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DEPARTMENT OF THE STATE ENGINEER
STATE OF NEW MEXICO

HERBERT W. YEO, STATE ENGINEER
COOPERATING WITH
THE UNITED STATES GEOLOGICAL SURVEY

Shallow Ground-Water Supplies in Northern Lea County, New Mexico

[redacted]

by
S. SPENCER NYE
United States Geological Survey

June, 1930

Bulletin No. 2

STATE ENGINEER
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SHALLOW GROUND-WATER SUPPLIES
IN
NORTHERN LEA COUNTY
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INTRODUCTION

Location and Size of Area

Lea County is in the southeast corner of New Mexico and is bounded on the east and south by Texas, on the north by Chaves and Roosevelt counties, and on the west by Chaves and Eddy counties. Lea County is about 108 miles long from north to south and 38 to 43 miles wide from east to west, and its area is more than 4,300 square miles. It includes Townships 9 to 26 and Ranges 32 to 39 East, but the area treated in this report includes not quite all of Townships 11 to 19 South.

General Features

Lovington, the county seat, is near the center of the county. Tatum, on the main highway between Roswell and Brownfield, Texas, and Hobbs, in the east-central part of the county, near the Texas line, are the only other towns of any consequence in northern Lea County. At the time of this investigation there were no railroad lines in the county, but in December, 1929, the Atchison, Topeka & Santa Fe Railway and the Texas & New Mexico Railway were granted permission to extend their lines from Seagraves, Texas, and Kermit, Texas, respectively, to Lovington, and early in 1930 the construction of the extension from Kermit to Lovington was begun. The Texas & New Mexico Railway joins the main line of the Texas & Pacific at Monahans, Texas.

A Federal aid highway from Roswell, New Mexico, to Brownfield and other points in Texas crosses the northern part of the county. It extends in a southeastward direction from Caprock to a point 2½ miles west of Tatum and thence due east through Tatum to the Texas line. Lovington, which is about 20 miles south of this highway, is connected with it by a north-south road to Tatum. Lovington is also served by highways to Artesia and Carlsbad, in the Pecos Valley, to Jal, in the southeastern part of the county, and to Seminole and Seagraves, Texas.

History and Purpose of the Investigation

Early in 1929 the Legislature of New Mexico passed "an act authorizing and directing the State Engineer to enter into a contract with the United States Geological Survey to make a survey of the ground-water supply in Lea County, New Mexico, and investigate the source of supply, the quantity of water available, and methods of conservancy of such underground waters, and making an appropriation therefor from the water reservoirs for irrigation purposes income fund."[1] The writer was assigned to the investigation and spent parts of September and October and all of November in a study of the shallow-water area in the northern part of the county. The investigation was made in cooperation with the State Engineer of New Mexico.

This paper is a preliminary report, for further field work is contemplated during 1930.

Acknowledgments

The investigation was conducted under the supervision of O. E. Meinzer, geologist in charge of the division of ground water, United States Geological Survey, who spent several days in the field with the writer during September and to whom he is indebted for helpful suggestions and criticism throughout the course of the investigation. Herbert W. Yeo, State Engineer of New Mexico, had several continuous water-stage recorders installed over wells, placed a level party in the field to run level lines to observation wells, and cooperated to the fullest extent. Arthur F. Brown, of the State Engineer's Department, Artesian Well Supervisor of the Roswell Artesian Basin, made monthly measurements of the water levels in the observation wells and looked after the water-stage recorders. O. Beaty, county agent, supplied much information in regard to wells and pumping plants and rendered assistance that greatly facilitated the work. The analyses of samples of water from the area were made by W. L. Lamar, of the Geological Survey. The writer also wishes to express his appreciation of the cooperation and hospitality of the residents of the area.

TOPOGRAPHY AND DRAINAGE

Nearly all of the northern half of Lea County lies within the southwestern part of the Llano Estacado, or Staked Plains, which is a remnant of the southern extension of the High Plains. The High Plains are remnants of a vast debris apron spread out along the east front of the Rocky Mountains and the mountain ranges of central New Mexico by streams flowing eastward and southeastward.

The Llano Estacado is a large, nearly flat plateau occupying much of eastern New Mexico and western Texas. It is bounded nearly everywhere by a prominent steep escarpment that rises 100 to 300 feet above the surrounding plains. In places, however, the edge of the Llano is marked by a gradual slope and is therefore indefinite. The surface of the Llano is a remarkably smooth grassy, treeless plain having a gradient to the east and the east-southeast of 10 to 15 feet to the mile. In many places, especially near its west margin, there are broad, shallow depressions, most of which are circular or nearly so. After very hard rains these depressions are sometimes filled with water, which slowly seeps into the ground or evaporates. There are no perennial streams on the Llano. In this region there is practically no surface drainage of any consequence, and the rainfall is disposed of chiefly by seepage and evaporation. There are a few incipient stream channels, but as a rule they fade out within a few miles or drain into one of the shallow depressions mentioned above. In the central and eastern parts of Lea County the depressions are generally less than 25 feet deep, but in the western part,

[1] House Bill 78, Approved March 13, 1929.

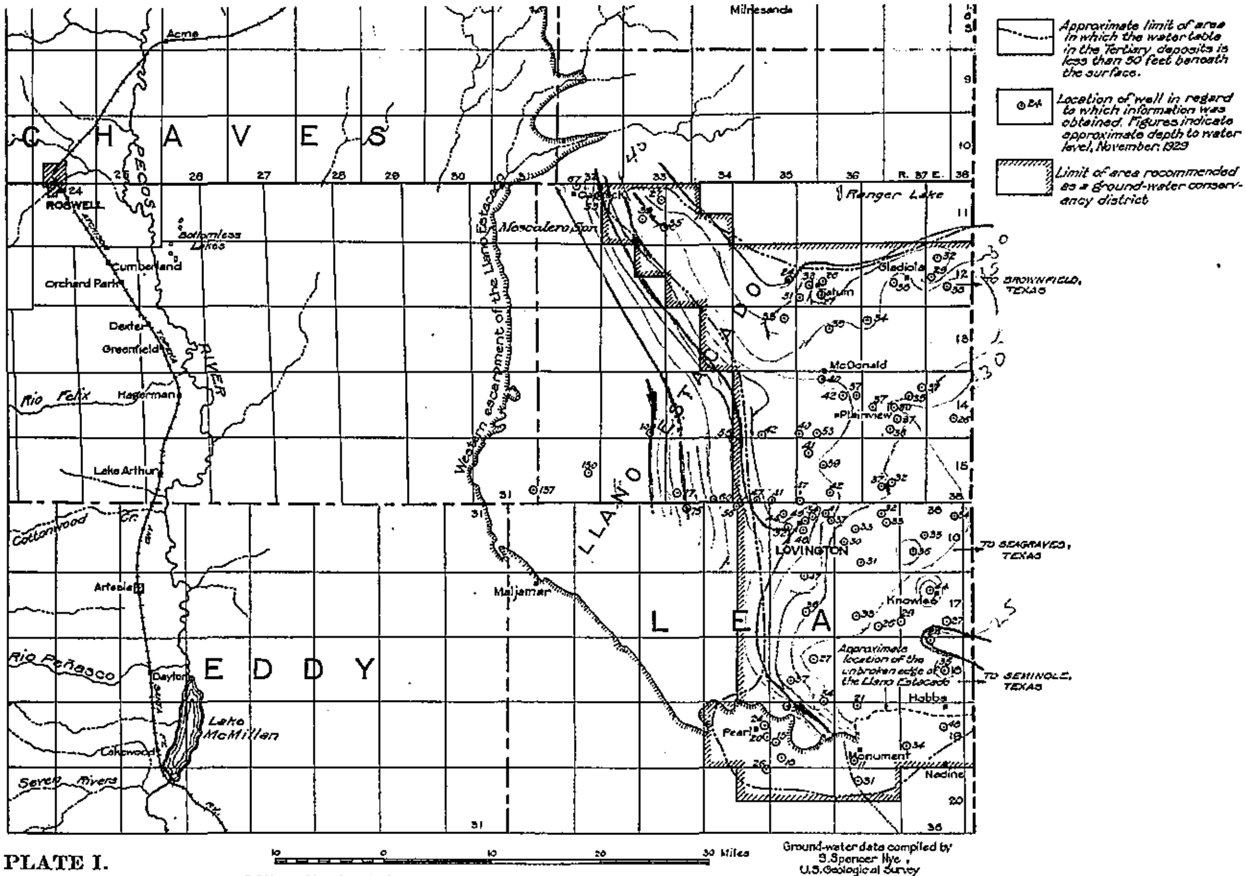

PLATE I.

MAP OF A PART OF SOUTHEASTERN NEW MEXICO

SHOWING THE AREA OCCUPIED BY THE LLANO ESTACADO AND THE APPROXIMATE OUTLINE OF THE SHALLOW-WATER AREA IN LEA COUNTY.

near the west edge of the Llano, where they are most numerous, many of the depressions are 50 to 75 feet or more deep. As a result of these depressions short canyon-like stream channels have been formed by the headward erosion of drainage tributary to the depressions.

In this region the Llano is bounded on the west by a somewhat irregular north-south escarpment rising 100 to 300 feet above gently undulating sandy plains that slope gradually westward to an irregular line of bluffs 100 to 300 feet high roughly parallel to and a short distance east of the Pecos River. The escarpment is due to a capping of resistant caliche 10 to 20 feet or more thick, locally referred to as the "cap-rock." The escarpment is a very prominent topographic feature that is plainly visible on clear days from favorably situated points 50 to 100 miles to the west. It lies along or a few miles west of the west line of Lea County. (See pl. 1). Near the southwest corner of T. 16 S., R. 32 E., it turns toward the southeast and continues in that direction as far as the center of the east line of T. 19 S., R. 34 E., where it swings irregularly eastward and dies out in the western part of T. 19 S., R. 37 E. In T. 19 S., R. 38 E., there is a very gradual slope from the surface of the Llano to that of the lower undulating plains on the south.

The southern half of Lea County consists of gently undulating sandy plains having a maximum relief of about 100 feet. There are many large undrained depressions and sink holes formed by the solution and removal of underlying soluble rocks. All the streams are ephemeral—that is, they flow only after heavy rains.

The portion of the county that lies within the Llano Estacado is from 4,400 to about 4,600 feet above sea level along the west side, and from 3,600 to about 3,900 feet above sea level along the east side. The highest altitude is in the northwestern part of the county, and the lowest, on the Llano, is near Hobbs. Lovington, the county seat, is 3,913 feet above sea level. In the southern half of the county the plains below the Llano slope toward the south and southwest. The lowest point in the county, about 2,900 feet above sea level, is in the southeastern part near the Texas line. The maximum relief in the county is, therefore, about 1,700 feet.

CLIMATE

The climate of the region is semi-arid, but as most of the rain falls during the growing season, April to October, it has been found possible to grow cotton and feed crops on the Llano without irrigation during wet years. In some years, however, the rainfall is insufficient to grow any crops without irrigation.

The distribution of the rainfall in this region is usually spotted and varies erratically within a few miles. The precipitation on the Llano in the northern half of the county is greater than in the southern half. In the vicinity of Lovington and Hobbs the annual precipitation has ranged from 5 to 27 inches. The temperature at Lovington, which is fairly typical of the northern half of the county, has ranged from —10° F. in January to 107° F. in June. The prevailing winds blow from the southwest during the fall, winter, and spring and from the southeast during the summer. Normally there is little or no wind during the summer, but during the spring there are very strong winds most of the time. The chief climatic data for Lovington, Hobbs, and Pearl, in central Lea County, are summarized in the table below. Hobbs is on the Llano Estacado near its southern edge, and Pearl is close to the edge but below the Llano.

AGRICULTURE

Most of Lea County is devoted to cattle raising, as throughout a very large part of the county there is little or no soil, and below the Llano Estacado the rainfall is generally insufficient to grow crops without irrigation. Furthermore, the county has been held back by lack of adequate transportation facilities.

Most of the arable land is on the Llano in the eastern half of the county, and in this area there are numerous dry farms. The land is devoted chiefly to feed crops, and dairying is practiced with fair success in spite of the poor transportation facilities that existed prior to 1930. In recent years cotton has been grown successfully during seasons of normal rainfall. With irrigation from shallow wells to supplement rainfall failures resulting from droughts can be eliminated. A number of pumping plants have been installed on farms in this area during the last few years, but because of lack of experience in irrigation, the rather high cost of fuel oil, and the lack of suitable markets due to the poor transportation facilities all but a few of the pumping plants have been abandoned. However, a few farmers have successfully operated their pumping plants. With the advent of the railroads many of the difficulties that have handicapped the farmers will be eliminated or mitigated to a large extent, and it appears probable that farming can be practiced successfully even during years of subnormal precipitation.

Not all the land in the eastern half of the county on the Llano is suitable for farming. Much of it is rocky, and the soil is too shallow. In the western half of the county practically all the land is rocky and there is little or no soil. Consequently that part of the county will always be suitable only for stock raising.

CLIMATIC DATA FOR STATIONS IN CENTRAL LEA COUNTY
(U. S. Weather Bureau)

Station	Altitude above sea level (feet)	Annual Precipitation (inches)				Mean annual temperature °F.	Growing Season		Mean annual snowfall (in.)
		Length of record (years)	Minimum	Maximum	Mean		Length of record (years)	Average length of growing season	
Lovington	3,913	19	5.15	23.69	18.84	58.8	8	207	6.8
Hobbs	3,600	15	5.28	27.06	15.77	59.7	10	210	6.6
Pearl	3,750	12			12.94		7	202	9.6

GEOLOGY

STRATIGRAPHY

General Relations

Nearly all of the area considered in this report is underlain by 50 to 300 feet of Tertiary deposits, consisting chiefly of clay, sand, and gravel. These deposits rest unconformably upon red beds of Triassic age. The thickness of the Triassic sediments beneath this area is not definitely known, but according to Adams[1] they may be as much as 1,400 feet thick. The Triassic sediments consist chiefly of brick-red to purplish-red shale and sandstone and rest unconformably upon a very thick series of red beds, gypsum, anhydrite, and salt of Permian age. South and southwest of the Llano, where the Tertiary sediments have been largely removed by erosion, the Triassic sediments are concealed in most places by loose wind-blown sand and residual materials of Quaternary age. In the area specifically covered by this report only the Tertiary deposits are exposed.

Tertiary System

The Llano Estacado is the result of the deposition of 50 to 300 feet of clay, sand, and gravel upon the eroded surface of the Triassic sediments by streams flowing eastward and southeastward from the Rocky Mountains and the mountain ranges of central New Mexico during Tertiary and possibly Pleistocene time. In this area the deposits are probably all of Tertiary age, but sufficient evidence to substantiate this statement has not been obtained. The heterogeneity of the materials makes it impossible to subdivide these deposits into stratigraphic units on any grounds other than paleontologic. Owing to the scarcity of fossils in the beds, it is considered impracticable to attempt any subdivision. Hence, for the sake of convenience, the term Tertiary deposits is applied to the entire series of clay, sand, gravel, and caliche overlying the Triassic rocks.

North of T. 19 S. the upper surface of the Tertiary deposits—the present land surface—is nearly a plane. Consequently, the variations in the thickness of the deposits are due chiefly to irregularities of the ancient land surface upon which the Tertiary materials were deposited. In T. 19 S., below the undissected surface of the Llano, variations in thickness are due not only to the ancient topographic relief but chiefly to the removal of varying amounts of these deposits by erosional agencies that have been active since early Pleistocene time. In this part of the area the deposits range from about 200 feet in thickness down to the vanishing point.

As the Tertiary materials were deposited by streams, they consist not of regularly bedded and continuous strata of clay, sand, and gravel, but of a heterogeneous mass of fine material (clay, sandy clay, and fine sand) ramified by lenses or trains of coarse sand and gravel that are highly irregular in size and shape. The distribution of the coarse materials is extremely erratic, both horizontally and vertically. *Plate 2 shows the lenticular bedding characteristic of the Tertiary deposits. The heterogeneity of the materials is ascribed to erratic conditions of stream flow. At times of high floods the streams were able to transport coarse sand and gravel, but as the waters subsided they could only carry fine sand and clay. The relatively clean gravel and sands were probably deposited

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[1]Adams, J. E., Triassic of West Texas: Am. Assoc. Petroleum Geologists Bull., vol. 13, No. 8, p. 1051, 1929.

*Not included herein.

Carboniferous System

Permian Series

The Triassic sediments rest unconformably upon several thousand feet of Permian strata, the upper part of which consists of a lenticular series of red beds, gypsum, anhydrite, and salt. The uppermost Permian strata are chiefly red shale and very fine sand with interbedded lenses of gypsum, anhydrite, dolomitic limestone. According to well records the red beds are underlain by a thick section consisting chiefly of anhydrite, which in turn is underlain by a thick salt series. The entire red bed, anhydrite, and salt series are more than 1,000 feet thick. It is not exposed in the area covered by this report but crops out extensively in the Pecos Valley west of Lea County.

Structure

In general the Triassic and Permian rocks beneath this area dip gently to the east and east-southeast. The regional eastward dip, however, is interrupted by gentle folds whose location and structure can be determined only by a study of well logs or by geophysical methods. The detailed structure of the Triassic and Permian rocks has little if any bearing upon the problems connected with this investigation. Hence no study was made of it. The Tertiary deposits do not appear to have shared in the deformation that affected the older rocks.

The lenticular bedding of the Tertiary deposits and the erosional unconformity between the Tertiary and Triassic sediments are regarded as the structural features having the greatest influence on the shallow ground-water conditions in this area. An unconformity represents a fossil land surface and reveals, to a certain extent, the topography existing prior to the deposition of the overlying sediments. The unconformity in this area indicates a long interval of time during which the Triassic rocks were subjected to the forces of erosion.

OCCURRENCE AND DEVELOPMENT OF THE GROUND WATER

Definition of Terms[1]

Most of the water that enters the rocks below the surface of the earth is drawn down by gravity until it reaches a zone where the interstices of all the permeable rocks are filled with water under hydrostatic pressure. That zone is called the "zone of saturation." The term "ground water" is applied to the water in the zone of saturation.

In places, there are one or more zones of saturation, or "perched" water bodies, formed by water that is prevented from reaching the main body of ground water by impermeable beds.

The upper surface of the zone of saturation in ordinary permeable soil or rock is called the "water table." Where the upper surface is formed by impermeable rock the water table is absent.[2] As a general rule the water table conforms roughly to the land surface and slopes in the same general directions. The gradient of the water table is its rate of change in altitude per unit of distance and may be expressed in feet

[1]For more detailed definition of terms used in ground-water hydrology see Meinzer, O. E., Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, 1923.

[2]Meinzer, O. E., the occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water Supply Paper 489, p. 30, 1923.

per mile, in percentage, or in other ways. The water table fluctuates up and down from time to time in response to local gains and losses in the zone of saturation.

An "aquifer" is a formation, group of formations, or part of a formation that is water-bearing.[3] The "porosity" of an aquifer is the ratio of the aggregate volume of its interstitial openings to its total volume. The "permeability" of an aquifer is its capacity to transmit water under pressure.

General Relations

Below a certain depth, which varies from a few feet to more than 150 feet, the Tertiary deposits in this area are saturated with water. West and south of the area underlain by the Tertiary deposits the depth to the water table increases greatly. Near the west edge of the Llano water is encountered in the Tertiary deposits at depths of 150 to 200 feet below the surface; but a short distance west of the western escarpment of the Llano, where the Tertiary deposits have been removed by erosion and the surface is 200 to 300 feet or more below that of the Llano, the water table is at depths of more than 200 feet. This is strikingly illustrated by the fact that the Texas Co., in order to obtain suitable water for domestic purposes and for the drilling of wells for oil a few miles north of Maljamar, near but below the "cap rock," drilled several water wells on the Llano a few hundred feet east of the escarpment. In the vicinity of Pearl and Monument, which are along the southern edge and below the Llano, adequate supplies of water for domestic purposes, stock, and irrigation are obtained at depths of 15 to 30 feet in the Tertiary deposits. Farther south, where the Tertiary deposits have been almost or entirely eroded away, wells are 200 to 300 feet or more deep. The available evidence indicates, therefore, that the zone of saturation in the Tertiary deposits beneath and near the southern edge of the Llano is perched and is held above the main water table by the relatively impervious shale in the upper part of the Triassic formations.

Practically all the water wells in the area covered by this investigation obtain their supply from the Tertiary deposits. The water, although somewhat hard, is generally satisfactory for domestic purposes, stock and irrigation. It is reported that a number of wells drilled for oil on the Llano encountered abundant supplies of potable water in sands at depths of 300 to 500 feet. These sands are probably in the Triassic formations. No definite information was obtained as to the difference in the head of the water from the Triassic sands and that from the Tertiary deposits. Water is encountered in the Permian strata, but it is generally very highly mineralized and unfit for all ordinary purposes. Consequently, the only sources of adequate supplies of potable ground water in this region are the aquifers in the Tertiary deposits and to some extent the aquifers in the Triassic formations.

WATER IN THE TERTIARY DEPOSITS

Occurrence

The water in the Tertiary deposits occurs in the interstitial openings between the grains of sand and clay and the pebbles of the gravel deposits. Where the deposits are partly or entirely consolidated the water may also

[3]Meinzer, O. E., Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, p. 30, 1923.

occur in the openings formed by fractures or by the solvent action of ground water. The most extensive aquifers are beds of fine loose or poorly consolidated sand. Other aquifers include gravel, varying mixtures of sand and gravel, and in places beds of cavernous caliche formed by the solution and removal of parts of the calcium carbonate of which the caliche is largely composed. The cavernous caliche is often referred to locally as "honey-combed rock" or "Water rock." The solution openings in it are usually much larger than the other openings in the Tertiary deposits, and it is therefore much more permeable than the other aquifers mentioned above. According to several water-well drillers the water in the Tertiary deposits does not, as a rule, rise appreciably above the level at which it is first encountered in a well, indicating that the water is not confined under pressure. They also state that in most places in the area covered by this report there are no distinct aquifers in the Tertiary deposits separated over large areas by impermeable materials. Most of the materials penetrated below the water table are said to be water-bearing, although they are not uniform in character and water-bearing properties. It is reported that as a general rule the materials encountered at depths of 80 to 150 feet are more permeable and therefore yield water more readily than those above. However, the character of the water-bearing materials in the Tertiary deposits varies erratically from place to place.

Water Table

Beneath the Llano in T's. 12 to 18 S. the water table slopes toward the east southeast. In most of the eastern half of that area the gradient of the water table closely approximates that of the land surface, and variations in the depth to the water table are therefore due largely to the rather small irregularities in the surface of the Llano. The water table in that part of the area is generally 25 to 50 feet below the surface. In R's. 37 to 38 E. the depth to the water table is in most places 25 to 40 feet. Throughout most of the western half of the area occupied by the Llano the gradient of the water table flattens out and is less than that of the land surface. Consequently, the depth to the water table increases toward the western escarpment of the Llano and is generally 50 to more than 150 feet below the surface. Near the western escarpment the water table probably slopes toward the west. The available data, although insufficient to determine its location, indicate that this ground-water divide is not more than 2 to 4 miles east of the escarpment. In T. 19 S. and in the northern part of T. 20 S., near the southern edge of the Llano in the general vicinity of Pearl and Monument, the water table slopes toward the southeast and south-southeast. On the Llano the water table is 20 to 55 feet below the surface, but below the Llano it is 15 to 25 feet below the surface in the vicinity of Monument. The depth to the water table in different parts of the area covered by this investigation is shown on Plate 1.

It is reported that in T's. 9 and 10 S. and in most of the eastern part of T. 11 S. the depth to the water table increases notably. This may be due largely to the higher altitude of the land surface. It is also reported that the Tertiary deposits contain few aquifers that yield water readily to wells. However, owing to lack of time no definite information was obtained in regard to the ground-water conditions in that part of the county.

In many regions the water table fluctuates up and down considerably from time to time in response to local gains and losses in the water in the zone of saturation and also to changes in barometric pressures. In this region, however, there appears to be very little fluctuation in the water table, and changes in barometric pressure appear to have little or no effect upon the level of the water table. During the period November 4 to 20, 1929, the writer measured the water level in 27 observation wells in different parts of the area. In each well the measurement was made with a steel tape from a definite reference point established at the well mouth. At most of the wells a semi-permanent bench mark consisting of a brass disk and nail was used. A few of the wells have a concrete collar, and at these wells the reference point was chiseled in the concrete collar. The water levels in most of these wells were again measured (with the same steel tape and at most of the wells from the same reference points) by A. F. Brown, of the State Engineer's Department, on February 19 and 20, 1930. At seven of the wells measurements were not made or were invalidated because the windmills over the wells were pumping. At most of these wells the windmills were cut off and the water levels were measured after an interval of about 20 minutes. It was found, however, that the water level did not fully recover during that interval. The writer also found that in a number of wells which had been pumped steadily for some time the water level did not recover fully for many hours. In 13 of the remaining 20 observation wells the water level had declined 0.01 to 0.15 foot during the three-month interval from November to February, and in the other 7 it had risen 0.01 to 0.17 foot. The well showing the greatest rise in the water table (0.17 foot) is one mile south of McDonald. In a well about 5 miles southeast of Tatum the water level rose 0.10 foot, and in a well 2 miles south of Monument the water level rose 0.11 foot. In the remaining wells showing a rise in the water table, the water level rose only 0.01 to 0.04 foot. Six of the seven wells are in T's. 13, 14, and 16 S. With the exception of the wells about 5 miles southeast of Tatum, the well 1 mile south of McDonald, and a well about 8 miles west of Lovington, in which the water level lowered 0.12 foot, the water levels in the observation wells in T's. 12 to 16 S. either rose or declined only 0.01 to 0.04 foot during the three-month interval. The wells showing the largest decline in water level, 0.15, 0.13, and 0.10 of a foot, are 4 miles south, about 4 miles southwest of Knowles, and 2 miles south of Hobbs, respectively. However, in a well 3 miles north of Hobbs the water level declined only 0.02 foot. In the well in the northeast corner of T. 20 S., R. 35 E., about 5 miles southeast of Pearl, the water level lowered 0.07 foot. The water-level measurements and the dates on which they were made are given in the table of wells accompanying this report.

On January 16, 17, and 18, 1930, R. F. Black and A. F. Brown, of the State Engineer's Department, installed an automatic water-stage recorder over each of the following wells: A dug well in the NW¼ SW¼ Sec. 29, T. 12 S., R. 36 E., 1 mile west and half a mile south from Tatum; a dug well in the NW¼ SW¼ Sec. 8, T. 15 S., R. 36 E. about 6 miles north of Lovington; and a well in the NE¼ SE¼ Sec. 19, T. 19 S., R. 36 E., about 5 miles east-southeast of Pearl. The recorders were serviced on February 19 and 20, 1930, by Mr. Brown, who reported that the water levels in the wells near Tatum and Pearl had lowered 0.01 and 0.03 foot respec tively during the intervals January 16 to February 19 and January 17 to February 20, respectively. At both wells the graphs made by the recorders were essentially straight lines. Apparently variations in the barometric pressure have no noticeable effect upon the level of the water table in this region. Mr. Brown stated that the clock controlling the operation of the recorder over the well north of Lovington had stopped a few days after the recorder was installed, but that there was no change whatever in the water level in this well during the interval from January 18 to February 20.

Movement and Disposal

According to the laws of hydraulics, ground water moves in the direction of the slope of the water table—from points of high pressure to points of low pressure—and toward points of discharge such as springs and wells. The rate of movement is controlled by the gradient of the water table and the permeability of the material in the zone of saturation. It has been established that the rate of movement of ground water through a porous formation varies directly as the hydraulic gradient.[1] The rate of movement also depends on the permeability of the material through which it must move. No data have yet been obtained from which to estimate the actual rate of movement of the ground water in the Tertiary deposits in Lea County, but as the gradient of the water table is small and as the permeability of the Tertiary deposits as a whole is probably low, for the bulk of the deposits consists of fine sand and clay, the rate of movement of the ground water is probably very slow. Gould,[2] in referring to the rate of movement of the ground water in the Tertiary deposits underlying the Panhandle of Texas, states that "it is doubtful if on an average the water moves more than 10 feet in a year." If the movement of ground water is fairly rapid the water table in an intake area is likely to decline appreciably during seasons when there is little or no recharge. The fact that the water table in this area remained practically stationary at a time when there was probably little if any recharge seems to indicate sluggish movement of the ground water. The rate of movement doubtless varies considerably in different places, for the trains of coarse sand and gravel in the Tertiary deposits, being much more permeable than the fine sand and clay, allow a more rapid movement of water through them. Moreover, the gradient of the water table is not everywhere the same. Along the southern edge of the Llano it is somewhat greater than it is beneath most of the Llano.

The ground water is disposed of through springs and wells and, where the water table is close to the surface, by evaporation and by the transpiration of plants. Nearly all the springs fed by ground water in the Tertiary deposits are along the edge of and below the surface of the Llano Estacado. Most of the springs are along the eastern, southern and northern margins. The springs are usually located at the base of the bluffs and along the contact between the Tertiary deposits and the underlying Triassic formations. According to the information obtained by the writer there are only two such springs in the region considered in this report. One, known as the Mescalero Spring, is at the base of the bluffs in Sec. 28, T. 11 S., R. 31 E. The other is in Monument Draw, in the south half

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[1]King, F. H., Principles and conditions of the movements of ground water: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 329, 1899.

[2]Gould, C. N., The geology and water resources of the western portion of the Panhandle of Texas: U. S. Geol. Survey Water-Supply Paper 191, p. 39, 1907.

of T. 19 S., R. 36 E. No information was obtained in regard to the amount of water discharged through these springs.

In places along the southern edge of the Llano the water table is close to the surface, and some of the ground water is doubtless disposed of through evaporation and transpiration by plants. The transpiration is the more effective process and probably accounts for the disposal of a large amount of ground water in that part of the area, for there are in places thick growths of mesquite, which usually sends its roots down to the water table and feeds largely upon ground water. Plants that depend largely upon ground water are known as "phreatophytes," or ground-water plants.[1] In T. 12 S., R. 38 E., the water table is very close to the surface in a few places in the bottom of a shallow draw, and in one place an artificial spring was made by digging a few feet down to the water table. It is used as a water hole for cattle. Throughout most of the area, however, the water table is too far below the surface to allow the disposal of ground water by evaporation or transpiration. Considerable water is also removed by pumpage from wells and by the flows of a few springs. In addition, water from the Tertiary deposits may sink to a deeper water table near the southern and western margins of the Llano.

Source and Quantity of Recharge

In most regions the water that falls upon the surface of the earth as rain or snow is disposed of in four ways: (1) direct run-off into streams and thence into the ocean; (2) transpiration by plants; (3) evaporation; and (4) seepage of water into the zone of saturation in the rocks. As a general rule the potable ground water recovered in wells is derived from that portion of the precipitation which eventually sinks into the ground. In the Llano Estacado there are no extensive surface drainage systems which carry off water that falls as rain or snow into the ocean or even into regions away from the Llano. It is true that the rainfall does not everywhere remain at or close to the place where it strikes the surface. The Llano Estacado is not perfectly flat. It slopes gently toward the east, east-southeast, or southeast, and water flows at the surface in many places after heavy rains. However, the water does not as a rule run far, and except near the margins of the Llano it does not flow off of the Llano. This is due to several factors. The surface of the Llano Estacado is remarkably smooth, and consequently, there is little opportunity for any great amount of rainfall to be concentrated along definite channels. There are incipient stream channels in many places, but they either fade out eastward within a few miles or drain into circular depressions from which there are no surface outlets. Furthermore, the ground is nearly everywhere covered by a mat of vegetation, chiefly grass, that greatly hinders the flow of water and thereby protects the ground from erosion by running water and prevents to a large extent the development of definite channel ways. In addition, the rains are so infrequent that the ground ordinarily becomes rather dry between rains and therefore absorbs moisture readily. Consequently, it is only during periods of heavy and prolonged rainfall that there is any appreciable flow of water at the surface.

A large proportion of the rainfall is disposed of by evaporation, as the air is normally dry. During the months of greatest precipitation—

[1]Meinzer, O. E., Plants as indicators of ground water; U. S. Geol. Survey Water-Supply Paper 577, 1927.

May to September—there is little wind, but the air is warm or hot and absorbs moisture quickly. During the fall, winter, and spring the wind generally blows more or less continuously, and during the spring the winds are very strong. Consequently, the rate of evaporation is relatively high the year round. A large proportion of the rainfall is also consumed by the plants. The rest sinks beyond reach of the roots and eventually reaches the zone of saturation in the Tertiary deposits. In many places the upper 10 feet or more of the Tertiary deposits are very fine-grained and have been firmly cemented together by calcium carbonate, forming hard, dense caliche that is only slightly permeable. In others, however, either there is little or no caliche near the surface or the caliche is comparatively soft and much less dense. Consequently, aside from local variations in precipitation, the amount of water that sinks into the ground and reaches the zone of saturation in the Tertiary deposits probably varies considerably from place to place, depending upon the permeability of the Tertiary materials above the water table.

In considering the possible sources of the ground water in the Tertiary deposits several facts must be borne clearly in mind. (1) The direction of the maximum gradient of the water table is east-southeast and southeast throughout most of the area occupied by the Llano. Therefore, the source of the ground water in the Tertiary deposits can not be at the east or south. It must be within or west and northwest of this area. (2) The Tertiary deposits underlying this area are cut off from the regions west, northwest, and north of the Llano Estacado by the western and northern escarpments of the Llano. (3) The western escarpment of the Llano lies along or close to the west boundary of Lea County. It is evident, therefore, that there are only two possible sources of the ground water in the Tertiary deposits in this area: Precipitation on the Llano in the northern half of Lea County and upward seepage of ground water in the Triassic and Permian formations into the Tertiary deposits.

It is obvious that the water in the formations underlying the Tertiary deposits can not be forced up into them unless the water is under a very considerable artesian pressure. It is also obvious that the water can not be under sufficient artesian pressure unless it is confined at a level at least as high as that of the water table in the Tertiary deposits underlying the Llano. The only regions to which the Triassic and Permian formations extend continuously and lie at altitudes higher than that of the Llano Estacado are west, northwest, and lie north of this area. The Triassic formations crop out in a wide belt between the Llano Estacado and the Pecos River, but the surface between the Llano and the Pecos slopes toward the west and is at a considerably lower altitude than that of the Llano. The only areas in which the Triassic formations crop out at an altitude higher than that of the Llano are north and northwest of the Llano Estacado—in the general vicinity and north of Fort Sumner and Tucumcari. It is conceivable, though probable, that water entering the Triassic formations in those areas might be confined under sufficient artesian pressure to be forced up into the Tertiary deposits in this area. However, the strata in the Triassic formations are lenticular, and it does not appear at all probable that the aquifers in those formations extend continuously from the outcrop areas into this area. Furthermore, the uppermost Triassic formations beneath this area consist very largely of impermeable shales. Hence, even if the aquifers in the lower part of the Triassic formations extend continuously from the outcrop areas into this area and even if they contain water under high artesian pressure, both of which appear improbable, it is very improbable that any appreciable quantity of the water in the Triassic aquifers is forced up into the Tertiary deposits through several hundred feet of relatively impermeable shale. The ground water in the Triassic formations, therefore, can not be considered an important source of the ground water in the Tertiary deposits beneath this area, and it is extremely improbable, if not impossible, that any of the water in the Tertiary deposits is derived from the Permian formations. In addition to the fact that the uppermost Permian and Triassic strata consist largely of impermeable shale, the formations in the upper part of the Permian contain large quantities of gypsum, anhydrite, and salts which are easily soluble in water. Nearly all the water in the red bed, anhydrite, and salt series of the Permian is very highly mineralized, whereas the water in the Tertiary deposits, although rather hard, has no noticeable taste and is of good quality for domestic purposes. Even if the artesian aquifers[1] which supply the wells in the Pecos Valley and which are stratigraphically lower than the Permian red beds eastward beneath this area, the water in them could not be forced up into the Tertiary deposits, because it is not under sufficient pressure. Furthermore, the water would have to be forced through the gypsum, anhydrite, and salt series and would thus become highly mineralized.

From the foregoing discussion it is quite evident that the only probable source and perhaps the only possible source of the ground water in the Tertiary deposits underlying this area is the rain and snow that fall on the Llano Estacado in or near the northern half of Lea County. The data available at present are too meager to permit an estimate of the amount of the annual recharge. Continuous records of the water levels in three wells since January 19, 1930, have been obtained by means of automatic water-stage recorders, and measurements of the water level in a number of observation wells have been made since November, 1929. During the period in which the records were obtained there was very little change in the level of the water table, and it is inferred that during this period there was little or no recharge from precipitation. However, it must be remembered that during the fall and winter the average monthly precipitation is about half an inch or less and as a general rule not all of it falls at one time. During the long intervals between these light rains or snows the ground has a chance to dry out, and as the interstitial openings in the Tertiary deposits are small, most of the water that sinks into the ground is probably held in the upper few feet of soil or rock by the force of adhesion. It is not until the materials above the water table become thoroughly moistened that notable quantities of water derived from precipitation reach the zone of saturation. Hence the light precipitation during most of the fall, winter, and spring probably contributes little or no water to this zone. During the summer rainy season there may be larger additions. Moreover, the uppermost Tertiary materials are fine grained, and the interstitial openings through which the water must percolate are very small. Consequently water that sinks into the ground can not reach the zone of saturation quickly. It is not to be expected, therefore that the level of the water table will respond immediately to the precipitation.

[1]Fiedler, A. G., and Nye, S. S., Geology and water resources of the Roswell Artesian Basin, New Mexico: U. S. Geol. Survey Water-Supply Paper (in preparation).

Furthermore, there is a wide variation in the amount of annual precipitation on the Llano Estacado in Lea County. It is quite evident, therefore, that from records covering only a few months and especially records obtained only during the months of least precipitation no definite conclusions can be drawn in regard to the annual recharge of the zone of saturation or to the proportion of the precipitation that contributes to the zone of saturation in the Tertiary deposits. An intelligent estimate of the annual recharge can be made only on the basis of accurate and continuous records of the fluctuation of the water table and of the precipitation over a period of years. It is very important, therefore, that the water-stage recorders which have been installed over wells in this area be maintained and that the monthly measurements of the water levels in the observation wells be continued for a period of years. The investigation has been planned with a view to obtaining such a long-term record.

Factors Influencing the Yield of Wells[1]

When a well is drilled it remains dry until it penetrates a permeable bed below the upper surface of the zone of saturation. Then water enters the well. The yield depends on the size and construction of the well and on the thickness and the permeability of the formations encountered below the water table. Porosity is often expressed as the ratio between the total volume of the interstices in a rock and the total volume of the rock. The size of the interstices does not affect the porosity. The permeability of a rock, on the other hand, depends not only upon the number of interstices, but also upon their size and the extent to which they open into one another. A clay may have a porosity equal to or greater than that of a sand, but it is so impermeable that it will not yield water readily. For that reason a well ending in clay remains empty even though the clay may be saturated with water.

It is practically impossible to predict the yield of a well drilled into the Tertiary deposit without first putting down a test hole, for the number, character, and water-yielding capacities of aquifers in these deposits are too erratic. One well may encounter mostly clay with only a few thin beds of sand; another well a short distance away may pass through several thick beds of coarse sand or gravel in the zone of saturation. This is to be expected and may be understood from the discussion of the origin and nature of these deposits given on a preceding page.

DEVELOPMENT

Wells

Information was obtained in regard to more than 100 representative wells on the Llano Estacado in Lea County and along the southern edge of the Llano. Most of the wells are in the eastern half of the county—in the most thickly settled part, which coincides roughly with the area in which the water table is less than 50 feet below the surface. All the wells draw from aquifers in the Tertiary deposits. They range in depth from 19 to 217 feet, but most of the wells on the Llano in the eastern half of the county are 40 to 80 feet deep. Most of the wells are drilled and are

[1]For more detailed discussion, see: Meinzer, O. E., The occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, pp. 2-4, 28-31, 50-52, 1923.

5 to 6 inches in diameter. The wells drilled for irrigation, however, are 8 to 18 inches in diameter. Some of the wells are dug, and some are both dug and drilled. The dug wells are generally 3 to 6 feet in diameter or in maximum dimension if they are rectangular.

All but a few of the wells have no casing, for in the central and eastern parts of the area the upper 50 feet or so of the Tertiary deposits is sufficiently firm to stand up without any casing. It is reported that in the western part of the area, however, the Tertiary deposits below the caliche are so loose that the wells must be cased. All the wells in the western part of the county in regard to which information was obtained are cased to the bottom. At the time of this investigation the drilled wells about 6 inches in diameter cost only $1.00 a foot. Those 8 or 9 inches in diameter cost only $1.00 to $1.50 a foot. Several wells 14 inches in diameter cost $2.00 a foot, and a well 18 inches in diameter cost $3.00 a foot.

Domestic and Stock Supplies

Water for domestic and stock supplies is obtained from drilled or dug wells. Many farms and ranches have two or more wells at or near the house. Practically all the wells are equipped with windmills, and many, in addition, have pump jacks attached to the windmills, as there is little or no wind during a large part of the summer months. In the eastern half of the area, where the water table is less than 50 feet below the surface, the wells are generally less than 70 or 80 feet deep, but in the western half the wells are 80 to 200 feet or more deep. Nearly every home in Lovington and Tatum had a well 60 to 80 feet deep equipped with a windmill.

Municipal Supplies

At the time of this investigation Hobbs was the only town in the area that was reported to have a municipal water-supply system, although it was stated that a bond issue to finance the installation of a municipal system at Lovington had been authorized. No detailed information was obtained in regard to the municipal supply at Hobbs. It is said to be obtained from wells drawing from the Tertiary deposits.

IRRIGATION SUPPLIES

Pumping Plants

In November, 1929, about 41 wells had been drilled for irrigation on the Llano and along the southern edge of the Llano in the eastern half of the county. Of these, 17 had either been entirely abandoned or were no longer in use, and 24 were still in use, although not every season. A few of the wells were equipped with turbine pumps, but most of them were equipped with centrifugal pumps. The latter were dug close to or a few feet below the water table and drilled the rest of the way. Most of the pumps were operated with Fordson tractors. The rest were operated with various types of kerosene, distillate, or oil engines. According to information obtained by Mr. Beaty, the county agent, and by the writer, the total cost of the pumping plants that had been installed, including the wells, ranged from $300 to $1,900, depending upon the depth and construction of the well and the equipment used. The cost of most of the pumping plants (including the wells), however, was between $1,000 and $1,500.

Yield and Drawdown of Wells

The pump wells in regard to which information was obtained are reported to yield from 200 to 700 gallons a minute. The wide variation in yield is due in large part to differences in the methods of construction of the wells and the type of equipment used. It is also due, however, to variations in the water-yielding capacity of the aquifers encountered by the wells. According to the information obtained by the writer the drawdown in the wells ranges from 3 to 20 feet and is not at all proportional to the yields of the wells. A well in the NW¼ NW¼ Sec. 32, T. 19 S., R. 36 E., was reported to have a drawdown of 18 to 20 feet when pumped at the rate of about 250 gallons a minute, whereas a well in the NE¼ NE¼ Sec. 24, T. 19 S., R. 35 E., was reported to have a drawdown of only 3 feet when pumped at the rate of 300 to 400 gallons a minute, and a well in the NW¼ NW¼ Sec. 30, T. 17 S., R. 38 E., was reported to have a drawdown of only 7 to 10 feet when pumped at the rate of about 700 gallons a minute. No opportunity was afforded, however, to make pumping tests and obtain specific information in regard to the yield and drawdown of any of the wells used for irrigation. It is planned to make a number of pumping tests during the summer of 1930. A rough test was made of the yield and drawdown of a shallow windmill well in the NW¼ NW¼ Sec. 4, T. 19 S., R. 37 E. The well had been pumped steadily for some time, and before the windmill was cut off the water level in the well was about 27 feet below the surface. Fifteen minutes after the windmill was cut off the water level in the well had risen about 4.8 feet, and after 40 minutes it had risen about 5 feet. The water level thus rose quickly during the first 15 minutes and very slowly during the next 25 minutes. Forty minutes after the windmill was cut off, although the water level was still rising very slowly, the windmill was turned on again, and 15 minutes later it was found that the water level had been lowered about 3.7 feet. During this time the windmill was pumping at the rate of 13 to 14 gallons a minute.

It is evident that there is a very wide variation in the yield and drawdown of wells drawing from aquifers in the Tertiary deposits. This is to be expected, for the character and water-bearing properties of the Tertiary deposits are not uniform but vary from place to place, even within very short distances. Hence the fact that a well at one place has a large yield and a small drawdown is no assurance that a well a short distance away will have a similar yield and drawdown. This may be readily understood from the discussion of the character, structure, and origin of the Tertiary deposits.

Extent of Shallow-water Area

The ground water in the Tertiary deposits is relatively shallow throughout all of the area occupied by the Llano Estacado in Lea County, but it is not everywhere within an economic pumping distance of the surface. There is no fixed maximum pumping lift for water for irrigation. The economical pumping lift depends upon many factors, such as the value of the crops raised, the cost of the fuel and labor required to operate the pumping plants, and the amount of water that must be pumped for irrigation each season, which vary widely in different regions and from time to time in the same region. In some regions it is economically feasible to pump water 100 to 150 feet or more for irrigation, and in others the economical pumping lift is less than 50 feet. It was not found practicable with the scanty data at hand to determine accurately the economical pumping lift in this area. It is doubtful if any set limit can be fixed, for one man may be able to operate a pumping plant much more efficiently and economically than another, and the factors entering into the determination of the economical pumping lift may change notably in a few years with the advent of the railroad. After a general consideration of the conditions in this region 50 to 60 feet has been assumed as the economical pumping lift in this area at the present time.

The approximate limits of the area in which the water table is less than 50 feet below the surface are shown on Plate 1. It includes most of T's. 12 to 15 S., R's. 35 to 38 E., and T's. 16 to 19 S., R's. 36 to 39 E., and a narrow belt extending northwestward on both sides of the highway between Tatum and Caprock. As the effective pumping lift is the sum of the depth to the water table and the amount of drawdown in a well, and as the amount of drawdown may be much more than 10 or 15 feet and therefore excessive in many places, it is probably not economically feasible to pump water for irrigation through all of the area outlined on Plate 1, especially near the western edge, where the water table is 45 to 50 feet below the surface. Furthermore, there are many places within that area, especially in the western portion, where there is little or no soil or where the soil is too shallow to raise crops successfully. In the eastern half of the area, however, in which the water table is generally less than 40 feet below the surface, most of the land is underlain by 2 to 3 feet or more of soil. Throughout most of the area on the Llano west of the area outlined above in which the water table is less than 50 feet below the surface, the caliche capping the Tertiary deposits is at or very close to the surface and there is little or no soil. There are very few places in that part of the county in which the soil is deep enough to grow crops successfully. Consequently, even if it should later be found profitable to pump water more than 50 or 60 feet for irrigation that part of the county will probably always be utilized only for stock grazing.

Present Development

There are numerous farms in the shallow-water area, but pumping plants have been installed on only a few of them. It was not until a few years ago that it was found possible to pump sufficient water for irrigation by drilling wells of large diameter to depths greater than had been necessary to obtain adequate supplies of ground water for domestic purposes and stock. As few of the farmers had had any experience in irrigation, several of those who installed pumping plants failed and others met with such little success that they abandoned or discontinued the use of the pumping plants after a year or two. Furthermore, feed crops and cotton can be grown with a fair amount of success during years of normal or abnormal precipitation, and as the years of subnormal precipitation are generally separated by several years of adequate precipitation, most of the farmers get along without resorting to irrigation. However, the farmers who have continued the use of irrigation have been quite successful and now state that they would not consider abandoning their pumping plants.

At the present time irrigation is used only to supplement rainfall in growing feed crops and cotton and in a few localities alfalfa. Some of the farmers near Pearl irrigate a few acres of garden truck, which they sell in near-by communities that have grown up recently as a result of the oil activity in the southern half of the county. The feed crops and cotton require only two to four irrigations a season, depending upon the amount of rainfall. Alfalfa and truck crops, of course, require more.

Considering the size of the area in which the ground water in the Tertiary deposits is within an economical pumping distance of the surface, it is evident that there has been very little development of the ground water for irrigation. It is expected, however, that irrigation development will be greatly stimulated by the improvement of markets and transportation facilities, the attraction of new settlers as a result of the construction of a railroad into the county, and the growth of nearby towns due to the oil development in the southern half of the county.

Quality of Water from the Tertiary Deposits

Samples of water from the Tertiary deposits were taken from 15 representative wells in various parts of the area for partial chemical analysis. They were analyzed by W. L. Lamar, of the United States Geological Survey, and the results are given in the following table.

PARTIAL ANALYSES OF WATERS FROM TERTIARY DEPOSITS IN LEA COUNTY, NEW MEXICO

Analyzed by W. L. Lamar

Number of wells corresponds to numbers in table of well records.
Parts per million.

Well from which sample was collected: No.	Well from which sample was collected: Owner	Date of Collection (1929)	Temperature	Total Dissolved Solids (calculated)	Calcium a/ (Ca)	Sodium and Potassium (Na-K) (calculated)	Carbonate Radical (CO3)	Bicarbonate Radical (HCO3)	Sulphate Radical (SO4)	Chloride Radical (Cl)	Nitrate Radical (NO3)	Total Hardness as CaCO3
9	Jerry Clay	Nov. 16	63	b/558	90	26	0	237	a/ 54	41	14	262
15	R. J. Craig..........	Nov. 16	..	1,157	145	263	0	230	401	222	35	375
18	School	Nov. 16	64	440	80	81	0	236	126	40	2.4	207
21-A	Tom Parsley	Nov. 14	62	739	130	137	0	209	199	169	11	327
22	J. W. Gray..........	Nov. 15	64	373	84	50	0	217	a/ 64	51	15	220
29	J. W. Shaddix......	Nov. 15	..	381	76	51	0	237	a/ 92	30	4.5	226
33	R. Heidel	Nov. 13	63	513	88	104	0	332	a/104	53	4.5	232
43	Miller Eidson	Nov. 7	65	254	60	28	0	216	a/ 28	22	0	176
47	J. P. Beverly.......	Nov. 6	63	410	84	62	0	254	a/ 54	38	44	218
49	E. B. Eaves.........	Nov. 6	..	336	84	38	0	225	a/ 62	28	12	216
67	J. S. Anderson......	Nov. 4	63	409	80	113	0	227	102	44	4.7	212
72-A	G. H. Lumpkin.....	Nov. 18	63	396	80	47	2.0	210	111	37	2.3	242
80-A	D. B. Wilhoit.......	Nov. 19	63	597	95	125	0	363	124	65	12	256
95-A	S. P. Jordan........	Nov. 20	64	668	84	158	0	261	225	79	6.8	222
96	Virgil Linam	Nov. 19	62	383	68	71	0	307	a/ 54	32	0	198

a/ By turbidity.
b/ Sample filtered. Iron in sediment 2.9 parts per million.

There is comparatively little variation in the quality of the water from the Tertiary deposits, and as shown by the analyses given above all the water is hard. However, most of the water is softer and much of it less mineralized than that used in the Roswell Artesian Basin. All the water is potable, and most of it has no noticeable taste. All the water from the Tertiary deposits in the area covered by this investigation can be used for domestic purposes, stock, and irrigation.

WATER IN THE TRIASSIC FORMATIONS

It is reported that in the southern half of the county, where the Tertiary deposits have been very largely or entirely removed by erosion, practically all the potable water obtained from wells is derived from sandstones in the Triassic formations. It is also reported that several wells drilled for oil in the Llano in the northern half of the county encountered abundant supplies of potable water in sandstones that are probably in the Triassic formations. No specific information, however, was obtained in regard to the aquifers and the water in the Triassic formations underlying Lea County.

WATER IN THE PERMIAN FORMATIONS

Although no specific information was obtained as to water in the Permian formations it is reported that deep wells drilled for oil in the southern part of the county encountered very highly mineralized water in these formations. In some places the water was so highly charged with hydrogen sulphide that men near the drilling rig fell unconscious after breathing the gas for a few seconds. The Permian formations beneath this area contain large amounts of gypsum, anhydrite, and salts. Consequently, practically all the water in them is highly mineralized, and it does not appear probable that they can be regarded as a source of ground-water supplies for any ordinary purpose.

CONCLUSIONS AND RECOMMENDATIONS

The ground water in the Tertiary deposits beneath the eastern half of the area considered in this report, T's. 11 to 19 S., is a relatively undeveloped economic resource that merits more serious consideration than it has thus far been accorded by the residents of this area. There are many years during which the precipitation is entirely inadequate to grow crops successfully, and crop failures at such times could be prevented by irrigation with water pumped from relatively shallow and inexpensive wells. The total cost of installing a pumping plant, including the cost of a satisfactory well, is relatively low compared with the cost in many other regions. Such an investment, even if it is considered merely as an insurance against crop failure, is worth while.

The ground water in the Tertiary deposits beneath this area may be considered an underground reservoir and may be compared to a surface reservoir in that additions and subtractions to it are being made constantly. A certain amount of water, which probably varies from year to year, is added to the underground reservoir by the water that falls as rain or snow on the Llano Estacado within Lea County, sinks into the ground, and eventually reaches the zone of saturation in the Tertiary deposits. Water is constantly being withdrawn from the underground reservoir through wells and springs and in other ways. It is evident, therefore, that if the amount of water withdrawn from the underground reservoir exceeds that which is added to it from time to time, the ground-water supply will be gradually depleted. It should be distinctly understood, therefore, that the supply of ground water in the Tertiary deposits is not inexhaustible in the sense that there is no limit to the amount of water that can be developed for irrigation. The supply will never be entirely exhausted, but if the ground water is developed to such an extent that the draft upon the underground reservoir greatly exceeds the annual recharge, the water table will be lowered until it is no longer economically feasible to pump the water for irrigation. If the ground-water supply is overdeveloped the pumping plants in the western part of the shallow-water area outlined on Plate 1 will be the first to be abandoned, but if the overdevelopment continues pumping plants in other parts of the area will in time have to be abandoned also.

In order to develop intelligently and conserve the supply of shallow ground water in the Tertiary deposits, it is recommended that continuous records of the position and fluctuation of the water table be obtained by means of automatic water-stage recorders installed over a few observation wells that are not in use and not very close to pumping plants or other wells that are pumped, and by periodic measurements of the water level in a number of other representative observation wells in different parts of the shallow-water area. The wells used for observation should be abandoned wells or wells that are used only infrequently, as the true position of the water table can not be obtained if a well is being pumped nor as a rule, within a reasonable length of time after a pump is cut off. It is also recommended that accurate records be kept, so far as possible, of the total amount of water pumped for irrigation each year within the shallow-water area in Lea County. In order to do this, records should be obtained of the number of pumping plants operated each year, the number of times each pumping plant is operated during the year, the length of time each pumping plant is operated, and the rate (in gallons a minute) at which each pumping plant is operated.

If it should be found after a period of years that the water table is being excessively lowered the farmers who have installed pumping plants should be given legal protection against further depletion of the supply by prohibiting the installation of new pumping plants for the irrigation of additional acreage.

As a result of a recommendation for the conservation of the artesian water in the Roswell Artesian Basin, which was made by A. G. Fiedler in a preliminary report[1] on that area, a law[2] was passed by the New Mexico State Legislature in March, 1927.

[1]Fiedler, A. G., Report on investigations of the Roswell Artesian Basin, Chaves and Eddy Counties, N. Mex.: New Mexico State Engineer Seventh Biennial Report, p. 60, 1926.

[2]New Mexico State Legislature, 8th Sess., Chap. 182, House Bill 314, approved March 16, 1927.

AN ACT

DECLARING WATERS IN UNDERGROUND STREAMS, ARTESIAN BASINS, RESERVOIRS, AND LAKES TO BE PUBLIC WATERS AND SUBJECT TO APPROPRIATION: CONFIRMING EXISTING RIGHTS TO THE USE OF SUCH WATERS; AND REGULATING APPROPRIATION, USE, AND MANAGEMENT THEREOF.

Be it enacted by the Legislature of the State of New Mexico:

Section 1. All waters in the State found in underground streams, channels, artesian basins, reservoirs, or lakes, the boundaries of which may be reasonably ascertained by scientific investigations or surface indications, are hereby declared to be public waters and to belong to the public, and subject to appropriation for beneficial uses under the existing laws of this State relating to appropriation and beneficial use of waters from surface streams.

Section 2. The State Engineer shall have the supervision and control of all such underground waters and of the method and manner of appropriation and use thereof, under the laws of this State.

Section 3. All waters of such underground streams, channels, artesian basins, reservoirs, or lakes now being used for beneficial purposes are hereby recognized as valid appropriations of such waters and hereby confirmed, and such use shall be subject to the rules and regulations of the State Engineer under the laws of this State.

Section 4. This Act is not intended to apply to the construction of wells by persons, corporations, or municipalities to obtain waters for domestic or stock-raising purposes.

Section 5. Upon the passage and approval of this Act, the State Engineer of the State of New Mexico shall proceed to the administration of the same as to any particular underground stream, channel, artesian basin, reservoir, or lake as defined in Section 1 hereof, upon a petition being presented to him requesting him so to do, signed by not less than 10 per cent of all the users of waters of such defined underground streams, channels, artesian basins, reservoirs, or lakes.

Section 6. That it is necessary for the preservation of the public peace, health, and safety of the inhabitants of the State of New Mexico that the provisions of this Act shall become effective at the earliest possible time, and therefore an emergency is hereby declared to exist, and this Act shall take effect and be in full force and effect from and after its passage and approval.

In January, 1929, as a result of a test case brought before the Supreme Court of the State of New Mexico, the law declared right in principle but unconstitutional because of a technicality.

Although there is no immediate danger of an overdevelopment of the shallow ground-water supply in Lea County it is by no means beyond the realm of possibility. If the law cited above is reenacted it is recommended that the residents of the area outlined on Plate 1 organize a conservancy district and petition the State Engineer to administer it in accordance with the provisions of the law in order that overdevelopment may be prevented. The farmers who have installed pumping plants should protect their investments by obtaining legal water rights to the amount of water necessary for the irrigation of the land they have under cultivation. It should be recognized, however, that some of the provisions of the law of 1927 and of previous laws with respect to the construction of wells and the weight of casings required, which were passed with special reference to conditions in the Roswell Artesian Basin, should not be applied in this area. The method of construction of wells in this area affects only the individual owner and has no effect upon the ground-water conditions in adjoining areas.

This paper is a preliminary report. Further field work will be done during the summer of 1930. In addition, it is planned to continue the investigation for several years by obtaining continuous records of the fluctuation of the water table in a few representative wells, periodic measurements of the position of the water table in other wells, records of the position of the water table in still other wells, records of the amount of water pumped for irrigation, records of the precipitation, and other data that will permit an estimate of the amount of recharge of the ground water in the Tertiary deposits. In this way it is hoped that an estimate can be made of the acreage which can be safely placed under irrigation with water from these deposits.