	C,W	S	
343a	NE¼NE¼NE¼ sec. 10	S. Pleasant View School	....	do	....	......	....	....	....	....	C,W	P	
344	NW¼SW¼ sec. 12	D. H. Enns	Old	do	2948	118	6	3.7	114 ±	11-27-37	C,W	D,S	Water in sand.
345	SW¼SW¼ sec. 17	Hooker Country Club	....	Flood plain	....	39	....	0.7	19.93	11-26-37	C,W	N	
346	NE¼NE¼SW¼ sec. 25	Mrs. A. L. Fletcher	Old	do	2740	22s	4.5	1.25	8.2	10-29-37	C,W	D,S	Water in gravel. Water rose 3.68 ft. after pumping stopped. Measured yield 2 gal. min.
347	N½SW¼ sec. 26	J. S. Beasley	1928	Slope	2778	36	6	2.0	30.24	10-29-37	C,W	S	Water rose 2.92 ft. in 2 hr. 40 min. after pumping stopped.
348	NE¼SW¼NE¼ sec. 34	Loan Co.	....	Flood plain	....	24	4	0.3	17.25	do	None	N	Dug well?
349	NW¼NW¼NW¼ sec. 34	....	....	do	....	32	42	1.0	31.34	do	None	N	Dug well, walled with rock.
	T. 3 N., R. 17 E. (Cont'd)												
350	See sec. 18, T. 3 N., R. 16 E.												
351	SE¼NW¼SW¼ sec. 36	Boss Neff	....	Upland flat	....	99	....	0.6	91.69	do	C,W	D,S	
354	See sec. 27, T. 6 N., R. 15 E.												
	T. 3 N., R. 18 E.												
60	SW¼NW¼ sec. 3	J. E. Friesen	1904	Upland flat	2867	118	6	2.5	100.76	12- 3-37	C,W	D,S	Water in gravel.
357	SW¼SW¼SW¼ sec. 4	Bible School	....	do	2879	127	....	0.5	103.06	12- 4-37	C,W	N	
358	NE¼NW¼NE¼ sec. 7	A. A. Hamm	Old	do	2902	130	5?	1.5	119.14	12- 2-37	C,W	D,S	Water in gravel.
359	NW¼NW¼SW¼ sec. 14	P. M. Krause	1916	Low hill on upland	2851	126	5?	1.0	113.57	do	C,W	N	
360a	SW¼SW¼SE¼ sec. 16	Chas. Chittenden	Old	do	2864	138	5	1.0	119.71	12- 4-37	C,W	D,S	Has watered 500-600 head stock.
361	SE¼SE¼SW¼ sec. 20	....	....	Undulating upland	2829	94	....	0.5	86	12- 2-37	C,W	S	
362	NW¼NW¼NW¼ sec. 20	....	....	Slope	2833	89	4.5	0.5	77.89	do	C,W	N	
363	SE¼SW¼ sec. 23	Loan Co.	Old	Upland flat	2824	100	3	0.5	95.81	12- 2-37	C,W	N	Water in gravel.
364	NE¼NE¼NE¼ sec. 28	DePew	....	do	2836	100	5	3.7	99.71	do	C,W	N	Water in coarse gravel.
365	SE¼SE¼ sec. 30	....	....	Flood plain	2738	14	5	3.1	11.42	do	C,W	N	
366	SE¼SE¼SE¼ sec. 31	....	....	do	....	11	5	0.75	4.79	1-14-38	None	N	
367	SE¼SE¼NW¼ sec. 33	....	....	Creek bottom	....	75	....	3.0	54.59	1-11-38	C,W	S	
369	See sec. 15, T. 6 N., R. 15 E.												
	T. 3 N., R. 19 E.												
372	NW¼NW¼ sec. 2	J. N. West	....	Upland flat	2788	126	....	0.4	117.65	1-18-38	C,W	N	Water in gravel, 136-150 ft.
373a	SE¼SE¼SW¼ sec. 4	J. S. Houston	1906	Undulating upland	2800	121	6	1.3	115.12	12- 3-37	C,W	D,S	Water in sand, 123-130 ft.
761	NW¼NW¼ sec. 7	Mrs. Cordia Humble	....	Dunes	2834	116	4.5	0.7	108.74	do	C,W	N	Water in fine sand.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M. P. (feet)[1]	Water level: Below M. P. (feet)	Water level: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 3 N., R. 19 E. (Cont'd)												
374	NE¼NE¼ sec. 12	Mrs. F. E. Powers	....	Undulating upland	2750	113	5?	0.7	105.54	do	C,W	N	Second water, in gravel.
375	NE¼SE¼ sec. 14	Geo. Headrick	1930	Dunes	2763	122	5	4.25	111.3±	do	C,W	D,S	Water in gravel. Stains children's teeth.
770	SW¼SW¼NW¼ sec. 15	A. C. DeHart	1906	do	2797	126	4.5	0.1	123.89	do	None	N	Originally 190 ft. deep, water in sand 124-190 ft.
376	NW¼NW¼SE¼ sec. 18	Vergil Thurman	Old	do	2816	119	5	0.3	115.0	do	C,W	D,S	Water in sand?
377	SW¼SW¼SW¼ sec. 19	W. H. Jacobs	....	Hill	2794	97	4.5	2.7	95.83	do	C,W	N	
765	SE¼SW¼ sec. 26	O. Joffree	....	Dunes	2765	117	6	3.25	107.2	do	C,W	S	
378	NE¼NE¼NE¼ sec. 28	....	....	Upland flat	2778	139	7	3.2	105.37	12-31-37	C,W	S	
379	SE¼SW¼ sec. 32	R. C. Johnson	....	Flood plain	2668	15	6	4.25	8.02	12- 3-37	C,W	N	
380	NE¼SE¼ sec. 33	R. E. Underwood	....	do	....	23	6	1.25	7.7	1- 8-38	C,W	S	
381	SE¼SW¼ sec. 34	O. Jolliff	....	do	2662	19	....	2.4	14.0	12- 3-37	C,W	S	
386	See sec. 3, T. 2 N., R. 14 E.												
	T. 4 N., R. 10 E.												
387[4]	SE¼SE¼ sec. 9	Chris Dencker	....	Upland flat	....	200s	....	....	130s	....	C,W	S,P	Water in gravel. Supplies Independence School.
388	NW¼NW¼NW¼ sec. 12	W. E. Briar	....	do	....	226	....	1.0	201.15	11- 5-37	C,W	N	Water in sand and gravel.
389	NW¼NW¼NE¼ sec. 19	Mrs. A. L. Buzzard	1937	do	....	209	4.5	1.3	182.35	11- 1-37	C,W	D,S	Reported depth 272 ft. Red beds 160 ft.
390	SW¼NE¼NE¼ sec. 25	J. T. Plaster	....	do	....	199	....	1.0	166.4±	11- 5-37	C,W	N	Water in gravel.
626	NW¼SW¼NW¼ sec. 27	John Copeland	1935	do	....	111	5	0.6	91.72	11- 6-37	C,W	D,S	
	T. 4 N., R. 11 E.												
395	SW¼SW¼SW¼ sec. 11	L. F. Wegener	....	Upland flat	....	167	....	0.5	164.1	11-10-37	C,W	D,S	Water in sand.
396[4]	SE¼SE¼SE¼ sec. 17	Center School, Dist. 147	....	do	....	225	....	....	....	....	C,W	P	Reported depth 252 ft.
397[4]	SE¼NE¼SE¼ sec. 19	M. W. Wright	1908	do	3572	154	5.5	0.75	153.25	11-13-37	C,W	D,S	Reported 200 ft. deep.
398	NE¼SE¼SE¼ sec. 20	W. R. Johnson	1932	do	....	190	6.6	0.75	136.44	12-17-37	C,W	D,S	Drilled to 230 ft., filled 34 ft. with gravel. Water in sand, 208-230 ft., also 137-153 ft.
399	See sec. 26, T. 2 N., R. 14 E.												
400	SE¼SE¼ sec. 26	....	....	do	....	137	....	2.0	112.92	11-10-37	C,W	S	
401	NW¼NW¼NW¼ sec. 26	....	....	Slope to lake	....	66	....	0.3	58.54	11-12-37	C,W	N	
402	NW¼NW¼SW¼ sec. 27	....	....	Upland flat	....	95	....	1.25	85.27	do	C,W	N	
85	SE¼NE¼ sec. 34	Geo. Dean	....	Slope to lake	....	46	4.5	1.2	43.1	8-27-37	None	N	Water in gravel.
403[4]	NW¼SE¼ sec. 19	Beaver, Meade & Engelwood RR. (Eva)	1931	Upland flat	....	300s	8	....	194s	....	C,Gs, 10	RR	Drilled to 493 ft.; filled back with gravel to 300 ft. level. Yielded 40 gal. a min. on test.
404	See sec. 4, T. 1 N., R. 14 E.												
405	SE¼SE¼SE¼ sec. 31	J. E. Jordan	1939	Upland flat	3546	153	4	1.0	86.72	7- 5-39	C,W	D	
	T. 4 N., R. 12 E.												
407	SE¼SE¼SW¼ sec. 1	....	....	Upland flat	....	157	5?	0.6	154.97	11-12-37	C,W	N	
408	SE¼NE¼SE¼ sec. 6	J. S. Rogers	1912	do	....	156	5	1.5	148.92	11-11-37	C,W	D,S	Water in gravel.
409	SW¼SW¼SW¼ sec. 7	School Dist. 92	....	do	....	154	....	0.5	152.82	11-12-37	C,W	N	
410	SE¼SE¼SE¼ sec. 10	J. J. Dunham	Old	Upland flat	....	147	5	0.6	145.65	11-12-37	C,W	D,S	Water in gravel, 149-153 ft.
411[4]	NE¼NE¼NE¼ sec. 17	L. H. Langston	1922	Low ridge	....	156	....	0.5	151.73	do	C,W	D,S	Water in sand? Water rose 0.2 ft. after pumping stopped.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL Height of M. P. (feet)[1]	Below M. P. (feet)	Date Measured	Method of lift[2]	Use of water[3]	Remarks
					T. 4 N., R. 12 E. (Cont'd)								
412[4]	NW¼NW¼NW¼ sec. 25	F. B. Buzzard	1935	Upland flat	......	391[5]	4.5	0.3	128±	do	C,W	D,S	Water in red beds, bad taste. Drilled to 453 ft., filled with gravel to 391 ft. Cased to 396 ft., with sand wall outside. Reported yield 3 gal. a min.
413	NW¼NE¼SE¼ sec. 29	....	......	do	......	133	......	2.1	112.96	do	C,W	N	Reported 240 ft. deep. 2d water in coarse sand 236-240 ft.
414	SE¼SE¼SE¼ sec. 31	....	......	do	......	99	......	0.8	94.13	11-10-37	C,W	D,S	
					T. 4 N., R. 13 E.								
419	SW¼SW¼NW¼ sec. 18	Elmer Shaffer	1916	Upland flat	......	184	6	1.0	164.68	11-12-37	C,W	D,S	Water in gravel.
551	SW¼SW¼SW¼ sec. 19	....	......	do	......	213	5	1.0	146.69	10-23-37	None	N	
420	SE¼SE¼SE¼ sec. 20	O. C. Glatthaar	1912	do	......	140	5	0.25	129.53	do	C,W	N	Water in sand.
421[4]	NW¼NW¼NW¼ sec. 22	Renfrew Investment Co.	Old	do	......	155	4	0.3	150.75	do	C,W	D,S	
422	NE¼SE¼ sec. 27	....	......	Creek bottom	......	123	—	1.75	107	do	C,W	N	
423	SE¼SE¼SW¼ sec. 35	K. Powell	1916	Upland flat	......	185	6	3.0	124.6	1-28-38	C,W	D,S	Reported 203 ft. deep, water in gravel, yield diminishes with pumping.
424	SW¼SE¼NE¼ sec. 36	....	......	Slope	......	74	....	2.66	71.96	1-28-38	C,W	S	
					T. 4 N., R. 14 E.								
507	SW¼SE¼SW¼ sec. 1	J. H. Wells	1914	Upland flat	......	181	6	....	165.87	10- 8-37	C,W	D,S	Reported 205 ft. deep. Third water in gravel 192-204 ft. Others at 90 ft., 115 ft.
428	NE¼NE¼SE¼ sec. 4	O. N. Heard	1905	do	......	201	5	....	188.9	do	C,W	D,S	Reported 206 ft. deep. Water in gravel, 200-206 ft. First water in sand, 180-190 ft.
429	SE¼NW¼NW¼ sec. 5	J. W. J. Williamson	1905	do	......	158	5	1.5	155.6?	do	C,W	D,S	Water in sand.
430	SE¼NE¼NE¼ sec. 10	....	......	Undulating upland	......	208	....	0.7	185.5±	do	C,W	N	
431[4]	NE¼NE¼SE¼ sec. 15	Konecke Estate	Old	Slope	......	179	5?	0.5	162.47	do	C,W	N	
432	NE¼NW¼ sec. 24	Kate M. Snyder	Old	Upland flat	......	189	....	....	177.97	do	C,W	N	Water in gravel.
433	NW¼NW¼NW¼ sec. 29	Interstate Nat'l. Bank, Kans. City	......	Flood plain	......	28	8	1.5	13.24	10-23-37	C,W	S	
72	SW¼SW¼NW¼ sec. 33	W. L. Ziegler	Old	Slope	3168	90[5]	4	2.0	74.37	do	C,W	D,S	Water in gravel?
434	SE¼NW¼ sec. 36	....	......	Creek bottom	......	21	7	2.5	18.52	1-22-38	C,W	S	
435	SE¼SE¼SE¼ sec. 13	Bertha Bauer	1917	Upland flat	......	199	6	1.5	177.75	5-26-38	C,W	D,S	Water in sand?
436	NE¼NE¼ sec. 24	Leo Holtgraver	Old	do	......	198	4	......	170.81	5-26-38	C,W	D,S	Water in gravel. Has watered 65 head of stock.
					T. 4 N., R. 15 E.								
438	NE¼SW¼SE¼ sec. 2	O. R. Lively	1936	Low hill on upland	......	165[5]	4	0.5	126	9- 9-37	C,W	D,S	Water in sand 130-165 ft.
439[4]	SE¼SE¼NE¼ sec. 4	Friendship School, Dist. 80	1924	Upland flat	......	151[5]	4.5	....	131[5]	......	C,W	P	Water in gravel. 136-150 ft.
440	NW¼SW¼NW¼ sec. 7	M. M. Bolino	Old	do	3174±	175±	6	....	167±	9-10-37	C,W	D,S	Reported 229 ft. deep. Water in sand. Waters 12 head of stock.
441	SE¼SE¼SE¼ sec. 9	Jennie A. Holt	1907	do	......	160	4	5.0	160.57	1-26-38	C,W	D,S	Water in sand.
442	NW¼SW¼SE¼ sec. 13	H. O. Wagner	Old	do	......	150[5]	5	0.5	129.71	9- 9-37	C,W	D,S	Water in sand.
235	SW¼SW¼SW¼ sec. 18	J. E. Bauer	Old	Upland flat	3162	189	....	0.5	168.59	9-10-37	C,W	N	Water in gravel.
443	NE¼SW¼SE¼ sec. 23	H. W. Klinsick, Est.	1907	Gentle slope	......	160[5]	6	....	133.84	9- 7-37	C,W	D,S	Water in sand.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M. P. (feet)[1]	Water level: Below M. P. (feet)	Water level: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 4 N., R. 15 E. (Cont'd)												
444	SW¼SE¼SE¼ sec. 24	Arthur Brune	1910	Upland flat	....	152[5]	5	0.9	126.6	do	C,W	D,S	Water in sand.
445	NE¼NW¼NW¼ sec. 25	W. H. Fechtler	1929	do	....	150[5]	5	1.15	129.95	do	C,W	D,S	Water in sand.
446	NW¼NE¼NW¼ sec. 8	....	....	do	....	163	....	0.25	149.37	7-26-38	C, W	N	Beside ephemeral pond.
	T. 4 N., R. 16 E.												
450	SW¼SE¼SE¼ sec. 1	Anna Warner	Old	Low hill on upland	3035	150	6	....	116.28	10-28-37	C,W	D,S	Water in sand.
451	NE¼NE¼NW¼ sec. 9	Charles Rose	Old	Upland flat	3024	124	5	0.3	115.56	do	C,W	D,S	Water in sand?
452	NW¼NW¼NE¼ sec. 11	Gottlieb Warner	Old	do	3035	138	6	2.0	132.76	10-28-37	C,W	D,S	Water in gravel.
453	NW¼NE¼NW¼ sec. 13	C. O. Finfrock	Old	do	3015	136	6	1.0	128.44	10-29-37	C,W	D,S	Water in sand.
454[4]	NE¼SE¼ sec. 16	George Lundgrin	1921	Low hill on upland	3008	125	4.5	1.5	119.09	10-29-37	C,W	D,S	Water in sand.
455	NW¼NE¼SE¼ sec. 22	George Herbel	....	Upland flat	2993	114	6	0.75	99.39	10-28-37	C,W	D,S	Water in gravel? Water rose 1.23 ft. in 15 min. after pumping stopped.
456	NE¼NE¼NE¼ sec. 24	Buffalo School Dist. 10	1916	do	2988	138	4.5	....	115.94	10-29-37	C,W	P	Water in sand.
457	NW¼NW¼NW¼ sec. 25	J. G. Hofferber	Old	do	2985	109	6	0.5	105.64	10-28-37	C,W	D,S	Water in sand?
458	NE¼NE¼SE¼ sec. 27	....	....	do	2991	104	5	0.5	94.29	1-17-38	None	N	
459	See sec. 21, T. 1 N., R. 14 E.												
460	NE¼SW¼NE¼ sec. 34			Creek bottom	2927	42	5	0.75	28.75	do	C,W	S	
461	See sec. 31, T. 1 N., R. 14 E.	....	....										
	T. 4 N., R. 17 E.												
466	NW¼NW¼NW¼ sec. 1	....	....	Upland flat	2951	118	....	0.5	107.6±	12- 2-37	C,W	S	
467	NE¼NE¼NW¼ sec. 3	A. H. Hollmann	1905	do	2976	144	6	....	122.5	do	C,W	D,S	Water in fine gravel, 125-144 ft. Redrilled 1932.
468	NW¼NW¼NW¼ sec. 8	C. A. Moore	....	do	3009	139	4.5	0.6	137.1	10-28-37	C,W	D,S	Water in gravel.
469	W. cent. SW¼ sec. 13	J. C. Burks	Old	do	2948	125	5	1.0	118.47	12- 2-37	C,W	D,S	Water in sand?
470[4]	SE¼NE¼ sec. 15	F. E. Smith	1916	Low hill on upland	2961	124	6	1.0	122.97	10-29-37	C,W	D,S	Water in gravel.
471	NE¼NE¼SE¼ sec. 19	Geo. Lundgrin	1913	do	3001	146	6	0.6	138.25	do	C,W	D,S	Water in sand and gravel.
472	NW¼NE¼ sec. 20	Floyd Jones	....	Low hill on upland	2989	147	4	1.0	138.75	10-29-37	C,W	D,S	Water in sand.
473	NW¼NE¼SW¼ sec. 26	A. V. Balzer	1905	Upland flat	2932	136	....	1.5	119.82	12- 2-37	C, W	D,S	
474	SE¼SW¼SW¼ sec. 30	Blanche A. Arnold	....	Slope	2932	93	....	1.8	78.37	10-29-37	C,W	S	Water in clay.
589	NW¼NW¼NW¼ sec. 34	August Lorenz	....	Upland flat	2935	141	....	0.5	120	do	C,W	S	
	T. 4 N., R. 18 E.												
478	NE¼NE¼ sec. 3	J. R. Nels	....	Upland flat	2908	98	6	0.4	84.5	12- 4-37	C,W	D,S	
479	NW¼NW¼NW¼ sec. 7	E. W. Hopkins	1905	do	2938	132	6	3.4	107.98	12- 7-37	C,W	S	Water in coarse gravel, 130-135 ft.
480	NE¼NE¼NE¼ sec. 11	J. A. Brandon	....	do	2888	124	....	4.3	103.25	12- 4-37	C,W	D,S	
481	SE¼SW¼SW¼ sec. 13	Alliance Ins. Co.	Old	Low hill on upland	2898	139	4.5	1.5	134.4	do	C,W	D,S	Water in gravel.
482	W. cent. NW¼ sec. 15	Federal Life Ins. Co., Okla. City	....	Slope	2871	84	....	2.3	72.54	do	C,W	N	Water in sand.
483	NE¼NE¼SE¼ sec. 19	F. McKirahan	Old	Upland flat	2908	126	6	0.5	109.48	do	C,W	D,S	
484[4]	NW¼NW¼NW¼ sec. 27	Anna Balzer	....	Undulating upland	2875	103	....	1.5	88.71	do	C,W	D,S	
795	NW¼NW¼SW¼ sec. 30	Herman Zable	....	Upland flat	2914	120	....	3.7	116.88	12- 7-37	C,W	N	Water in gravel.
485	SE¼NE¼NE¼ sec. 32	I. W. Wiebe	....	do	2893	119	....	3.8	109.21	do	C,W	D,S	Water in sand?
486	SW¼SW¼NW¼ sec. 36	John Elmore	....	Low hill on upland	2864	134	....	1.0	116.23	12 -4-37	C,W	D,S	
487	SE¼SE¼ sec. 34	J. E. Friesen	1915	Upland flat	....	119	5	1.5	101.31	7-26-38	C,W	N	Beside ephemeral pond.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL: Height of M. P. (feet)[1]	WATER LEVEL: Below M. P. (feet)	WATER LEVEL: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 4 N., R. 19 E.												
491	NW¼SW¼ sec. 5	....	....	Undulating upland	2866	116	....	3.0	113.78	12- 4-37	C,W	N	
492	SE¼NE¼NW¼ sec. 10	J. W. Nitts	....	Low ridge	2825	129	....	1.75	113.8	9-23-37	C,W	N	Water in clay.
493	SW¼SW¼SE¼ sec. 12	Jonas Redger	....	Gentle slope	2791	169	8	0.8	125.4	do	C,W	N	
494	SE¼SE¼SE¼ sec. 16	J. M. Mendenhall	....	Upland flat	2816	144	....	0.8	107.35	9-14-37	C,W	N	Water in clay.
495	SE¼NE¼NE¼ sec. 19	G. E. Klassen	Old	Undulating upland	2853	129	6	1.25	115.84	do	C,W	D,S	Water in sand.
496	NW¼NW¼NE¼ sec. 21	Dr. W. A. Hodges	1936	Upland flat	....	262[5]	12½-8	....	105[5]	....	T,Gs,85	I,105	See log. 12.5-in. casing, 0-200 ft., 8-in. 200-262 ft., perforated 100-262 ft. Reported yield, 550 gal. a min.
497	NW¼NW¼SW¼ sec. 21	R. M. Van Hyning	1936	do	2821	280[5]	12½-8	1.0	104.8	9-13-37	T,Gs	I,30	See log. 12.5-in. casing 0-186 ft., 8-in., 186-280 ft., perforated 100-280 ft. Reported yield 450 gal. a min. with 38 ft. drawdown.
498	SW¼SE¼ sec. 28	S. B. Howell	Old	Low hill on upland	2817	123	5	1.2	112	9-13-37	None	N	
499[4]	NE¼NE¼SE¼ sec. 30	G. D. Mires	Old	Upland flat	2839	119	6	....	110.77	do	C,W	D,S	Water in clay and sand.
	T. 5 N., R. 10 E.												
504	NE¼SE¼NW¼ sec. 13	....	....	Slope	....	218	....	1.0	206.95	10-19-37	C,W	S	
505	NE¼NE¼NE¼ sec. 16	J. C. Euards	....	Upland flat	....	800[5]	7	0.8	204.86	do	C,W	N	Poor water.
506	SE¼SW¼SW¼ sec. 22	Mandy Loftis	....	do	....	247	....	0.5	220.97	do	C,W	N	Water in sand and gravel.
507	See sec. 1, T. 4 N., R. 14 E.												
508	SW¼SW¼SW¼ sec. 32	....	....	Upland flat	....	219	5	1.0	176	11- 1-37	C,W	N	

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Height of M. P. (feet)	Below M. P. (feet)	Date Measured	Method of lift	Use of water	Remarks
	T. 5 N., R. 11 E.												
512	NE¼NW¼NE¼ sec. 2	F. W. Dieckman	1907	Upland flat	....	195	4.5	3.0	190.88	11-11-37	C,W	D,S	Water in sandstone.
513	SE¼SE¼SE¼ sec. 2	J. W. Chatwell	1913	do	....	198	5	2.0	187.33	do	C,W	D,S	Reported 220 ft. deep, water in gravel 203-220 ft. Has watered 500 head of stock.
514[4]	NW¼NE¼ sec. 10	E. R. Oswald	....	do	....	200	4	1.0	197.38	do	C,W	D,S	Water in sand.
515	NW¼NW¼NW¼ sec. 20	E. L. Brewer	1917	do	3613	221	6	....	210.35	do	C,W	D,S	Water in gravel.
516	SE¼SE¼SE¼ sec. 23	Modene Price	1920	Slope	....	164	6	1.0	160.08	do	C,W	D,S	Water in sandstone?
517[4]	NW¼NW¼ sec. 25	L. Bacon	....	do	....	150[5]	....	....	120[5]	....	C,W	D,S,P	Supplies Triumph School, Dist. 140.
518	NW¼SW¼NW¼ sec. 32	....	....	Flood plain	3500±	100	4	2.25	90.68	11-11-37	C,W	S	5 ft. above channel of Goff Creek.
	T. 5 N., R. 12 E.												
522	SE¼SE¼SW¼ sec. 5	J. F. Carder	1914	Upland flat	....	205	6	1.3	191.3	12-17-37	C,W	D,S	Water in sand and gravel, 189-214 ft.
523	SW¼SE¼SW¼ sec. 6	E. Tucker	Old	do	....	211	4	0.7	196.8±	do	C,W	D,S	Water in gravel?
524[4]	SE¼SW¼SW¼ sec. 9	C. A. Fowler	....	do	....	220[5]	....	....	200[5]	....	C,W	D,S,P	Supplies Richland Center School, Dist. 100.
525	NE¼NW¼ sec. 21	Roy L. Booth	1915	do	....	202	6	1.0	188.95	12-17-37	C,W	D,S	Water in gravel?
526	NE¼NE¼NE¼ sec. 23	B. F. Gloden	Old	Hill	....	203	5	1.0	186.75	do	C,W	D,S	Water in gravel?
527	NE¼NE¼NE¼ sec. 28	Loan Co.	....	Slope	....	139	....	1.0	133.89	do	C,W	N	Water in gravel.
530	See sec. 26, T. 5 N., R. 14 E.												
	T. 5 N., R. 13 E.												
532	SW¼SE¼SW¼ sec. 1	J. L. Peters	....	Upland flat	....	230	....	....	210?	10-22-37	C,W	N	Water in sand.
533	SW¼NE¼NE¼ sec. 2	C. A. Talbot	....	Low hill on upland	....	229	....	0.6	219.1	do	C,W	D,S	Water in sand.
534	NE¼NW¼ sec. 3	........Emanuel	....	do	....	222	....	1.0	205.5	do	C,W	D,S	Water in gravel.
535	NW¼SW¼ sec. 7	Martha E. Bacon	1893	Slope	....	215	7	1.5	187.5±	do	C,W	D,S	Water in gravel.

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water Level: Height of M. P. (feet)[1]	Water Level: Below M. P. (feet)	Water Level: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 5 N., R. 13 E. (Cont'd)												
536	SW¼SW¼SW¼ sec. 9	W. C. Finley	....	Upland flat	....	190	....	0.25	185.55	do	C,W	N	Water in sand.
537[4]	NE¼NW¼NE¼ sec. 11	E. L. Blake	....	Undulating upland	....	......	....	....	210[6]	....	C,W	D,S,P	Supplies school. Water in sand.
538[4]	SE¼NE¼NE¼ sec. 13	Henry Hiller	....	Upland flat	....	240[5]	....	....	200[5]	....	C,W	D,S,P	Supplies Brown's Corner and Comet Schools.
539	NW¼NE¼ sec. 15	Ida Russels	....	Hill on upland	....	219	....	1.0	217	10-22-37	C,W	N	Water in gravel.
540	SW¼SW¼SW¼ sec. 23	Herman Witt	Old	Undulating upland	....	204	....	0.25	196	do	C,W	D,S	Water in gravel.
541	NW¼SW¼ sec. 30	....	....	Flat 25 ft. above cr.	....	123	4	2.0	121.7	do	C,W	N	
	T. 5 N., R. 14 E.												
120	NE¼NE¼ sec. 2	Joe Gribble	Old	Low hill on upland	....	199	6	0.65	196.95	10-20-37	C,W	S	Water in gravel?
545	NW¼NW¼NW¼ sec. 3	Lloyd Wilkers	Old	Upland flat	....	213	....	1.0	187	do	C,W	D,S	
546	SW¼NE¼ sec. 5	....	....	do	....	208	5	1.5	198	do	C,W	N	
547	SE¼SE¼ sec. 16	....	....	do	....	174	5	0.5	174?	do	C,W	N	
530	SE¼NE¼NE¼ sec. 26	....	....	Low hill on upland	....	183	....	1.0	178.5	do	C,W	N	
548	NW¼NW¼NW¼ sec. 28	....	....	Upland flat	....	188	....	0.5	180.98	do	C,W	N	
549	SW¼SW¼SE¼ sec. 30	....	....	Undulating upland	....	180	....	1.5	177.56	10- 8-37	C,W	N	
550[4]	SW¼NW¼NW¼ sec. 32	W. A. Albers	....	Upland flat	....	165	6	1.5	160±	do	C,W	D,S	Reported 173 ft. deep, water in gravel, 169-173 ft.
551	See sec. 19, T. 4 N., R. 13 E.												
552	See sec. 1, T. 3 N., R. 12 E.												
553	SW¼ sec. 36	....	....	Upland flat	....	300+	9	1.5	167.12	10- 8-37	None	N	Drilled to supply water for drilling of gas well.
	T. 5 N., R. 15 E.												
557	NW¼SE¼NE¼ sec. 7	Joe Sturdivan	Old	Upland flat	....	165	6	3.12	154.35	1-26-38	C,W	N	Water in gravelly clay.
558	SW¼SW¼NW¼ sec. 10	........Gibson	— —	do	3162	155	....	0.5	146.52	9-20-37	C,W	S	
559[4]	NE¼NE¼NE¼ sec. 15	J. F. Gibson	1906	do	....	160[5]	5	....	142[5]	------	C,W	D,S,P	Supplies school. Water in sand.
560	NE¼NE¼NW¼ sec. 16	C. E. Daly	1916	do	3167	164	6	....	153.2	9-21-37	C,W	D,S	Water in sand.
561	SW¼SW¼ sec. 21	Elmer Hier	Old	do	3142	139	5	0.8	131.66	9-20-37	C,W	D,S	Water in sand.
562	SW¼SW¼SE¼ sec. 30	G. H. Richardson	....	do	------	161	....	2.6	152.48	1-26-38	C,W	N	
563	NE¼NE¼NW¼ sec. 35	J. E. Johnston	Old	do	3120	137	....	0.5	133.8	9-11-37	C,W	D,S	Water in gravel.
	T. 5 N., R. 16 E.												
567	SW¼SW¼SE¼ sec. 3	....	....	Gentle slope	3097	154	....	3.5	146.32	12-16-37	C,W	N	
568	NE¼NE¼NE¼ sec. 5	F. A. Swinger	....	Upland flat	3128	164	4	0.6	141.37	12-15-37	C,W	D,S	
569	SW¼NW¼ sec. 6	....	....	Upland flat	3145	163	6	1.5	150.55	9-20-37	C,W	N	
570	SW¼SE¼SW¼ sec. 10	Helen E. Payne	Old	Low hill	3103	162	5	1.0	148.68	12-16-37	C,W	D,S	Water in gravel?
571	NE¼NE¼ sec. 13	Geo. Dycinger	....	Upland flat	3056	152	....	0.1	140.6	do	C,W	D,S	Water in gravel.
572	SE¼SE¼ sec. 18	Olga V. Holland	Old	do	3135	138	....	0.5	129.22	do	C,W	N	
573[4]	SE¼SE¼SE¼ sec. 20	J. C. Eaton	1905	Hill	3108	141	4	1.0	134.59	12-15-37	C,W	D,S	Water in coarse sand.
574	SE¼SE¼SW¼ sec. 25	Bertha Meisel	....	Upland flat	3044	154	....	0.5	146.18	12-14-37	C,W	N	
575	NW¼SW¼NW¼ sec. 26	....	——	do	3055	140	....	0.4	132.52	12-15-37	C,W	N	
576	SE¼SE¼SW¼ sec. 32	....	....	do	3041	122?	....	0.3	118.49	10-28-37	C,W	S	

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M. P. (feet)[1]	Water level: Below M. P. (feet)	Water level: Date Measured	Method of lift[2]	Use of water[3]	Remarks
					T. 5 N., R. 17 E.								
580	NE¼SE¼NE¼ sec. 1	Peter Balzer	......	Upland flat	2977	115	--	0.75	103.49	12-13-37	C,W	N	Water in gravel.
581	SE¼SE¼NE¼ sec. 5	......Shain	......	Undulating upland	......	138	....	5.2	135.31	12-24-37	C,W	D,S	Water in gravel.
582	NE¼NE¼ sec. 7	....	......	do	......	145	4.5	0.7	139.38	12-14-37	None	N	
583	SE¼NE¼ sec. 9	A. Buggard	Old	Upland flat	3013	139	5?	0.3	123.01	12- 7-37	C,W	D,S	Water in gravel?
584	SW¼SW¼SE¼ sec. 11	W. W. Tatlinger	Old	Hill	2994	153	6	0.4	123.27	do	C,W	D,S	Water in gravel.
585a	SE¼SE¼SW¼ sec. 17	B. F. Huebener	1906	Upland flat	3030	145?	5?	0.4	137.78	12-14-37	C,W	D,S	Water in sand?
586	SE¼SE¼NE¼ sec. 21	Glenn Teel	Old	Low hill	3010	147	6	0.6	130.9±	12-14-37	C,W	D,S	Water in coarse sand.
587	SW¼SW¼SW¼ sec. 24	Albert Jackson	Old	Upland flat	2967	133	....	1.2	110.1	12- 7-37	C,W	D,S	Water in gravel.
588	SW¼SE¼ sec. 26	J. J. Parham	Old	do	2969	129	—	1.0	118.62	12-16-37	C,W	D,S	Water in sand?
589	See sec. 34, T. 4 N., R. 17 E.												
590	NE¼NE¼NE¼ sec. 31	E. D. Blackwelder	......	Low hill	3023	145	....	0.75	143.13	12-14-37	C,W	D,S	
591	NE¼NE¼SE¼ sec. 32	A. Gieselman	......	Upland flat	3003	147	6	1.16	135.09	do	C,W	N	Water in gravel.
592	NW¼ sec. 34	City of Hooker	1931 & 1933	do	2984	260s	8	....	140s	......	A.E. 50 & 75	P	2 wells. Water in sand. 240-260 ft. 8-in. casing, lower 60 ft. perforated. Gravel wall 2-in. thick.
592a	do	do	1907 & 1917	do	do	200s	6	do	do	——	C,E,7.5	P	2 wells. Water in sand. 6-in. casing, lower 60 ft. perforated. Yield 60 gal. a min.
593	NW¼SE¼ sec. 36	....	......	Gentle slope	2925	110	—	0.5	107.89	12- 7-37	C,W	S	
					T. 5 N., R. 18 E.								
597	NE¼NE¼NW¼ sec. 2	....	......	Upland flat	2824	89	4	0.7	78.13	12- 8-37	C,W	N	
598	NE¼NE¼ sec. 4	....	------	Hill	2926	100	....	2.0	94.95	12-13-37	C,W	D,S	
509	NE¼NE¼NE¼ sec. 7	L. B. Lazenby	Old	Upland flat	2952	112	....	1.5	92.68	12-11-37	C,W	D,S	Water in gravel.
600	NE¼NE¼SE¼ sec. 11	W. R. Farmer	......	do	2895	91	....	4.75	82.44	do	C,W	N	Water in sand.
601	NW¼NW¼ sec. 16	Henry Lazwell	......	Gentle slope	2937	116	5	1.25	98.99	12-13-37	C,W	N	
602	NW¼NE¼NE¼ sec. 19	Carl M. and Anna Stanford	......	Low hill	2953	112	....	3.0	109.62	do	C,W	D,S	
603a	NE¼NE¼NE¼ sec. 22	J. M. Howell	Old	Upland flat	2912	104	4	0.7	85.4	12-11-37	C,W	D,S	
504	NW¼NW¼NW¼ sec. 33	J. W. Elmore	......	do	2907	93	......	0.3	78.21	do	C,W	N	
605a	SE¼SE¼SE¼ sec. 35	Phoenix School	......	do	2888	......	......	....	94s	......	C,H	P	
606	SW¼NW¼ sec. 36	Sally Wiggins	Old	Low hill	2902	115	5	0.6	100.95	12-11-37	C,W	N	
					T. 5 N., R. 19 E.								
609	NE¼NE¼ sec. 2	L. C. Ogletree	Old	Low hill	2889	141	......	0.25	128.38	12- 6-37	C,W	D,S	Water in gravel?
610	SE¼SW¼SW¼ sec. 4	J. F. Brookless	......	Gentle slope	2906	100	......	0.3	93.7	12- 8-37	C,W	N	Water in sand.
611	SE¼NE¼NE¼ sec. 7	J. A. McGary	Old	Low hill	2915	91	8	3.6	87.35	12- 8-37	C,W	D,S	Water in gravelly sand.
612	NE¼SE¼ sec. 9	W. L. Brookless	Old	Upland flat	2885	102	6	0.5	100.2±	12- 8-37	C,W	D,S	Water in fine gravel.
613a	NW¼NW¼ sec. 14	C. H. Morehouse	1904	do	2873	128	5?	1.8	112.93	12- 6-37	C,W	D,S	Irrig. peach trees, 1937.
614	NE¼SE¼ sec. 20	H. A. Landess	Old	Low hill	2873	113	6	1.0	102.83	do	C,W	D,S	Water in gravel and clay.
615	NE¼NW¼ sec. 24	C. E. Moorehouse Est.	1885	do	2846	133	5	0.5	109.48	do	C,W	D,S	Reported 200 ft. deep, water in gravel, 150-160 ft.
616	SE¼NE¼SE¼ sec. 26	G. P. Clark	1908	do	2818	131	6	3.0	113.63	do	C,W	S	Water in gravel.
617	N. cent. NE¼ sec. 27	T. F. Ogletree	......	Upland flat	2829	108	......	0.75	95.99	do	C,W	D,S	Water in gravel.
618	See sec. 11, T. 3 N., R. 10 E.												

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL: Height of M. P. (feet)[1]	WATER LEVEL: Below M. P. (feet)	WATER LEVEL: Date Measured	Method of lift[2]	Use of water[3]	Remarks
	T. 5 N., R. 19 E. (Cont'd)												
619	NE¼NE¼ sec. 31	....	....	Low hill	2857	121	....	1.0	102.71	do	C,W	N	
620	NW¼SW¼NW¼ sec. 34	A. Mendenhall	Old	Upland flat	2856	107	....	1.0	100.73	do	C,W	N	Water in gravel.
621	See sec. 2, T. 3 N., R. 10 E.												
626	See sec. 27, T. 4 N., R. 10 E.												
	T. 6 N., R. 10 E.												
627	NE¼NE¼ sec. 15	....	....	Low hill	....	209	5?	1.0	208.4	10-14-37	C,W	N	
628[4]	SE¼SE¼SW¼ sec. 31	D. R. Brown	1926	Upland flat	....	291	6?	1.2	257.5	10-13-37	C,W	D,S	Water in "rock".
629	NE¼SE¼NE¼ sec. 34	....	....	do	....	270	....	1.0	255±	10-19-37	C,W	N	
630	NE¼NE¼SE¼ sec. 36	Stella Carter	1917	do	....	259	5	1.5	249.8	do	C,W	D,S	Water in quicksand. Water rose 2.48 ft. in 15 min. after pumping stopped.
	T. 6 N., R. 11 E.												
635	NE¼NW¼ sec. 19	L. E. Besterfelt	Old	Hill	....	254	6	1.0	245.6	10-14-37	C,W	D,S	Feeble yield
636	NW¼SW¼NW¼ sec. 26	Mrs. I. M. Richterberg	1911	Upland flat	....	230[5]	6	0.6	206.8	11-11-37	C,W	D,S	Water in gravel?
637[4]	NE¼NE¼NE¼ sec. 30	Grace Schuss	....	do	3650	244?	....	1.1	237.87	do	C,W	D,S	Water in sand. Water rose 5.25 ft. in 1 hr. after pumping stopped.
638	SW¼NW¼NW¼ sec. 32	....	....	do	3657	258	4	0.75	253±	do	None	N	
	T. 6 N., R. 12 E.												
643	NW¼NW¼ sec. 15	E. S. Ingraham	1930	Upland flat	....	223	5	1.5	210.8	11-13-37	C,W	N	
644[4]	SE¼NE¼NE¼ sec. 21	C. L. Griffith	1907	do	....	233	5	0.3	223.3	do	C,W	D,S	Redrilled in 1915.
645	NW¼NW¼ sec. 23	Beryl Griffith	1929	do	....	268	6	....	233.47	do	C,W	D,S	Water in coarse gravel.
646	SE¼SE¼NE¼ sec. 30	....	....	Upland flat	....	209	....	0.5	197.07	11-13-37	C,W	N	
	T. 6 N., R. 13 E.												
651[4]	SE¼SE¼SE¼ sec. 22	C. E. Garret	....	Upland flat	....	230[5]	....	....	205[6]	....	C,W	D,S,P	Supplies Pleasant Plains School, Dist. 68.
652	SW¼SE¼SE¼ sec. 23	Wm. Finley	1914	Undulating upland	....	219	4	2.0	208.58	10-21-37	C,W	D	Water in sand and gravel, 220-232 ft.
653	NW¼NE¼ sec. 27	G. E. Reardon	1920	Upland flat	....	210	6	1.5	208±	do	C,W	D,S	Water in clay.
654	NW¼NW¼SW¼ sec. 29	........Rosler	....	do	....	248	....	1.5	226.46	do	C,W	N	Water in gravel.
	T. 6 N., R. 14 E.												
659	SW¼SW¼ sec. 12	....	....	Low hill	....	200?	4	....	191±	10-21-37	C,W	N	
660	NW¼SW¼ sec. 20	Dr. Ewing	....	do	....	235	....	0.5	225.05	10-20-37	C,W	N	Water in "rock."
661	See sec. 8, T. 3 N., R. 12 E.												
662[4]	SW¼SW¼SW¼ sec. 25	Joe Gribble	Old	do	....	215?	4	....	210±	10-21-37	C,W	D,S	Water in gravel?
	T. 6 N., R. 15 E.												
667	NE¼NE¼NW¼ sec. 14	I. V. Blankenship	Old	Upland flat	3165	162	5	1.3	134	9-22-37	C,W	D,S	Water in gravel.
369	NE¼NE¼ sec. 15	....	....	Low hill	....	163	....	....	156.1	do	C,W	N	
668	SW¼SW¼NW¼ sec. 23	C. E. Simmons	1917	Upland flat	3184	164	6	....	156.39	do	C,W	D,S	Reported 194 ft. deep, water in sand and gravel 184-210 ft.
669	SE¼SW¼SE¼ sec. 25	Emery Decker	....	Undulating upland	....	179	....	0.4	162.45	9-21-37	C,W	N	

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	Water level: Height of M. P. (feet)[1]	Water level: Below M. P. (feet)	Water level: Date Measured	Method of lift[2]	Use of water[3]	Remarks
					T. 6 N., R. 15 E. (Cont'd)								
670	SE¼SE¼SW¼ sec. 26	Grace Isham	Old	Upland flat	....	185	5	—	162.9	do	C,W	D,S	
354	SE¼SE¼SW¼ sec. 27	A. M. Fankhauser	Old	do	3175	166	5?	1.0	149.01	do	C,W	S	
671a	NE¼NE¼NE¼ sec. 29	Block School Dist. 97	....	do	....	170	....	....	163.5±	1-26-38	C,W	P	Water in gravel. 162-170 ft.
672	N. cent. NE¼ sec. 35	J. A. Kennedy	Old	Undulating upland	3175	182	5	1.0	163	9-20-37	C,W	D,S	
					T. 6 N., R. 16 E.								
677	NW¼NE¼NE¼ sec. 14	B. F. Hollenback	....	Dunes	....	142	5?	1.7	129.66	12-24-37	C,W	N	Water in red shale?
678	SE¼SE¼ sec. 18	J. H. Cope	Old	Upland flat	3157	150	....	0.7	139.46	12-15-37	C,W	D,S	Water in gravel.
842	NW¼NE¼ sec. 22	C. A. Rahm	....	Hill in dunes	3118	143	4.5	1.7	123.8	do	C,W	N	Water in gravel.
679	E. cent. SE¼ sec. 25	J. W. Morgan	Old	Upland flat	3082	151	....	1.0	142.27	12-14-37	C,W	D,S	Water in sand.
680a	NE¼NE¼NE¼ sec. 29	Dague School	Old	do	3147	171	....	0.8	141.2	12-15-37	C,W	P	Water in gravel.
681	NW¼NE¼NW¼ sec. 30	A. W. Sledge	....	Undulating upland	3157	165	....	1.5	143.97	9-21-37	C,W	N	Wator in gravel.
682	NW¼SW¼SW¼ sec. 35	B. H. Schockley	1918	Upland flat	3100	162	5	0.5	145.83	12-15-37	C,W	D,S	
					T. 6 N., R. 17 E.								
686	NW¼NE¼NW¼ sec. 15	Butler Hadley	———	Upland flat	3023	131	....	2.4	118.12	12-14-37	C,W	N	Water in gravel.
687	SW¼SW¼NW¼ sec. 17	Eva Daniels	Old	do	3070	158	....	....	132.94	12-14-37	C,W	D,S	Water in gravel.
688	SW¼NW¼SW¼ sec. 22	Mrs. Guard	....	Dunes	———	123	....	1.0	111.77	do	C,W	N	
689	NW¼SW¼ sec. 23	Wm. Adams	....	Hill	3018	145	....	0.4	123.34	12-13-37	C,W	N	Water in gravel.
					T. 6 N., R. 17 E. (Cont'd)								
690	NW¼SW¼ sec. 24	L. M. Shives	1927	Dunes	2999	122	6	2.5	111.8	do	C,W	S	Water in sand.
691	SW¼SE¼SW¼ sec. 28	F. M. Olney	———	do	3045	148	5	1.0	136.25	12-14-37	C,W	N	Water in gravel.
692a	NE¼NE¼NE¼ sec. 30	Lemon School	———	Upland flat	....	165	....	....	145a	....	C,W	P	Water in gravel.
693	SW¼SE¼SW¼ sec. 31	Lorenz Muller	1906	do	3065	172	5	4.4	147±	12-14-37	C,W	D,S	Water in gravel and sand, 151-159 ft.
694	SE¼SE¼SW¼ sec. 35	Alfred Buzzard	....	Dunes	2998	131	....	0.7	122.72	12-13-37	C,W	N	Water in gravel.
					T. 6 N., R. 18 E.								
698	SW¼SE¼SE¼ sec. 11	Mrs. Hassie Bruce	Old	Hill	2960	116	....	0.3	110.35	12- 8-37	C,W	D,S	Water in gravel.
699	SW¼SE¼SE¼ sec. 17	Mary Weller	Old	Upland flat	2988	109?	....	1.25	107.54	12-11-37	C,W	D,S	Water in gravel. Feeble
700	NW¼NW¼ sec. 18	....	....	Undulating upland	2983	124	5	1.0	103.98	12-13-37	C,W	N	
701a	SE¼SE¼SW¼ sec. 20	Buena Vista School	....	Hill	2981	133	....	1.3	114.55	12-23-37	C,W	P	Water in gravel. Water temp. 60.5° F.
702a	SE¼SE¼SW¼ sec. 22	Albert Goos	Old	do	2973	135a	4	0.6	122±	12-11-37	C,W	D,S	Water in sand?
703	SE¼SE¼SE¼ sec. 23	Insurance Co.	Old	do	2930	120	....	−3.4	92.5	12- 8-37	C,W	D,S	Water in gravel.
704	SE¼SE¼SE¼ sec. 29	....	....	Upland flat	2958	109	....	3.0	100.35	12-23-37	C,W	N	
705	SE¼SE¼NE¼ sec. 30	C. F. Stevens	1902	Hill	2980	118	....	1.0	108.93	12-11-37	C,W	D,S	Water in gravel?
706a	SE¼NW¼SW¼ sec. 25	Town of Tyrone	1923	Upland flat	2926	285a	14	1.0	102	7-26-38	C,E,10	P	2 similar wells. Water in 5 beds of gravel. Yield reported as 65 gal. a min. Measured W. well while E. well was pumping.
					T. 6 N., R. 19 E.								
709	SW¼SE¼ sec. 10	....	....	Hill	....	104	4.75	0.3	95.92	12- 6-37	C,W	N	
710	W. cent. NW¼ sec. 14	H. M. Hadsell	Old	Upland flat	2885	101	5?	0.75	97.06	do	C,W	D,S	Water in sand?
711	SW¼SW¼ sec. 15	T. R. King	Old	do	2889	108	5?	0.1	98.34	do	C,W	D,S	Water in sand?

Well No.	Location	Owner or name	Date completed	Topographic situation	Altitude (feet)	Depth (feet)	Diameter (inches)	WATER LEVEL: Height of M. P. (feet)[1]	WATER LEVEL: Below M. P. (feet)	WATER LEVEL: Date Measured	Method of lift[2]	Use of water[3]	Remarks
					T. 6 N., R. 19 E. (Cont'd)								
712	NW¼SW¼ sec. 20	W. C. Farmer	1916	Upland flat	2915	107	4	3.25	100.2±	12- 8-37	C,W	D,S	Water in gravel.
713	NW¼NW¼SW¼ sec. 21	R. C. Matkin	....	do	2877	135	......	0.5	110.28	12-30-37	C,W	D,S	Water in gravel.
714	NE¼NE¼SE¼ sec. 30	....	....	Slope	2912	131	......	4.3	92.1	12- 8-37	C,W	N	
715[4]	NE¼NE¼NW¼ sec. 33	C. E. Butcher	....	Low hill	2916	114	5?	1.0	103.21	12- 6-37	C,W	D,S	Water in sand.
716	SW¼SE¼SE¼ sec. 34	F. L. Fraim	....	do	2893	121	......	0.8	106.42	12-31-37	C,W	D,S	Water in gravel and clay.
761	See sec. 7, T. 3 N., R. 19 E.												
765	See sec. 26, T. 3 N., R. 19 E.												
770	See sec. 15, T. 3 N., R. 19 E.												
795	See sec. 30, T. 4 N., R. 18 E.												
842	See sec. 22, T. 6 N., R. 16 E.												

1 Height of Measuring Point (M. P.) above ground. Usually top of casing, water pipe clamp, coupling, or tee discharge pipe.
2 Pumps: C, cylinder; T, turbine; Cent., centrifugal. Power: W, windmill; H, hand; G, natural gas engine; Gs, gasoline engine; K, kerosene engine. E, electric motor. Number indicates horse power.
3 Use: D, domestic; S, stock; I, irrigation (number indicates acres); Ind., Industrial; P, public; RR, railroad; N, not used.
4 For analysis of water, see table on pp.......
5 Reported.
6 Estimate based on measurements of nearby wells.

APPENDIX A

Bench Mark Elevations in Texas County, Oklahoma, from first and second order leveling by the United States Coast and Geodetic Survey. Figure 13 indicates the locations of the lines of leveling in Texas County and the number of each line. Bench marks recovered are shown on Plate I.

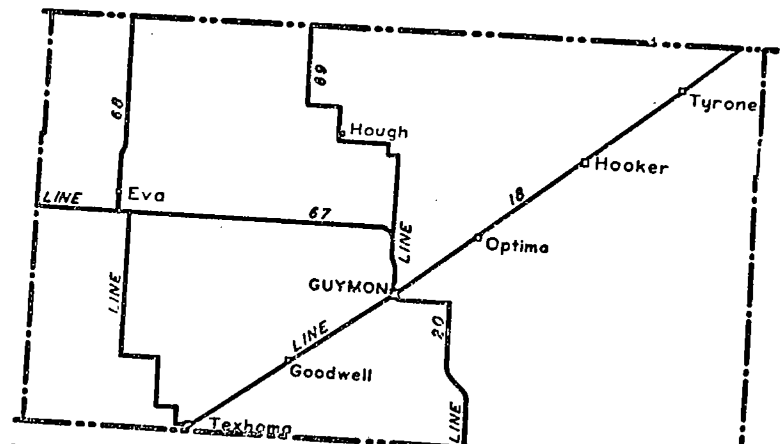


FIGURE 13. Index map of U. S. Coast and Geodetic Survey level lines in Texas County, Oklahoma.

First Order Leveling. Line No. 18—Dalhart, Texas, to Liberal, Kansas. Oklahoma Section, along CRI&P RR., Texhoma to Kansas-Oklahoma Boundary.

(Adjusted Elevations)

A 14 1933: At Texhoma, at Fourth and Elm Streets, at the S. side of high school, in brick wall E. of E. entrance, and 4 ft. above ground. Std. disk, set vertically. (Intersection with line No. 68). El. 1,063.384 meters 3,488.786 feet.

Texhoma, top of W. rail of the CRI&P RR. at the Main Street crossing. El. 3,490.2 feet.

B-14 1933: At Texhoma, on the CRI&P RR., about 18½ poles SW of milepost No. 494, in top of E. concrete block foundation of city water tank, and 51 ft. NW of C/L of track. Std. disk. (Intersection with line No. 68). El. 1,062.805 meters 3,486.886 feet.

Top of W. rail opposite CRI&P RR. milepost 494. El. 3,485.5 feet.

*C-14 1933: SW¼ NE¼ sec. 33, T1N, R12E, about 0.8 mi. NE along the CRI&P RR., from the station at Texhoma. About 23 poles SW of milepost 493,

* Shown on Plate I.

about 163 yards SE of C/L of track, at a 12-inch box culvert under Hwy. No. 54, and in the top of the NE end of the NW head wall. Std. disk. El. 1,059.868 meters
3,477.250 feet.

Top of W. rail opposite CRI&P RR. milepost 493. El. 3,476.3 feet.

Top of W. rail opposite CRI&P RR. milepost 492. El. 3,458.1 feet.

**D-14 1933*: SW¼ NW¼ sec. 26, T1N, R12E, about 2.6 mi. NE along the CRI&P RR. from the station at Texhoma, about 30 poles SW of milepost 491, about 3 poles NE of a road crossing, about 135 ft. SE of C/L of track, at a box culvert under Hwy. No. 54, and in the NE end of the NW concrete head wall. Std. disk. El. 1,032.421 meters
3,452.818 feet.

Top of W. rail opposite CRI&P RR. milepost 491. El. 3,427.1 feet.

Top of W. rail opposite CRI&P RR. milepost 490. El. 3,384.5 feet.

E-14 1933: About 4.6 mi. NE along the CRI&P RR. from the station at Texhoma, about 27 poles SW of milepost 489, and at the SE side of the SW end of steel bridge 489 8, in the top of the concrete abutment. Std. disk. El. 1,027.873 meters
3,372.280 feet.

RV-2. About 4.6 mi. NE along the CRI&P RR. from the station at Texhoma, and in the top of the N. end of the E. concrete abutment of bridge 489 8 over Frisco Creek. Std. Monel-metal rivet. El. 1,027.489 meters
3,371.020 feet.

F-14 1933: About 5.2 mi. NE along the CRI&P RR. from the station at Texhoma, about 2½ poles SW of milepost 489, 25 feet SE of C/L of track, and in the top of the SW end of the SE head wall of a concrete box culvert. Std. disk. El. 1,020.506 meters
3,348.110 feet.

Top of W. rail opposite CRI&P RR. milepost 489. El. 3,357.9 feet.

Top of W. rail opposite CRI&P RR. milepost 488. El. 3,359.1 feet.

**G-14 1933*: SW¼ NW¼ sec. 9, T1N, R13E, about 7.3 mi. NE along the CRI&P RR. from the station at Texhoma, about 2 poles NE of milepost 487, about 2 poles NE of a road crossing, opposite wooden culvert 486 9, about 135 ft. SE of C/L of track, at a box culvert under Hwy. No. 54, and in the top of the NE end of the NW concrete head wall. Std. disk. El. 1,016.018 meters
3,333.386 feet.

Top of W. rail opposite CRI&P RR. milepost 486. El. 3,324.9 feet.

H-14 1933: About 0.9 mi. SW along the CRI&P RR. from the station at Goodwell, about 2 poles SW of milepost 485, 48 ft. SE of C/L of track, 50 ft. SW of a right-of-way fence corner, opposite a pole, and 2 ft. NW of the right-of-way fence. Std. disk, set in top of a concrete post. El. 1,005.729 meters
3,299.629 feet.

Top of W. rail opposite CRI&P RR. milepost 485. El. 3,301.5 feet.

J-14 1933: At Goodwell, at the Panhandle A. and M. College, at the S. side of the S. entrance to Hughes-Strong Hall, and in the front brick wall, about 4 ft. higher than the street. Std. disk, set vertically. El. 1,007.794 meters
3,306.404 feet.

K-14 1933: At Goodwell, at the front entrance to the M. E. Church South, and in the top of the NW end of the second concrete step from the bottom. Std. disk. El. 1,005.512 meters
3,298.917 feet.

L-14 1933: At Goodwell, about 2½ poles SW of the CRI&P RR. station, about 7½ poles SW of milepost 484, 54 ft. SE of C/L of track, and in the top of the N. corner of the concrete foundation of a railroad oil pump. Std. disk. El. 1,003.610 meters
3,292.677 feet.

* Shown on Plate I.

Goodwell, top of W. rail of the CRI&P RR. at the Main Street crossing. El. 3,291.6 feet.

Top of W. rail opposite CRI&P RR. milepost 484. El. 3,289.4 feet.

Top of W. rail opposite CRI&P RR. milepost 483. El. 3,268.3 feet.

M-14 1933: About 1.6 mi. NE along the CRI&P RR. from the station at Goodwell, about 18 poles SW of milepost 482, about 145 ft. SE of C/L of track, at a 36-ft. concrete highway bridge, and in the top of the SW end of the NW head wall. Std. disk. El. 992.440 meters
3,256.030 feet.

Top of W. rail opposite CRI&P RR. milepost 482. El. 3,265.6 feet.

Top of W. rail opposite CRI&P RR. milepost 481. El. 3,236.7 feet.

N-14 1933: About 3.7 mi. NE along the CRI&P RR. from the station at Goodwell, about 16½ poles SW of milepost 480, about 150 ft. SE of C/L of track, at a 20-ft. concrete culvert under Hwy. No. 54, and in the top of the NE end of the NW head wall. Std. disk. El. 984.594 meters
3,230.289 feet.

Top of W. rail opposite CRI&P RR. milepost 480. El. 3,225.5 feet.

P-14 1933: About 5.6 mi. SW along the CRI&P RR. from the station at Guymon, about 8 poles SW of milepost 479, opposite a station sign, 45 ft. SE of C/L of the main track, and 2 ft. NW. of the right-of-way fence. Std. disk, set in the top of concrete post. El. 978.751 meters
3,211.119 feet.

Top of W. rail opposite CRI&P RR. milepost 479. El. 3,205.9 feet.

Q-14 1933: About 4.6 mi. SW along the CRI&P RR. from the station at Guymon, about 7 poles SW of milepost 478, 90 ft. SE of C/L of track, and in the top of the NE end of the NW head wall of an 8-ft. concrete box culvert. Std. disk. El. 969.303 meters
3,180.122 feet.

Top of W. rail opposite CRI&P RR. milepost 478. El. 3,175.2 feet.

R-14 1933: About 3.5 mi. SW along the CRI&P RR. from the station at Guymon, about 3 poles SW of milepost 477, at a road crossing, 54 ft. SE of C/L of track, 18 ft. NE of C/L of the side road, at a 6-ft. box culvert under a road, and in the top of the NW end of the NE concrete head wall. Std. disk. El. 961.282 meters
3,153.806 feet.

Top of W. rail opposite CRI&P RR. milepost 477. El. 3,156.4 feet.

*Top of W. rail opposite CRI&P RR. milepost 476. Near intersection of E-W sec. line and U. S. Hwy. No. 54, near SE cor. sec. 2, T2N, R14E. El. 3,137.7 feet.

S-14 1933: SW¼ sec. 1, T2N, R14E, about 2.2 mi. SW along the CRI&P RR. from the station at Guymon, about 27 poles SW of milepost 475, about 7 poles NE of a road crossing, 90 ft. SE of C/L of track, at an 18-inch concrete box culvert under Hwy. No. 54, and in the top of the NE end of the NW head wall. Std. disk. El. 953.062 meters
3,126.838 feet.

Top of W. rail opposite CRI&P RR. milepost 475. El. 3,123.0 feet.

T-14 1933: At Guymon, at the SW side of the front entrance to the high school, and in a sandstone column, 4 ft. above the ground. Std. disk, set vertically. (Intersection with Line No. 69.) El. 954.037 meters
3,130.036 feet.

**U-14 1933*: At Guymon, at the SE cor. of Main and Fourth Streets, at the E. side of the N. entrance of the county courthouse, and in a concrete block of the brick wall, 3 ft. above ground. Std. disk, set vertically. (Intersection with Line No. 69). El. 952.761 meters
3,125.850 feet.

* Shown on Plate I.

V-14 1933: At Guymon, at the Fourth Street crossing of the CRI&P RR. about 240 ft. S. of C/L of track, at the city water tank, at Fourth and Sullivan Streets, and in the top of the N. concrete block foundation. Std., disk. El. 951.393 meters
3,121.362 feet.

Top of W. rail opposite CRI&P RR. milepost 473. El. 3,112.0 feet.

Guymon, top of W. rail of the CRI&P RR. at C/L of a road crossing the track 29½ poles south of milepost 472. El. 3,105.3 feet.

Top of W. rail opposite CRI&P RR. milepost 472. El. 3,079.6 feet.

**W-14 1933*: SW¼ NW¼ sec. 28, T3N, R15E, about 1.7 mi. NE along the CRI&P RR. from the station at Guymon, about 33 poles SW of milepost 471, at a road crossing, about 105 ft. SE of C/L of track, at a concrete culvert under a road, and in the top of the SE end of the NE head wall. Std. disk. El. 939.065 meters
3,080.916 feet.

Top of W. rail opposite CRI&P RR. milepost 471. El. 3,041.4 feet.

**X-14 1933*: NW¼ SW¼ sec. 22, T3N, R15E, 0.1 mi. NE along US Hwys. Nos. 54-64, from point where hwys. cross N-S line between secs. 21 and 22. About 3.1 mi. NE along CRI&P RR. from the station at Guymon, about 20 poles SW of milepost 470, about 3 poles NE of a road crossing, 85 ft. SE of C/L of track, at a concrete box culvert under hwy., and in the top of the NE end of the NW headwall. Std. disk. El. 921.006 meters
3,021.667 feet.

Top of W. rail opposite CRI&P RR. milepost 470. El. 2,999.8 feet.

Top of W. rail opposite CRI&P RR. milepost 469. El. 2,957.5 feet.

Y-14 1933: About 4.9 mi. NE along the CRI&P RR. from the station at Guymon, about 28½ poles SW of milepost 468, and in the top of the SW end of the SE side of the concrete head wall of a bridge under track. Std. disk.
El. 898.213 meters
2,946.887 feet.

Top of W. rail opposite CRI&P RR. milepost 468. El. 2.999.8 feet.

RV 3: About 5.7 miles NE along CRI&P RR. from the station at Guymon, and in the top of the N. end of the E. abutment of bridge 4679. Std. Monel-metal rivet. El. 890.911 meters
2,922.930 feet.

**Z-14 1933*: NE¼ SE¼ sec. 12. T3N, R15E, about 2.2 mi. SW along CRI&P RR. from the station at Optima, about 4½ poles SW of milepost 467, at a concrete railroad bridge for overpass a side road running W. from US Hwys. Nos. 54-64, about 0.7 mi. NE of the NE end of a concrete hwy. bridge over Beaver (North Canadian) River. In the top of the SW end of the SE headwall. Std. disk.
El. 893.831 meters
2,932.511 feet.

Top of W. rail opposite CRI&P RR. milepost 466. El. 2,985.2 feet.

**A-15 1933*: NE¼ NW¼ sec. 5, T3N, R16E, at Optima, about 6 poles SW of the CRI&P RR. station, at milepost 465, at a road crossing, 45 ft. NW of C/L of track, and 9 ft. NE of a pole. Std. disk, set in the top of a concrete post.
El. 920.929 meters
3,021.415 feet.

Optima, top of W. rail opposite the CRI&P RR. station. El. 3,022.0 feet.

Top of W. rail opposite CRI&P RR. milepost 464. El. 3,011.9 feet.

**B-15 1933*: SW¼ SW¼ sec. 27, T4N, R16E, about 1.8 mi. NE along the CRI&P RR. from the station at Optima, about 2 poles SW of milepost 463, at bridge 4631 over Pony Creek, and in the top of the SE side of the SW concrete abutment, 7 ft. SE of C/L of track. Std. disk. El. 905.673 meters
2,971.362 feet.

* Shown on Plate I.

**RV-4 (CRI&P RR.)*: About 1.8 mi. NE along the CRI&P RR. from the station at Optima, in the top of the N. end of the E. concrete abutment of bridge 4631. Std. Monel-metal rivet.
El. 905.640 meters
2,971.254 feet.

Top of W. rail opposite CRI&P RR. milepost 463. El. 2,973.1 feet.

**C-15 1933*: NE¼ sec. 27, T4N, R16E, about 2.9 mi. NE along the CRI&P RR. from the station at Optima, about 1 pole NE of milepost 462, about 6 poles SW of a road crossing, and in the top of the SW end of the SE head wall of a 20-foot concrete bridge. Std. disk, stamped "C 14 1933", by mistake.
El. 908.393 meters
2,980.286 feet.

Top of W. rail opposite CRI&P RR. milepost 461. El. 3,008.9 feet.

**D-15 1933*: SE¼ SW¼ sec. 13, T4N, R16E, about 4.9 mi. NE along the CRI&P RR. from the station at Optima, at milepost 460, about 6 poles NE of a road crossing, 90 ft. SE of C/L of track, at a 6-ft. concrete box culvert under U. S. Hwy. Nos. 54-64, and in the top of the NE end of the NW head wall. Std. disk.
El. 914.663 meters
3,000.857 feet.

Top of W. rail opposite CRI&P RR. milepost 459. El. 3.003.8 feet.

Top of W. rail opposite CRI&P RR. milepost 458. El. 3,012.3 feet.

E-15 1933: SE¼ sec. 7, T4N, R17E, about 3.5 mi. SW along the CRI&P RR. from the station at Hooker, about 32 poles SW of milepost 457, 48 ft. NW of C/L of track, 30 ft. NE of C/L of a crossroad, and 3 ft. NW of a pole. Std. disk, set in the top of a concrete post.
El. 916.835 meters
3,007.983 feet.

Top of W. rail opposite CRI&P RR. milepost 457. El. 2,994.5 feet.

F-15 1933: About 1.8 mi. SW along the CRI&P RR. from the station at Hooker, about 5 poles SW of milepost 456, about 1 pole SW of a yard limit sign, 80 ft. SE of C/L of track, at a concrete box culvert under Hwy. Nos. 54-64, and in the top of the NE end of the NW head wall. Std. disk.
El. 911.541 meters
2,990.614 feet.

Top of W. rail opposite CRI&P RR. milepost 456. El. 2,994.1 feet.

Top of W. rail opposite CRI&P RR. milepost 455. El. 2,988.6 feet.

G-15 1933: At Hooker, on the CRI&P RR. about 20½ poles SW of milepost 454, at the city water tank, and in the top of the S. concrete block foundation. Std. disk.
El. 909.639 meters
2,984.374 feet.

**HOOKER 1933*: At Hooker, at Main Street and Broadway, and 10 ft. SE of the SW side of the front entrance to the First National Bank, between the curb and the sidewalk. Std. disk, stamped "HOOKER 1933" and set in the top of a concrete post.
El. 909.644 meters.
2,984.390 feet.

H-15 1933: At Hooker, at the NW end of Broadway, at the S. corner of the high school, in the concrete block foundation of the SW wall, and 3.5 ft. above the ground. Std. disk, set vertically.
El. 912.845 meters
2,994.892 feet.

About 1.5 mi. NE of Hooker, top of W. rail of the CRI&P RR. at C/L of a road crossing the track.
El. 2,979.0 feet.

About 2 mi. NE of Hooker, about 13½ poles SW of milepost 452, top of W. rail of the CRI&P RR. at C/L of a road crossing the track. El. 2,973.8 feet.

J-15 1933: About 2.2 mi. NE along the CRI&P RR. from the station at Hooker, about 5 poles SW of milepost 452, at a road crossing, 45 ft. NW of C/L of track, 8 ft. SE of a fence corner, and 2 ft. NW of a pole. Std. disk, set in the top of a concrete post.
El. 904.198 meters
2,966.523 feet.

* Shown on Plate I.

**K-15 1933*: About 3.7 mi. NE along U. S. Hwy. No. 54 from junction with U. S. Hwy. No. 64 at Hooker. About 4.1 mi. NE along the CRI&P RR. from the station at Hooker, about 8 poles SW of milepost 450, 90 ft. SE of C/L of track, at a 6-ft. concrete box culvert under Hwy. No. 54, and in the top of the NE end of the NW head wall. Std. disk. El. 900.647 meters
2,954.873 feet.

Top of W. rail opposite CRI&P RR. milepost 449. El. 2,949.5 feet.

L-15 1933: About 6.1 mi. NE along the CRI&P RR. from the station at Hooker, about 8 poles SW of milepost 448, at a road crossing, 60 ft. SW of C/L of the road, 45 ft. NW of C/L of track, and 18 ft. W. of a pole. Std. disk, set in the top of a concrete post. El. 895.732 meters
2,938.747 feet.

Top of W. rail opposite CRI&P RR. milepost 448. El. 2,939.0 feet.

**M-15 1933*: About 6.7 mi. NE along U. S. Hwy. No. 54 from junction with U. S. No. 64 at Hooker. About 3.2 mi. SW along the CRI&P RR. from the station at Tyrone, about 6 poles SW of milepost 447, 90 ft. SE of C/L of track, at a 2-ft. concrete culvert under Hwy. No. 54, and in the top of the NE end of the NW head wall. Std. disk. El. 892.685 meters
2,928.751 feet.

Top of W. rail opposite CRI&P RR. milepost 447. El. 2,928.5 feet.

Top of W. rail opposite CRI&P RR. milepost 446. El. 2,922.9 feet.

**N-15 1933*: SW¼ sec. 35, T6N, R18E, about 8.35 mi. NE along U. S. Hwy. No. 54 from junction with U. S. Hwy. No. 64 at Hooker, about 0.1 mi. NE along hwy. from intersection with N-S section line road. About 1.5 mi. SW along CRI&P RR. from the station at Tyrone, about 17 poles SW of milepost 445, 90 ft. SE of C/L of track, at a concrete box culvert under hwy., and in the top of the NE end of the NW head wall. Std. disk. El. 890.208 meters
2,920.624 feet.

Top of W. rail opposite CRI&P RR. milepost 445. El. 2,920.9 feet.

TYRONE 1933: At Tyrone, on the CRI&P RR., about 5 poles SW of milepost 444, about 120 ft. NW of C/L of the main track, at the War Memorial, and in the center of the top of the NE side of the concrete foundation. Std. disk, stamped "TYRONE 1933." El. 892.070 meters
2,926.733 feet.

Tyrone, top of W. rail opposite the CRI&P RR. station. El. 2,925.9 feet.

P-15 1933: At Tyrone, on the CRI&P RR., opposite milepost 444, about 310 ft. S. of C/L of main track, and in the top of the N. concrete block foundation of the city water tank. Std. disk. El. 890.348 meters
2,921.083 feet.

Q-15 1933: At Tyrone, at Sixth and Beatrice Streets, in the S. brick wall of the grammar school, 2 ft. from the SE corner, and 3.5 ft. above the ground. Std. disk, set vertically. El. 895.280 meters
2,937.264 feet.

Top of west rail opposite CRI&P RR. milepost 443. El. 2,920.4 feet.

**R-15 1933*: NE¼ sec. 19, T6N, R19E, about 2.0 mi. NE along the CRI&P RR. from the station at Tyrone. About 0.28 mi. SW along U. S. Hwy. No. 54, from the line between secs. 19 and 20. About 1 pole SW along RR. from milepost 442, 90 ft. SE of C/L of track, at a concrete culvert under Hwy. No. 54, and in the top of the NE end of the NW headwall. Std. disk. El. 887.812 meters
2,912.763 feet.

**S-15 1933*: SW¼ NW¼ sec. 16, T6N, R19E, about 3.7 mi. NE along the CRI&P RR. from the station at Tyrone. About 0.2 mi. NE along U. S. Hwy. No. 54 from the line between secs. 16 & 17. About 12 poles SW along RR. from milepost 440, 90 ft. SE of C/L of track, at a concrete box culvert under Hwy. No. 54, and in the top of the NE end of the NW headwall. Std. disk. El. 884.414 meters
2,901.615 feet.

* Shown on Plate I.

Top of W. rail opposite CRI&P RR. milepost 440. El. 2,901.1 feet.

OKLAHOMA-KANSAS BOUNDARY.

A-21 1933: At Oklahoma-Kansas State Line. About 4.9 mi. SW along the CRI&P RR. from the station at Liberal, Seward County, Kansas, about 5 poles SW of milepost 439, 45 ft. SE of C/L of track, and 2 ft. NW of the right-of-way fence. Std. disk, set in the top of a concrete post. El. 879.648 meters
2,885.978 feet.

Second Order Leveling. Line No. 20

Stinnett, Texas, to Guymon, Oklahoma

Oklahoma Portion—along road from Hitchland, Texas, to Guymon, Oklahoma
(Unadjusted Field Elevations)

A-103 1934: At Hitchland, Hansford County, Tex., 445 ft. W. of Big Jo Lumber Co. yard; 35 ft. N. of C/L of Okla.-Texas State Line road; 3 ft. E. of fence cor.; Std. disk set in concrete post. El. 938.6029 meters
3,079.400 feet.

**B-103 1934*: 2.8 mi. W. of Hitchland; 0.1 mi. E. of approximate SW cor. sec. 32, T1N, R16E; opposite "T" road intersection, where Texas Hwy. No. 88 joins State Line road; 90 ft. E. of point where Texas Hwy. No. 88 turns S. at sec. line correction corner; 30 ft. N. of C/L of State Line road; Std. disk set in concrete post. El. 948.7135 meters
3,112.571 feet.

**C-103 1934*: 4.9 mi. NW of Hitchland; near SW cor. sec. 20, T1N, R16E; 40 ft. E. of C/L of road from Hitchland to Guymon; 75 ft. N. of C/L sec. line road to E.; 30 ft. SE of D. D. Delay's mail box. Std. disk set in concrete post. El. 944.9868 meters
3,100.344 feet.

**D-103 1934*: 6.9 mi. NW of Hitchland; near SE cor. sec. 7, T1N, R16E, on east side hwy.; 78 ft. N. of C/L of hwy.; 63 ft. W. of gate in fence; at outside curve; Std. disk set in concrete post. El. 904.3487 meters
2,967.017 feet.

**E-103 1934*: 8.9 mi. NW of Hitchland; near SE cor. sec. 1, T1N, R15E; 30 ft. NE of C/L, at NW end and outside of curve where abandoned road and telephone line turn NW; 0.3 mi. N. of point where same road crossed Coldwater Creek; 500 ft. W. of present road; 300 ft. N. of S. line sec. 1: Std. disk set in concrete post. El. 881.9700 meters
2,893.597 feet.

**F-103 1934*: 9.7 mi. SE of Guymon; near SE cor. sec. 26, T2N, R15E; 35 ft. W. of C/L of hwy.; 33 ft. N. of C/L sec. line road; at SE fence cor. and E. of gate; Std. disk set in concrete post. El. 935.3649 meters
3,068.776 feet.

**G-103 1934*: 7.7 mi. SE of Guymon; near SW cor. sec. 13, T2N, R15E; 39 ft. E. of C/L hwy.; 33 ft. N. of C/L sec. line road; 42 ft. NW of W. M. Ewalt's mail box; Std. disk set in concrete post. El. 933.6039 meters
3,062.999 feet.

**H-103 1934*: 5.7 mi. SE of Guymon; near NW cor. sec. 12, T2N, R15E; 42 ft. E. of C/L hwy.; 29 ft. S. of C/L sec. line road; Std. disk set in concrete post. El. 933.5049 meters
3,062.674 feet.

**J-103 1934*: 3.7 mi. SE of Guymon; near NW cor. sec. 2, T2N, R15E; 45

* Shown on Plate I.

ft. S. of C/L Okla. Hwy. No. 35; 65 ft. W. of H. C. Janson's house; Std. disk set in N. end of E. headwall of concrete culvert, over hwy. grade ditch.
El. 934.0599 meters
3,064.495 feet.

**K-103 1934*: 1.7 mi. SE of Guymon; near NE cor. sec. 5, T2N, R15E; 30 ft. W. of C/L sec. line road; in E. end of S. headwall of concrete culvert on Okla. Hwy. No. 35; Std. disk. El. 946.3616 meters
3,104.855 feet.

Second Order Leveling. Line No. 67

Guymon, Oklahoma to Clayton, New Mexico

Texas County Portion—along U. S. Highway No. 64 from Guymon to Cimarron County line.

(Unadjusted Field Elevations)

X-75 1935: 4.6 mi. N. of C. H. at Guymon, along U. S. Hwy. No. 64 and road to Pony Creek; near SW cor. sec. 6, T3N, R15E, at point where Hwy. 64 turns NW. 52 ft. E. of C/L of N-S road, about 20 ft. N. of fence, and 2 ft. E. of fence post. Std. disk set in concrete post. (Intersection with Line No. 69)
El. 918.2548 meters
3,012.641 feet.

**E-72 1935*: 4.9 mi. N. of Guymon, along Hwy. No. 64; about 200 ft. NW of hwy. curve sign; 2 ft. NW of gate to Cimarron Utilities Co. No. 1 Gas Well, and 48 ft. SW of C/L of hwy. Std. disk set in concrete post. El. 924.7981 meters
3,034.108 feet.

**F-74 1935*: 6.1 mi. NW of Guymon, near NW cor. sec. 1, T3N, R14E, along Hwy. No. 64; on a curve in the hwy.; on the S. curb of a concrete box culvert, at the E. end of culvert and 19 ft. S. of C/L of hwy. Std. disk set in concrete box culvert. El. 945.0899 meters
3,100.682 feet.

**F-72 1935*: 7.0 mi. NW of Guymon, along Hwy. No. 64; in the N. curb of a concrete box culvert; at the W. end of culvert, 200 ft. E. of fence corner and 21 ft. N. of C/L of hwy. Std. disk set in concrete box culvert. El. 942.4274 meters
3,091.947 feet.

**G-74 1935*: 7.9 mi. NW of Guymon, along Hwy. No. 64. On the S. curb of a concrete box culvert, at the E. end of culvert, about 110 ft W. of a fence, and 21 ft. S of C/L of hwy. Std. disk set in concrete box culvert. El. 946.2551 meters
3,104.505 feet.

**G-72 1935*: 8.9 mi. NW of Guymon, along Hwy. No. 64; in yard of Easterwood School, 95 ft. N. of C/L of hwy. 42 ft. E. of C/L of a cross road, and 2 ft. E. of flag pole. Std. disk set in concrete post El. 962.6373 meters
3,158.253 feet.

**H-74 1935*: 9.8 mi. NW of Guymon along Hwy. No. 64. About 0.2 mi. E. of a cross road, on the S. curb of a concrete box culvert, and 18.5 ft. S. of C/L of hwy. Std. disk set in concrete box culvert. El. 966.8204 meters
3,171.977 feet.

H-72 1935: 11.0 mi. NW of Guymon, SE cor. sec. 36, T4N, R13E, along Hwy. No. 64. 2 ft. SW of a fence corner and 48 ft. N. of C/L of hwy. Std. disk set in concrete post. El. 979.9784 meters
3,215.146 feet.

**J-74 1935*: 12.0 mi. NW of Guymon, along Hwy. No. 64. At a cross road, 37 ft. E. of C/L of cross road, 50 ft. S. of C/L of hwy., and 2 ft. E. of a fence corner. Std. disk set in concrete post. El. 996.8037 meters
3,270.347 feet.

* Shown on Plate I.

J-72 1935: 13.0 mi. NW of Guymon, along Hwy. No. 64; at intersection of cross road to Goodwell (Panhandle A. & M. College), 50 ft. N. of C/L of hwy. and 2 ft. W. of a telephone pole. Std. disk set in concrete post.
El. 1,002.4344 meters
3,288.820 feet.

**K-74 1935*: 14.0 mi. W. of Guymon, along Hwy. No. 64. At a cross road, 48 ft. N. of C/L of hwy.; 85 ft. E. of C/L of cross road, and 1 ft. S. of a telephone pole. Std. disk set in concrete post.
El. 1,008.4173 meters
3,308.449 feet.

**K-72 1935*: 15.1 mi. W. of Guymon, along Hwy. No. 64; at a cross road, 55 ft. W. of C/L of the cross road, 50 ft. N. of C/L of hwy., and 2 ft. E. of a telephone pole. Std. disk set in concrete post.
El. 1,011.1514 meters
3,317.419 feet.

**L-74 1935*: 16.1 mi. W. of Guymon, along Hwy. No. 64. About 200 ft. E. of a highway camp, 15 ft. W. of C/L of a cross road, 48 ft. S. of C/L of hwy. and 2 ft. N. of a fence corner. Std. disk set in concrete post. El. 1,018.4942 meters
3,341.710 feet.

**L-72 1935*: 17.0 mi. W. of Guymon, near SE cor. sec. 36, T4N, R12E, along Hwy. No. 64; at a school building, 120 ft. N. of NE corner of building, 50 ft. N. of C/L of the hwy.; 35 ft. W. of C/L of a cross road and 2 ft. W. of a telephone pole. Std. disk set in concrete post.
El. 1,026.3734 meters
3,367.360 feet.

**M-74 1935*: 18.0 mi. W. of Guymon, along Hwy. No. 64; at a cross road; 50 ft. E. of C/L of the cross road, 48 ft. N. of C/L of hwy., and 2 ft S. of a telephone pole. Std. disk set in concrete post.
El. 1,029.2415 meters
3,376.770 feet.

**M-72 1935*: 19.0 mi. W. of Guymon, along Hwy. No. 64. At a cross road, 52 ft. N. of the C/L of hwy.; 29 ft. W. of C/L of cross road and 2 ft. NE of a fence corner. Std. disk set in concrete post.
El. 1,028.8929 meters
3,375.626 feet.

**N-74 1935*: 20.1 mi. W. of Guymon, along Hwy. No. 64. About 0.1 mi. W. of a cross road, on the S. curb of a concrete box culvert, and 18.5 ft. S. of C/L of hwy. Std. disk set in concrete box culvert.
El. 1,033.3731 meters
3,390.325 feet.

**N-72 1935*: 21.1 mi. W. of Guymon, along Hwy. No. 64. At a school house, at a cross road, 155 ft. NW of the NW corner of the school house. 50 ft. N. of C/L of hwy. and 2 ft. W. of a telephone pole. Std. disk set in concrete post.
El. 1,043.5158 meters
3,423.601 feet.

P-74 1935: 22.0 mi. W. of Guymon, along Hwy. No. 64. At a cross road, on the S. curb of a concrete box culvert, at the E. end of the culvert, 60 ft. E. of C/L of the cross road, and 18.5 ft. S. of C/L of hwy. Std. disk set in concrete box culvert.
El. 1,047.1424 meters
3,435.500 feet.

**P-72 1935*: 23.0 mi. W. of Guymon, near NE cor. sec. 1, T3N, R11E, along Hwy. No. 64. At intersection of road to Texhoma, 50 ft. N. of C/L of hwy. and 45 ft. E. of C/L of cross road. Std. disk set in concrete post. El. 1,054.8988 meters
3,460.947 feet.

**Q-74 1935*: 24.1 mi. W. of Guymon, along Hwy. No. 64. About 0.1 mi. W. of a cross road, on the S. curb of a concrete box culvert, at the E. end of the culvert, and 18.5 ft. S. of C/L of hwy. Std. disk set in concrete box culvert.
El. 1,061.1146 meters
3,481.340 feet.

**C-72 1935*: 25.0 mi. W. of Guymon, along Hwy. No. 64. At a cross road, about 100 ft. NE of the NE corner of a brick house, 53 ft. S. of C/L of hwy.;

* Shown on Plate I.

30 ft. W. of C/L of cross road, and 3 ft. S. of a fence corner. Std. disk set in concrete post. El. 1,066.4459 meters
3,498.831 feet.

R-74 1935: 26.0 mi. W. of Guymon, along Hwy. No. 64. At a cross road, W. of the cross road in the S. curb of a concrete box culvert; at the E. end of the culvert and 18.5 ft. S. of C/L of hwy. Std. disk set in concrete box culvert.
El. 1,066.9103 meters
3,500.355 feet

R-72 1935: Near SE cor. sec. 32, T4N, R11E, 27.0 mi. W. of Guymon, along Hwy. No. 64; at intersection of a cross road from Eva to Rice; 33 ft. W. of C/L of the cross road, 105 ft. N. of C/L of hwy. and 3 ft. SW of a telephone pole. Std. disk set in concrete post. El. 1,074.8387 meters
3,526.366 feet.

S-72 1935: Near NW cor. sec. 5, T3N, R11E, 28.0 mi. W. of Guymon, along Hwy. No. 64. At intersection with road to the town of Eva, 52 ft. S. of C/L of hwy.; 33 ft. E. of C/L of cross road, and 3 ft. E. of a telephone guy pole. Std. disk set in concrete post. El. 1,080.8540 meters
3,546.102 feet.

S-74 1935: Near NE cor. sec. 1, T3N, R10E, 29.0 mi. W. of Guymon, along Hwy. No. 64; about 65 ft. W. of a section line fence, on the S. curb of a concrete box culvert, at the E. end of the culvert, and 20 ft. S. of C/L of hwy. Std. disk set in concrete box culvert. El. 1,092.0328 meters
3,582.778 feet.

T-72 1935: 30.0 mi. W. of Guymon, along Hwy. No. 64; about 400 ft. W. of a white house, at a cross road, 50 ft. N. of C/L of hwy., 45 ft. E. of C/L of cross road, and 2 ft. W. of a telephone pole. Std. disk set in concrete post.
El. 1,099.9044 meters
3,608.603 feet.

T-74 1935: 31.0 mi. W. of Guymon along Hwy. No. 64. About 0.1 mi. E. of a section line fence, on the S. curb of a concrete box culvert, at the E. end of the culvert, and 20 ft. S. of C/L of hwy. Std. disk set in concrete box culvert.
El. 1,096.5639 meters
3,597.643 feet.

U-72 1935: 32.1 mi. W. of Guymon, along Hwy. No. 64; at a cross road, about 400 ft. SW of a shingle house; 130 ft. W. of C/L of cross road, 50 ft. N. of C/L of hwy. and 2 ft. W. of a telephone pole. Std. disk set in concrete post.
El. 1,101.7075 meters
3,614.519 feet.

U-74 1935: 33.1 mi. W. of Guymon, along Hwy. No. 64, about 85 ft. E. of a section line fence, 50 ft. N. of C/L of hwy.; and 2 ft. W. of a telephone pole. Std. disk set in concrete post. El. 1,110.7939 meters
3,644.330 feet.

V-72 1935: 34.1 mi. W. of Guymon, along Hwy. No. 64, about 0.6 mi. E. of Cottonwood Station, at a cross road, 50 ft. N. of C/L of hwy.; 3 ft. E. of a telephone pole. Std. disk set in concrete post. El. 1,118.4319 meters
3,669.389 feet.

V-74 1935: 35.1 mi. W. of Guymon, near SE cor. sec. 36, T4N, R.9E, along Hwy. No. 64; at Cimarron-Texas County Line; 50 ft. N. of C/L of hwy.; 2 ft. W. of a telephone pole. Std. disk set in concrete post. El. 1,124.9406 meters
3,690.743 feet.

* Shown on Plate I.

Second Order Leveling. Line No. 68

Texhoma, Oklahoma to Point Rock, Kansas.
Texas County Section, Texhoma, through Eva to Kansas-Oklahoma Line, near Elkhart.
(Unadjusted Field Elevations)

A-14 1933: At Texhoma, Fourth and Elm Streets, S. side of high school, in brick wall E. of E. entrance, and 4 ft. above ground. Std. disk, set vertically. (Intersection with line No. 18). El. 1,063.384 meters
3,488.786 feet.

B-14 1933: At Texhoma, on CRI&P RR. about 18½ poles SW of milepost No. 494, in top of E. concrete block foundation of city water tank, and 51 ft. NW of C/L of track. Std. disk. (Intersection with Line No. 18). El. 1,062.805 meters
3,486.886 feet.

A-72 1935: On W. line of SW¼ sec. 32, T1N, R12E, 0.9 mi. W. of high school in Texhoma, on old road to Eva. At turn in road to N., 50 ft. E. of C/L of N-S road, 1 ft. N. of fence post. Std. disk set in concrete post. El. 1,060.7524 meters
3,480.152 feet.

M-71 1935: Near SE cor. sec. 30, T1N, R12E, 1.6 mi. NW of Texhoma high school, along old road to Eva. About 0.8 mi. N. of road west from Texhoma. At cross road, 175 ft. N. of cross road, about 39 ft. W. of C/L of road, 15 ft. W. of a gate, at fence corner. Std. disk set in concrete post. El. 1,051.6855 meters
3,450.405 feet.

B-72 1935: Near SE cor. sec. 19, T1N, R12E, 2.6 mi. NW of Texhoma high school. About 100 ft. NW of road intersection where old road to Eva turned west. 40 ft. W. of fence corner, and about 65 ft. W. of a N-S road, 2 posts west of fence corner. Std. disk set in concrete post. El. 1,033.3669 meters
3,390.305 feet.

N-71 1935: Near SW cor. sec. 19, T1N, R12E, 3.6 mi. NW of Texhoma high school. About 100 ft. E. of cross road, about 28 ft. N. of C/L of E-W road, at a fence post. Std. disk set in concrete post. El. 1,025.6750 meters
3,365.069 feet.

C-72 1935: Near NW cor. sec. 25, T1N, R11E, 4.5 mi. NW of Texhoma high school. About 200 ft. E. of road intersection where old road to Eva turned N.; 44 ft. S. of C/L of road, and 6 posts east of a fence corner. Std. disk set in concrete post. El. 1,044.0245 meters
3,425.270 feet.

P-71 1935: Near SE cor. sec. 14, T1N, R11E, 5.8 mi. NW of Texhoma high school. About 1.0 mi. N. of turn in old road to Eva. At "T" road intersection, about 30 ft. W. of C/L of road, about 8 ft. N. of fence corner and cattle guard. 2 ft. E. of first fence post N. of fence corner. Std. disk set in concrete post.
El. 1,038.5066 meters
3,407.167 feet.

D-72 1935: Near NE cor. sec. 14, T1N, R11E, 6.7 mi. NW of Texhoma high school. About 400 ft. S. of Beaver River, 50 ft. W. of C/L of road, 1 ft. E. of a fence corner. Std. disk set in concrete post. El. 1,010.9225 meters
3,316.668 feet.

Q-71 1935: Near SW cor. sec. 1, T1N, R11E, 7.8 mi. NW of Texhoma high school. About one telephone pole N. of a side road to E., about 30 ft. E. of C/L of the road, and 2 ft. W. of a telephone pole. Std. disk set in concrete post.
El. 1,038.7560 meters
3,407.985 feet.

A-74 1935: Near NW cor. sec. 1, T1N, R11E, 8.8 mi. NW of Texhoma high school. About 100 ft. S. of the center of a cross road where the old road to Eva

* Shown on Plate I.

makes a right angle turn to the W., 40 ft. E. of C/L of the road, and 1 ft. S. of a telephone pole. Std. disk set in concrete post. El. 1,039.1223 meters
3,409.187 feet.

**R-71 1935*: Near NE cor. sec. 3, T1N, R11E, 9.6 mi. NW of Texhoma high school. At a dim cross road, 67 ft. S. of C/L of the road, 30 ft. W. of C/L of the dim cross road, 15 ft. S. of a fence corner. Std. disk set in concrete post.
El. 1,050.0390 meters
3,445.003 feet.

**B-74 1935*: Near SE cor. sec. 33, T2N, R11E, 10.6 mi. NW of Texhoma. About 150 ft. SE of a stucco house, about 50 ft. W. of C/L of a cross road, 40 ft. N. of C/L of the road, 2 telephone poles W. of a fence corner. Std. disk set in concrete post. E. 1,057.3101 meters
3,468.858 feet.

**S-71 1935*: Near NE cor. sec. 5, T1N, R11E, 11.6 mi. N. of Texhoma. At a corner where the old road to Eva turns N., about 43 ft. S. of C/L of the E-W road, and 38 ft. W. of C/L of the N-S road, 8 ft. S. of a fence corner. Std. disk set in concrete post. El. 1,062.2295 meters
3,484.998 feet.

MOUSE, Ref. Mk. No. 2 1931: Near NW cor. sec. 33, T2N, R11E, 12.6 mi. NW of Texhoma. About 78 ft. E. of the C/L of road, and 3 ft. S. of a wire fence, and 50 ft. E. of a fence corner. Std. ref. mark set in concrete post. Stamped MOUSE No. 2 1931.

MOUSE, Triang. Sta 1931: Sec. 33, T2N, R11E, 12.6 mi. NW of Texhoma, about 0.5 mi. E. of C/L of road, 65 ft. N. of a fence corner, 2 ft. W. of a fence. Std. triangulation disk set in concrete post. Stamped MOUSE 1931.
El. 1,062.1561 meters
3,484.757 feet.

MOUSE, Ref. Mk. No. 1 1931: 12.6 mi. NW of Texhoma. N. of MOUSE Triangulation station, and 1 ft. W. of a fence line. Std. ref. disk set in concrete post. Stamped MOUSE No. 1 1931.

MOUSE, Ref. Mk. No. 2 1934: 12.6 mi. NW of Texhoma. About 150 ft. E. of Triangulation station MOUSE, in a fence line, and 150 ft. E. of fence corner. Std. ref. disk set in concrete post. Stamped MOUSE No. 2 1934.

**C-74 1935*: Near NE cor. sec. 29, T2N, R11E, 13.6 mi. N. of Texhoma (13.5 mi. S. of Eva). About 0.1 mi. S. of bridge over North Fork, opposite third telephone pole south of bridge. About 35 ft. W. of C/L of road, 3 ft. N. of a fence post. Std. disk set in concrete post. El. 1,037.5683 meters
3,404.089 feet.

**T-71 1935*: Near NE cor. sec. 20, T2N, R11E, 12.4 mi. S. of Eva, along old road to Texhoma. About 0.2 mi. S. of a farm house, about 0.1 mi. S. of the top of a hill, and 33 ft. W. of C/L of road. Std. disk set in concrete post.
El. 1,061.8055 meters
3,483.607 feet.

**U-71 1935*: Near NW cor. sec. 16, T2N, R11E, 11.5 mi. S. of Eva. About 34 ft. E. of C/L of road, at a cross road, and about 30 ft. S. of cross road, 4 ft. E. of a telephone pole. Std. disk set in concrete post. El. 1,070.3173 meters
3,511.533 feet.

**V-71 1935*: Near NE cor. sec. 8, T2N, R11E, 10.5 mi. S. of Eva. At a side road to the W., about 24 ft. S. of side road. About 83 ft. W. of C/L of road and 1 ft. N. of a fence line, and 3 ft. W. of a fence corner. Std. disk set in concrete post. El. 1,060.8101 meters
3,480.341 feet.

**W-71 1935*: Near NW cor. sec. 4, T2N, R11E, 9.5 mi. S. of Eva. About 32 ft. E. of C/L of road, 3 ft. E. of a fence corner, and 1 ft. N. of a fence line. Std. disk set in concrete post. El. 1,066.2780 meters
3,498.280 feet.

* Shown on Plate I.

**X-71 1935*: Near SE cor. sec. 29, T3N, R11E, 8.5 mi. S. of Eva. About 0.5 mi. S. of James School, Dist. 26. At a crossroad, about 30 ft. N. of cross road, 75 ft. W. of C/L of road, and 20 ft. W. of a fence corner. Std. disk set in concrete post.
El. 1,074.9063 meters
3,526.588 feet.

KEYLON Azimuth 1934: Sec. 29, T3N, R11E, 7.9 mi. S. of Eva. In a school yard, about 48 ft. W. of C/L of road, and about 6 ft. S. of school yard fence. Std. ref. disk set in concrete post. Stamped KEYLON Azimuth 1934.

Triangulation Station KEYLON 1934: 7.9 mi. S. of Eva. About 0.6 mi. E. and N. of a road, 0.2 mi. NE of a gate in a section line fence, about 450 ft. E. of the fence line, on top of a broad flat knoll. Std. triangulation disk set in concrete post. Stamped KEYLON 1934.
El. 1,085.1316 meters
3,560.136 feet.

KEYLON Ref. Mk. No. 1 1934: 7.9 mi. S. of Eva. About 191 ft. N. of the triangulation station. Std. ref. mark set in concrete post. Stamped KEYLON No. 1 1934.

KEYLON Ref. Mk. No. 2 1934: 7.9 mi. S. of Eva. 241 ft. E. of the triangulation station. Std. ref. mark set in concrete post. Stamped KEYLON No. 2 1934.

**Y-71 1935*: Near SW cor. sec. 21, T3N, R11E, 7.5 mi. S. of Eva. About 30 ft. N. of C/L of a side road to W. and a faint road to E., about 28 feet E. of C/L of the road, and 2 ft. W. of a telephone pole. Std. disk set in concrete post.
El. 1,081.2652 meters
3,547.451 feet.

Z-71 1935: Near NW cor. sec. 21, T3N, R11E, 6.5 mi. S. of Eva. About 200 yds. NE of a farm house, in the SE corner of a "T" road intersection. 70 ft. E. of C/L of the road. At the top of a hill, and 25 ft. E. of a telephone line. Std. disk set in concrete post.
El. 1,069.8307 meters
3,509.936 feet.

**D-74 1935*: Near NW cor. sec. 16, T3N, R11E, 5.5 mi. S. of Eva. About 175 ft. N. of a green and white farm house, in the SE cor. of a "T" road intersection, 90 ft. E. of C/L of the road. 30 ft. S. of a cross road, and 3 posts E. of a fence corner. Std. disk set in concrete post.
El. 1,066.1347 meters
3,497.810 feet.

**E-74 1935*: Near NW cor. sec. 9, T3N, R11E, 4.5 mi. S. of Eva. In the SE cor. of a cross road, about 50 ft. E. of C/L of the road. Std. disk set in concrete post.
El. 1,079.1885 meters
3,540.638 feet.

(INTERSECTS AND COINCIDES WITH LINE NO. 67, FOR FOLLOWING TWO STATIONS:)

**R-72 1935*: Near SE cor. sec. 32, T4N, R11E, 27.0 mi. W. of Guymon, along Hwy. No. 64; at intersection of a cross road from Eva to Rice; 33 ft. W. of C/L of the cross road, 105 ft. N. of C/L of hwy. and 3 ft. SW of a telephone pole. Std. disk set in concrete post.
El. 1,074.8387 meters
3,526.366 feet.

**S-72 1935*: Near NW cor. sec. 5, T3N, R11E, 28.0 mi. W. of Guymon, along Hwy. No. 64. At intersection with road to the town of Eva, 52 ft. S. of C/L of hwy.; 33 ft. E. of C/L of cross road, and 3 ft. E. of a telephone guy pole. Std. disk set in concrete post.
El. 1,080.8540 meters
3,546.102 feet.

**A-75 1935*: Near NW cor. sec. 32, T4N, R11E, 1.5 mi. S. of Eva, along the hwy. to Texhoma. About 200 yds. W. of a farm house, 215 ft. S. of C/L of a cross road, 75 ft. E. of C/L of hwy., 3 posts E. of a fence cor., and 1 ft. N. of a fence line. Std. disk set in concrete post.
El. 1,087.1309 meters
3,566.695 feet.

**B-75 1935*: Near NE cor. sec. 30, T4N, R11E, 0.5 mi. S. of Eva, along hwy. to Texhoma. In the SW cor. of a cross road, about 54 ft. W. of C/L of hwy.,

* Shown on Plate I.

48 ft. S. of the cross road, 21 ft. S. of a telephone pole, at the second fence post S. of a fence corner. Std. disk set in concrete post. El. 1,086.8019 meters
3,565.616 feet.

C-75 1935: Near NW cor. sec. 20, T4N, R11E, 0.6 mi. N. from Eva, along hwy. to Elkhart, Kansas. In the SE cor. of a cross road, about 135 ft. E. of C/L of hwy., 36 ft. S. of the cross road, opposite the second fence post from the corner, and 1 ft. N. of the fence line. Std. disk set in concrete post.
El. 1,090.7310 meters
3,578.507 feet.

D-75 1935: Near NE cor. sec. 18, T4N, R11E, 1.6 mi. N. from Eva, along the hwy. to Elkhart. About 52 ft. W. of C/L of hwy., and about 40 ft. S. of a cross road. Std. disk set in concrete post. El. 1,094.2803 meters
3,590.151 feet.

**E-75 1935*: SW¼ sec. 5, T4N, R11E, 2.7 miles north of Eva, along hwy. to Elkhart. At the intersection of a road, in the W. end of the wye intersection, 125 ft. E. of C/L of hwy., and 33 ft. N. of C/L of section line road, about 3 ft. N. of a fence line. Std. disk set in concrete post. El. 1,094.0600 meters
3,589.429 feet.

**F-75 1935*: Near SW cor. sec. 32, T5N, R11E, on std. parallel, 3.7 mi. N. from Eva, along hwy. to Elkhart. About 70 ft. E. of C/L of hwy., about 29 ft. N. of a cross road, and 2 ft. E. of a gate post. Std. disk set in concrete post.
El. 1,087.5063 meters
3,567.927 feet.

G-75 1935: Near NW cor. sec. 32, T5N, R11E, 4.6 mi. N. from Eva, along the hwy. to Elkhart. 0.2 mi. S. of bridge over Goff Creek, 49 ft. E. of C/L of hwy., about 25 ft. S. of a telephone pole and 1 ft. W. of a fence post. Std. disk set in concrete post. El. 1,067.4621 meters
3,502.165 feet.

**H-75 1935*: Near SE cor. sec. 19, T5N, R11E, 5.8 mi. N. from Eva, along the hwy. to Elkhart. About 350 ft. N. of a telephone line branching toward the E., 48 ft. W. of C/L of hwy., and 2 ft. N. of a telephone pole. Std. disk set in concrete post. El. 1,092.2446 meters
3,583.472 feet.

**J-75 1935*: Near SW cor. sec. 17, T5N, R11E, 6.8 mi. N. from Eva, along the hwy. to Elkhart. (7.6 mi. S. of Elkhart, Kansas). About 225 ft. NW of a frame farm house, 50 ft. E. of C/L of hwy., 40 ft. N. of a side road, 4 ft. N. of a telephone pole. Std. disk set in concrete post. El. 1,101.3130 meters
3,613.224 feet.

MARSHALL Ref. Mk. No. 2 1934: 7.9 mi. N. of Eva, along the hwy. to Elkhart. (6.5 mi. S. of Elkhart) About 90 ft. S. of C/L of a cross road, 49 ft. E. of C/L of hwy. 1 ft. W. of a fence line. Std. Ref. Mark set in concrete post. Stamped MARSHALL Ref. No. 2 1934.

MARSHALL Ref. Mk. No. 1 1934: 8.0 mi. N. from Eva, along the hwy. to Elkhart. 130 ft. E. of Marshall triangulation station. Std. Ref. Mark set in concrete post; stamped MARSHALL No. 1 1934.

**Triangulation Station MARSHALL 1934*: SW¼ sec. 8, T5N, R11E, 8.0 mi. N. of Eva, along the hwy. to Elkhart. About 60 ft. E. of C/L of hwy., about 45 ft. N. of a cross road. Std. disk set in concrete post. Stamped MARSHALL 1934.
El. 1,104.9849 meters
3,627.271 feet.

**K-75 1935*: Near NE cor. sec. 7, T5N, R11E, 9.0 mi. N. from Eva, along the hwy. to Elkhart. About 45 ft. S. of a cross road, 46 ft. W. of C/L of hwy., about 8 ft. W. of a telephone pole, guy pole. Std. disk set in concrete post.
El. 1,106.2476 meters
3,629.414 feet.

* Shown on Plate I.

**L-75 1935*: Near SE cor. sec. 31, T6N, R11E, 9.8 mi. N. from Eva, along the hwy. to Elkhart. About 32 ft. N. of C/L of a side road to W., 47 ft. W. of C/L of hwy., and 2 ft. N. of a telephone pole. Std. disk set in concrete post.
El. 1,109.1077 meters
3,638.798 feet.

**M-75 1935*: Near SW cor. sec. 29, T6N, R11E, 10.8 mi. N. from Eva, along the hwy. to Elkhart, (3.8 mi. S. of Elkhart). About 47 ft. E. of C/L of hwy., 38 ft. N. of C/L of a cross road, and 4 ft. N. of a telephone pole. Std. disk set in concrete post.
El. 1,116.0622 meters
3,661.614 feet.

**N-75 1935*: Near SW cor. sec. 20, T6N, R11E, 11.8 mi. N. from Eva, along the hwy. to Elkhart (2.8 mi. S. of Elkhart). In the yard of Cosmos School District No. 114, about 55 ft. E. of C/L of hwy., about 40 ft. N. of a cross road, 3 ft. E. of a concrete walk, in the school yard. Std. disk set in concrete post.
El. 1,112.4627 meters
3,649.805 feet.

P-75 1935: Near SE cor. sec. 18, T6N, R11E, 12.9 mi. N. from Eva along the hwy. to Elkhart, (1.7 miles south of Elkhart). About 105 ft. N. of C/L of a cross road. About 49 ft. W. of C/L of hwy., and 3 ft. N. of a telephone pole. Std. disk set in concrete post..
El. 1,115.9969 meters
3,661.400 feet.

KANSAS-OKLAHOMA STATE LINE.

A-93 1935: 13.8 mi. N. from Eva, along the hwy. to Elkhart, Kansas (0.8 mi. south of Elkhart) near Kansas-Oklahoma boundary, 50 ft. N. of the State line. About 75 ft. NW of C/L of the AT&SF RR. tracks, on top of the concrete base of the Kansas-Oklahoma State Line Monument, in the most southerly corner. Std. disk set in concrete monument.
El. 1,102.5959 meters
3,617.433 feet.

Second Order Leveling. Line No. 69

Vicinity of Rolla, Kansas to Guymon, Oklahoma

Oklahoma Portion

(Unadjusted Field Elevations)

**E-76 1935*: On Oklahoma-Kansas Boundary, near NW cor. sec. 14, T6N, R13E, 11.8 mi. NW of Hough, along hwy. to Rolla, Kansas. (8.9 mi. S. of Rolla). At the Kansas-Oklahoma State Line, at the triangular intersection, about 60 ft. S. of C/L of hwy. along the State Line, and about 10 ft. W. of C/L of hwy. to Hough. Std. disk set in concrete post.
El. 1,022.9684 meters
3,356.189 feet.

A-76 1935: Near W¼ cor. sec. 26, T6N, R13E, 9.4 mi. NW of Hough, about 0.2 mi. S. of two frame houses, about 80 ft. W. of C/L of hwy. and 1.5 ft. S. of a fence post. Std. disk set in concrete post
El. 1,019.6599 meters
3,345.334 feet.

**B-76 1935*: Near E¼ cor. sec. 3, T5N, R13E, 7.1 mi. NW of Hough. About 1.5 mi. N. of a turn in hwy. About 55 ft. W. of C/L of hwy. and 15 ft. W. and 1.5 ft. N. of a fence corner. Std. disk set in concrete post. El. 1,021.4813 meters
3,351.310 feet.

**C-76 1935*: Near E¼ cor. sec. 3, T5N, R13E, 7.1 mi. NW of Hough. About 1.5 mi. N. of a turn in hwy. About 55 ft. W. of C/L of hwy., and 15 ft. W. and 1.5 ft. N. of a fence corner. Std. disk set in concrete post.
El. 1,017.1405 meters
3,337.068 feet.

**D-76 1935*: Near S¼ cor. sec. 7, T5N, R14E, 3.1 mi. N. of Hough, along hwy. to Rolla. About 0.5 mi. W. of a turn in hwy., about 29 ft. N. of C/L of hwy.

* Shown on Plate I.

and 13 ft. W. and 1 ft. S. of a fence corner for fence to north. Std. disk set in concrete post. El. 1,007.7689 meters
3,306.322 feet.

**Q-75 1935*: Near E¼ cor. sec. 19, T5N, R14E, 1.0 mi. N. of Hough. About 100 ft. W. of C/L of hwy., 45 ft. W. of fence corner and 1 ft. N. of fence line to W. Std. disk set in concrete post. El. 1,003.5894 meters
3,295.890 feet.

R-75 1935: Near N¼ cor. sec. 32, T5N, R14E, 1.0 mi. SE of Hough, along hwy. to Guymon; about 0.5 mi. S. and 0.5 mi. E. of Hough; about 75 ft. S. of C/L of hwy. and 1 ft. W. of a fence post. Std. disk set in concrete post.
El. 997.1284 meters
3,271.412 feet.

**S-75 1935*: 3.1 mi. SE of Hough, along hwy. to Guymon. About 1.5 mi. W. of a turn in hwy. About 60 ft. N. of C/L of hwy. 20 ft. N. of fence corner and 1.5 ft. W. of a fence to the north. Std. disk set in concrete post.
El. 985.9718 meters
3,234.809 feet.

**T-75 1935*: Near W¼ cor. sec. 36, T5N, R14E, 5.3 mi. SE of Hough, along hwy. to Guymon. About 0.5 mi. N. of Standard Parallel, about 2/3 of telephone pole distance S. of an E-W fence. About 29 ft. E. of C/L of hwy. and 3 ft. S. of a telephone pole. Std. disk set in concrete post. El. 978.7867 meters
3,211.236 feet.

**U-75 1935*: Near NE cor. sec. 12, T4N, R14E, 7.5 mi. SE of Hough, along hwy. to Guymon. About 38 ft. S. of C/L of a cross road, about 48 ft. W. of C/L of hwy., and 10 ft. S. of a telephone pole. Std. disk set in concrete post.
El. 965.2914 meters
3,166.960 feet.

**V-75 1935*: Near NW cor. sec. 19, T4N, R15E, 8.6 mi. N. of Guymon, along hwy. to Hough, (9.4 mi. SE of Hough). About 29 ft. S. of C/L of a cross-road, about 145 ft. E. of C/L of hwy., 5 ft. W. of telephone pole and 1 ft. N. of fence line. Std. disk set in concrete post. El. 963.8415 meters
3,162.203 feet.

**W-75 1935*: Near SE cor. sec. 25, T4N, R14E, 6.6 mi. N. of C. H. at Guymon, along road to Hough. About 2.0 mi. due N. along road from point where U. S. Hwy. No. 64 turns W. About 35 ft. N. and 2 ft. W. of a section line fence corner and about 52 ft. W. of C/L of road. Std. disk set in concrete post. El. 953.9767 meters
3,129.839 feet.

X-75 1935: Near SW cor. sec. 6, T3N, R15E, 4.6 mi. N. of C. H. at Guymon, along U. S. Hwy. No. 64 and road to Pony Creek. At the intersection of an E-W road with a road bearing N. at a point where U. S. Hwy. No. 64 turns from a N. to NW'ly direction. 52 ft. E. of C/L of the NS road, about 20 ft. N. of a fence, and 2 ft. E. of a fence post. Std. disk set in concrete post. (Intersection with line No. 67). El. 918.2548 meters
3,012.641 feet.

**Y-75 1935*: 3.6 mi. N. of C. H. at Guymon, along U. S. Hwy. No. 64 and road to Pony Creek. On a concrete bridge, on the E. end of the N. abutment. Std. disk set in top of concrete abutment. El. 915.0381 meters
3,002.087 feet.

**Z-75 1935*: 2.0 mi. N. of C. H. at Guymon, along U. S. Hwy. No. 64 and road to Pony Creek. 0.6 mi. SE of bridge over Beaver River. About 53 ft. W. of C/L of hwy., 2 ft. W. of a fence post, and 1.5 ft. W. of a fence corner. Std. disk set in concrete post. El. 921.8677 meters
3,024.494 feet.

* Shown on Plate I.

First Order Leveling. Intersection with Line No. 18.

(Adjusted Levels)

T-14 1933: At Guymon, Texas County, Okla., at the SW side of the front entrance to the high school, and in a sandstone column, 4 ft. above the ground. Std. disk, set vertically.
El. 954.037 meters
3,130.036 feet.

**U-14 1933*: At Guymon, Texas County, at the SE cor. of Main and Fourth Streets, at the E. side of the N. entrance of the county courthouse, and in a concrete block of the brick wall, 3 ft. above the ground. Std. disk, set vertically.
El. 952.761 meters
3,125.850 feet.

KEY TO ABBREVIATIONS

C. H.	Court House
C/L	Center Line
Ref. Mk.	Reference Mark
Std.	Standard

* Shown on Plate I.

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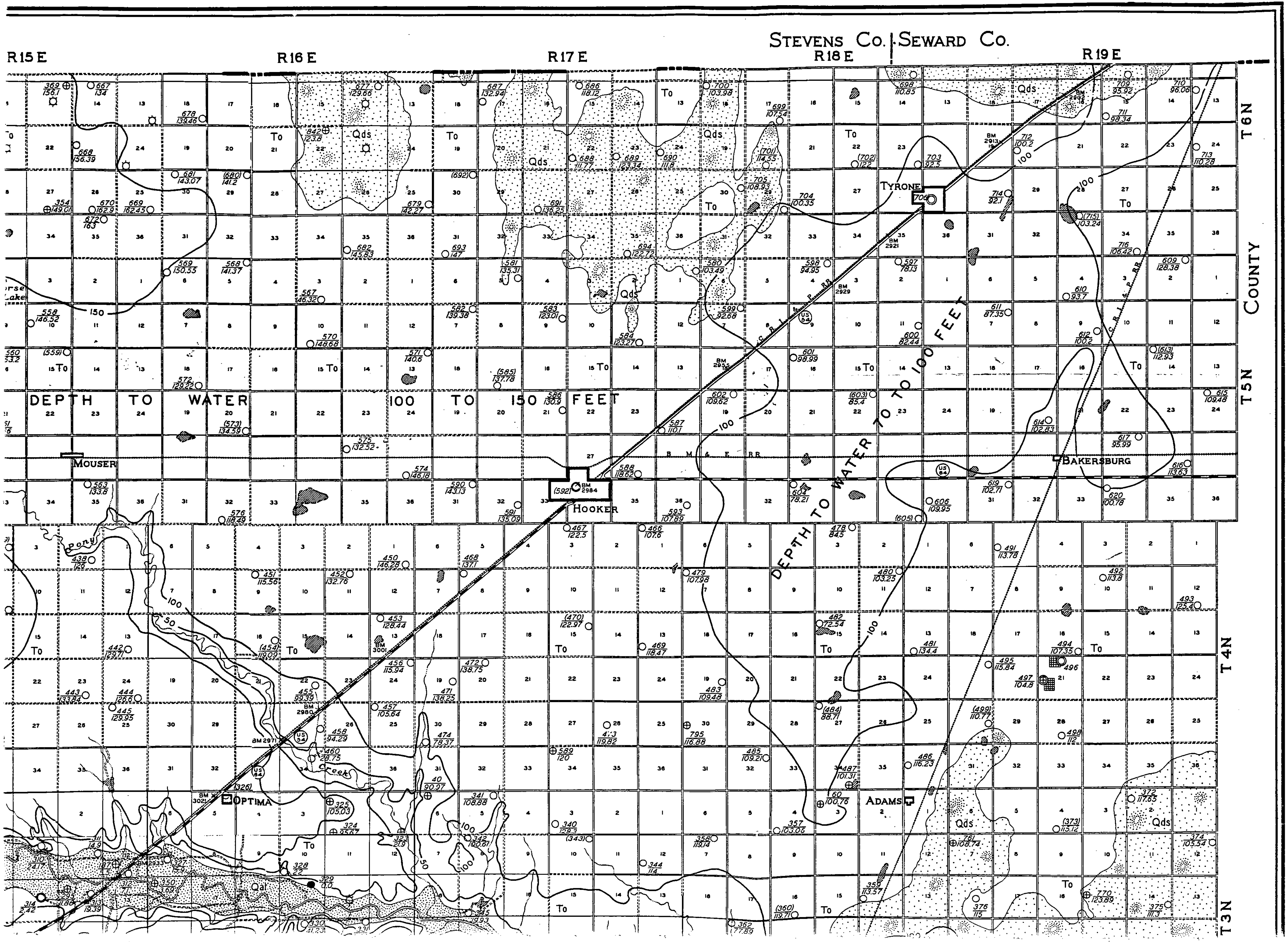


EXPLANATION

QUATERNARY

Qal

ALLUVIUM

Sand, silt, and gravel on flood plains. Coarser portions yield adequate supplies of water which generally is of good quality except in the valleys of Paloduro Creek and its tributaries. In places probably would supply a limited amount of water to irrigation wells.

Qds

DUNE SAND

Sand. Sand dunes absorb all the rainfall and are areas favorable to recharge of the ground water reservoir, but are above the water table and do not supply water directly to wells.

TERTIARY — PLIOCENE

To

OGALLALA FORMATION

Calcareous sands, gravels, silts, and clays, in general but slightly consolidated. Principal aquifer. Furnishes adequate supplies of water of good quality to domestic and municipal wells, generally from depths greater than 100 feet. Gravels and coarser sands probably would supply water to irrigation wells in parts of the county.

TRIASSIC(?), JURASSIC(?), CRETACEOUS

ᵵR

TRIASSIC (?)

Red, yellow and gray clays, with interbedded soft, red and gray sandstones. Furnishes meager supplies of water to stock and domestic wells and may be more or less mineralized. Includes small areas of fossiliferous Cretaceous sandstone, and older beds thought to be possibly Jurassic.

CARBONIFEROUS — PERMIAN

Cc

CLOUD CHIEF FORMATION

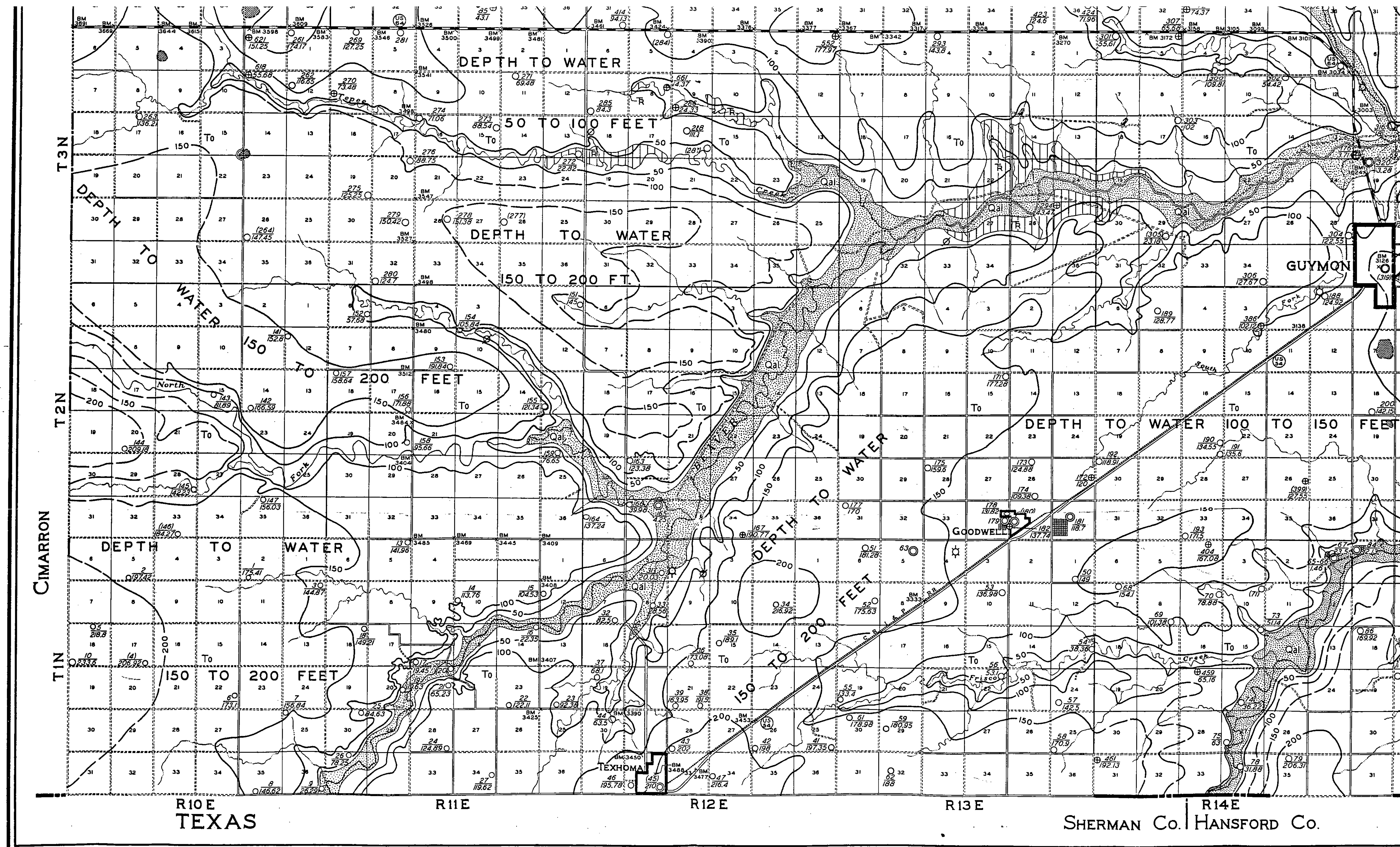
Red clay or shale with minor beds of sandstone and gypsum. Yields small supplies of highly mineralized water from the sandstones and from joints in the clay.

TEMPORARY LAKE OR POND

(78) / 121.91

WINDMILL WELL

Number above the line is number used in well tables. Lower number is depth to water below measuring point. (78) indicates water analysis.

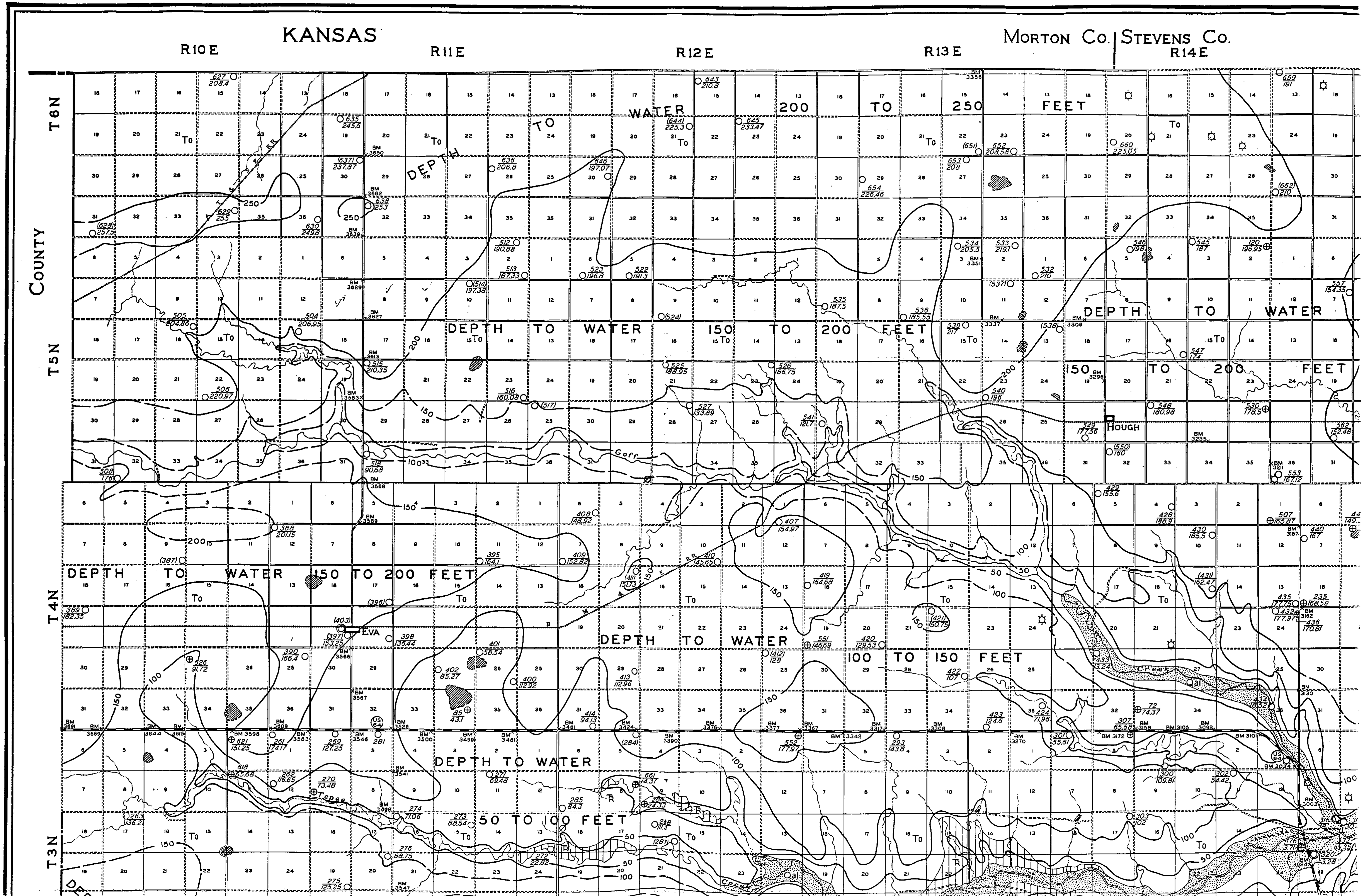


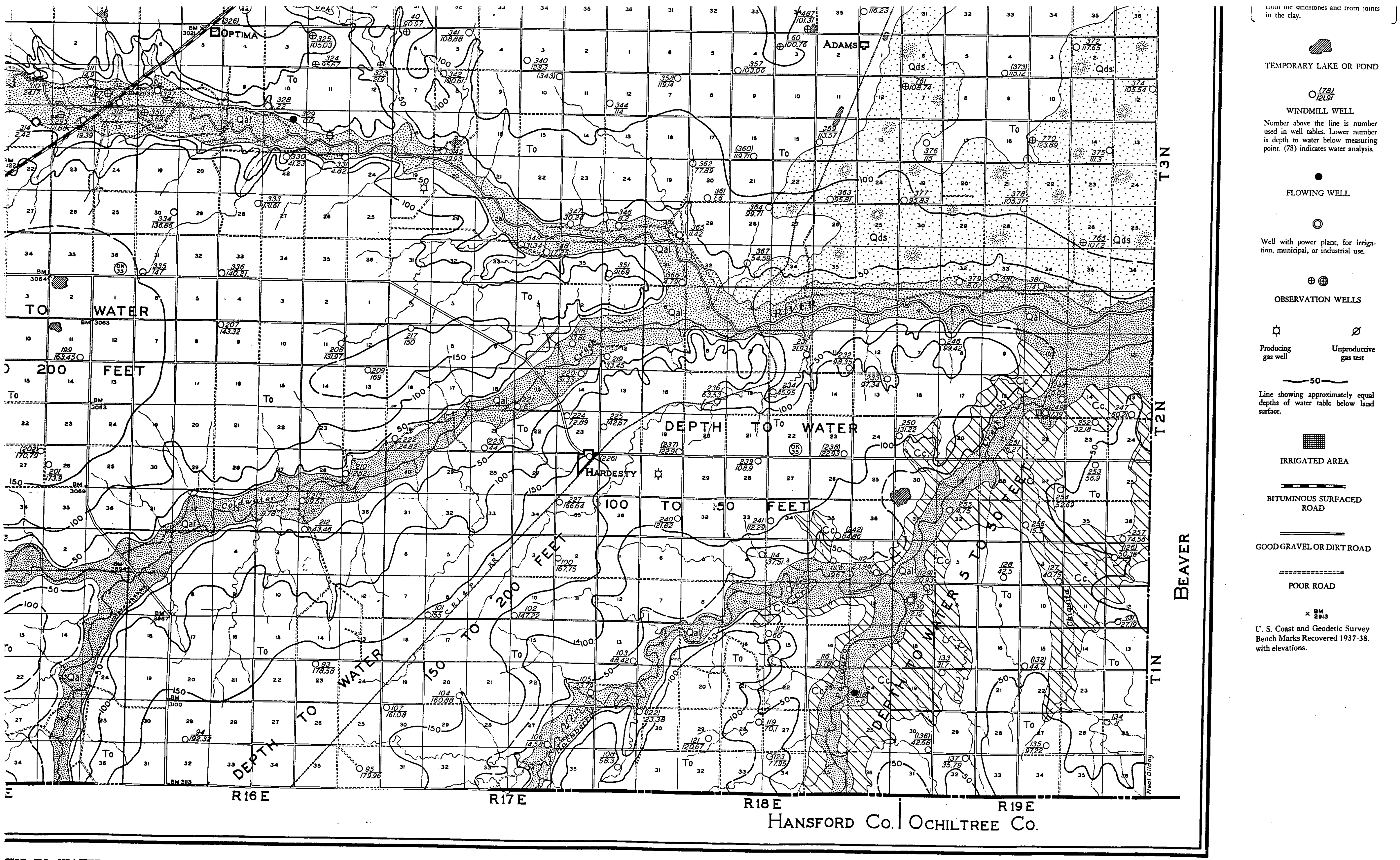
Base Map by State Mineral Survey, Works Progress Administration, Project 65-65-538. Sponsored by Oklahoma Geological Survey, 1936-37. Checked in field and from Aerial Photographs, 1937.

The Texas-Oklahoma boundary line recently was re-surveyed, along 36 degrees 30 minutes North Latitude, and found to be 126 to 409 feet south of the base line in Texas County. The small strip of land south of the base line, T. 1 S., is not shown on this map.

MAP OF TEXAS COUNTY, OKLAHOMA, SHOWING GEOLO

Scale 0 1 2 3 4

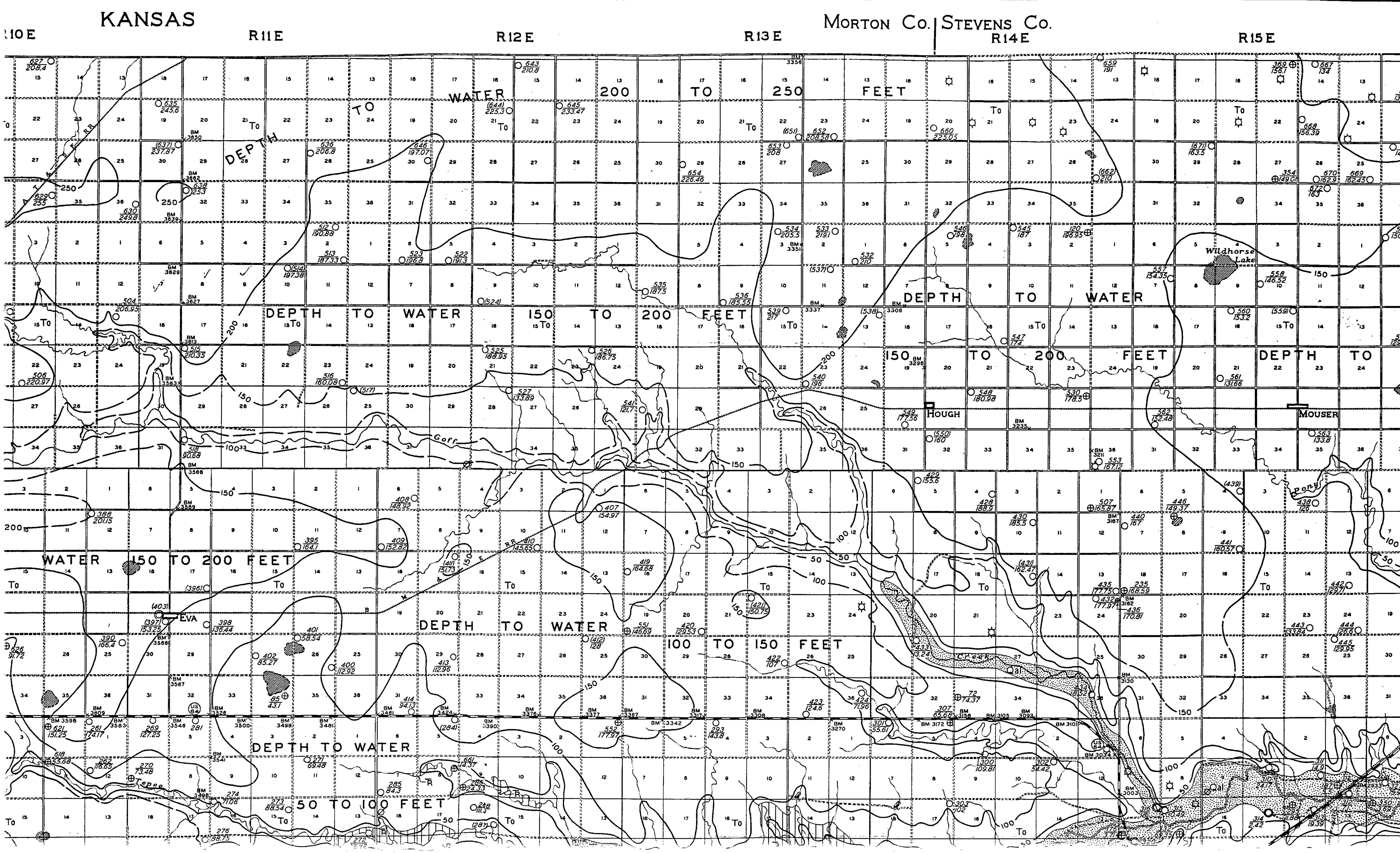

KANSAS
R10E
R11E
R12E
R13E
MORTON CO. | STEVENS CO.
R14E
T6N
T5N
T4N
T3N
COUNTY
DEPTH TO WATER 200 TO 250 FEET
DEPTH TO WATER 150 TO 200 FEET
DEPTH TO WATER 150 TO 200 FEET
DEPTH TO WATER 150 TO 200 FEET
DEPTH TO WATER 100 TO 150 FEET
DEPTH TO WATER
50 TO 100 FEET
HOUGH
EVA
Goff
Tepee



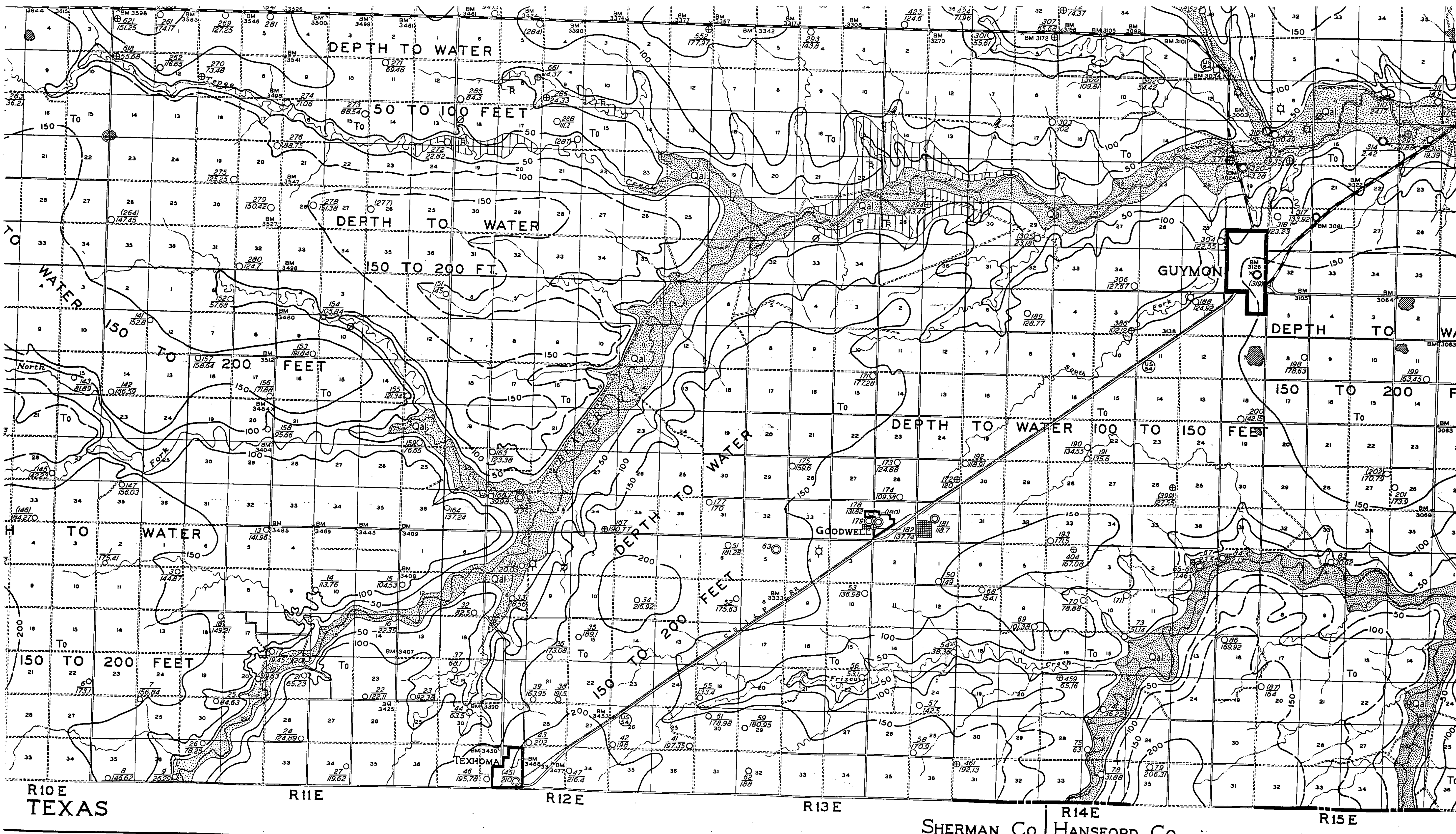
THS TO WATER IN WELLS

Miles

Geology Modified after Gould and Lonsdale.
Hydrology by S. L. Schoff, 1937.



KANSAS
MORTON CO.
STEVENS CO.
R10E
R11E
R12E
R13E
R14E
R15E
DEPTH TO WATER 200 TO 250 FEET
DEPTH TO WATER 150 TO 200 FEET
DEPTH TO WATER
150 TO 200 FEET
DEPTH TO W
WATER 150 TO 200 FEET
DEPTH TO WATER 100 TO 150 FEET
DEPTH TO WATER
50 TO 100 FEET
Wildhorse Lake
HOUGH
MOUSER
EVA
Goff
Creek
Tepee
Pony



., Works Progress
.38. Sponsored by
.6-37. Checked in
., 1937.

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MAP OF TEXAS COUNTY, OKLAHOMA, SHOWING GEOLOGY AND DEPTHS TO WATER IN

Scale 0 1 2 3 4 5 6 Miles