GROUND-WATER RESOURCES IN THE VICINITY OF NOCONA, MONTAGUE COUNTY, TEXAS

By
W. L. Broadhurst and C. R. Follett

PREPARED IN COOPERATION WITH THE UNITED STATES DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY

December 1944

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INTRODUCTION

The City of Nocona is in north-central Montague County about 75 miles northwest of Fort Worth. The population was 2,605 in 1940 and somewhat less than 3,000 in 1944. The municipal water supply has been obtained from deep wells since about 1912; and the present supply is obtained from nine wells ranging from 371 to 727 feet in depth, which draw water from sands and sandstones of Carboniferous age. The water is pumped with Peerless Hi-Lift pumps and cylinder pumps; and the yield of the pumps ranged from 6.5 to 32 gallons a minute, a total of about 170 gallons a minute from the nine wells, when they were measured in November 1944 (see well tables on p. 10.) The facilities for storing water consist of an elevated tank and a concrete reservoir having a combined capacity of 150,000 gallons, which is sufficient for only about half a day's supply during periods of heavy demand. Because of the small yield of the wells and lack of adequate storage, the city has been "out of water" many times.

In the summer of 1944 a Citizens Water Committee was appointed to investigate the water resources available to the city; and in July the Texas State Board of Water Engineers received a formal request for assistance from Mr. Harry L. Whitman, Chairman of the Citizens Water Committee.

In response to this request, a field investigation of the ground-water resources in the vicinity of Nocona was made by the Geological Survey, U. S. Department of the Interior, in cooperation with the State Board of Water Engineers. The work was done between November 7 and 20, 1944 by the writers under the direction of Walter N. White, Principal Engineer in the Geological Survey, who is in charge of the ground-water work in Texas. The field work consisted of an inventory of water wells in the vicinity of Nocona and a series of pumping tests on part of the municipal wells. Samples of water were collected from several wells in the area, and chemical analyses of the water were made by W. W. Hastings, Chemist, Quality of Water Division of the Geological Survey at Austin.

Geology

The surface geology of Montague County is relatively simple. Rocks of Carboniferous age underlie the entire area and in general dip northwestward at the rate of about 70 feet to the mile. Resting unconformably upon these rocks in the southeastern part of the county are sands, clays, and limestones of Cretaceous age, which dip southeastward at the rate of about 40 feet to the mile. A geologic map of Montague County is shown in figure 1. This map was reproduced from the University of Texas Bulletin 3001 1/, through the courtesy of Dr. E. H. Sellards, Director of the Bureau of Economic Geology.

The Carboniferous rocks, which crop out in Montague County and underlie Nocona to a depth of approximately 2,000 feet, consist of variegated red, brown, and blue shales and sandy shales that grade horizontally and vertically into cross-bedded sandstones. The sandstones are locally conglomeratic but consist chiefly of very fine-grained quartz sand and silt, and as a rule they yield only small quantities of water to wells.

The southeastern part of the county is underlain by rocks of the Trinity group of Cretaceous age. These rocks dip toward the southeast and consist chiefly of fine-grained quartz sand occurring in massive beds 20 to 40 feet thick. Numerous clay beds ranging from a few inches to several feet in thickness occur throughout the group. The base of the Trinity is marked by a conglomerate containing well-rounded quartz pebbles that are an inch or more in diameter. The sands of the Trinity group yield water to wells more freely than the underlying sandstones of the Carboniferous, but in the outcrop area (designated on the map by the symbol Kt) the water is rather hard.

For discussions of the geologic formations in Montague County, the reader is referred to the reports by Gordon 2/ and Bullard and Cuyler 3/ .

1/ Contributions to geology, The University of Texas Bulletin 3001, opposite p. 64, 1930.

2/ Gordon, C. H., Geology and underground waters of the Wichita Region in north-central Texas: U. S. Geol. Survey Water-Supply Paper 317, pp. 35-44, 1913.

3/ Bullard, F. M. and Cuyler, R. H., A preliminary report on the geology of Montague County, Texas: The University of Texas Bull. No. 3001, pp. 37-76, 1930.

Records of wells, well logs, and water analyses

Data regarding the Nocona wells, several privately owned wells in the vicinity of Nocona, the City of Bowie well near Stoneburg, and old wells at Bowie and Montague are given in the tables of well records, well logs, and water analyses. The locations of the wells are shown in figure 1; and brief discussions of the wells are given below.

Nocona wells.- The investigation disclosed that partial logs of wells 5, 7, and 8 were the only written records available for eight of the wells. These eight wells furnished all the municipal water supply prior to April 1944 when well 9 was put down. The following information was obtained orally from Mayor Jack Foster and several city employees, from Mr. Jack McBride, well driller at Nocona who deepened several of the wells, and by observations of the writers during the investigation.

Well 1 is a few feet east of the concrete reservoir. The year in which it was drilled and the original depth of the well are unknown; however, the well was deepened to 388 feet by Mr. McBride, who reports that sand was encountered from 375 feet to the bottom of the well. The well is equipped with a Peerless Hi-Lift pump. The yield on November 17, 1944, after five days of continuous operation, was 32 gallons a minute. The water level in the well was not measured.

Well 2 was drilled to a depth of about 600 feet in 1926, and for several years thereafter it was pumped with air. In the summer of 1944 it was deepened to 712 feet with a spudder, and the driller reports that the only sand encountered was from 682 to 704 feet. The well is equipped with a jack pump. The yield on November 17, 1944 was 19 gallons a minute after two hours pumping, and at this rate the pump apparently was sucking air. Five days after the pump had been shut down, and 48 hours after the pump in well 9, located 190 feet away which draws from the same sand, had been shut down, the water level in well 2 was 268 feet below the surface.

Well 3 was drilled to a depth of about 600 feet in 1926 and was formerly pumped with air. It is now equipped with a Peerless Hi-Lift pump, and the yield on November 17, 1944 was 10½ gallons a minute. The depth to water in this well was not measured.

Well 4 was drilled to a depth of about 600 feet in 1926, and it too was formerly pumped with air. It is equipped with a jack pump, and the yield on November 17, 1944 was 6½ gallons a minute. The water level was not measured.

Well 5, about one-fourth mile east of the pump station, was drilled to a depth of 405½ feet in 1938. (See log.) Some time later the well was deepened to about 525 feet. It is equipped with a jack pump, and the yield on November 13, 1944 was 12 gallons a minute. On November 16, about 68 hours after the pump had been shut down following about 72 hours of pumping, the water level was 321 feet below the surface. Well 6, the only other nearby well that had been pumped recently, had been shut down 68 hours. (See inset map.)

Well 6, located 124 feet north of well 5, was drilled to a depth of about 600 feet in 1942. It is equipped with a jack pump. After 24 hours pumping the yield was 17 gallons a minute and the pumping level was about 486 feet. Forty hours after the pump was shut down following 24 hours of pumping the water level was 306 feet below the surface. (Well 5 had been shut down five days.) The yield of the well, therefore, was about one-tenth of a gallon a minute per foot of drawdown.

Well 7, near the south edge of town, was drilled in 1938 to a depth of 426 feet and later was deepened to about 500 feet. (See partial log.) It is equipped with a jack pump. On a test it yielded 23 gallons a minute, and after about 12 hours of operation the pumping level was 346 feet below the surface and was still declining at the rate of about 5 feet per hour. The remainder of the pumping test on this well was of little value because the "cups" in the pump started wearing out rapidly, the yield decreased, and the pumping level came up. Three days after the pump had been shut down the water level was 182 feet below the ground. (Well 8 had been idle about two weeks.) The yield of the well, therefore, was less than one-seventh of a gallon a minute per foot of drawdown.

Well 8, about 250 feet south of well 7, was drilled in 1939 to a depth of 426 feet and later was deepened to 508 feet. (See partial log.) It is equipped with a Peerless Hi-Lift pump, but during the first part of the investigation the pump was out of order. After the well had been idle about two weeks, and well 7 had been shut down 3 days, the water level was 141 feet below the surface. The well was operated a few hours during the latter part of the investigation, but the yield was not measured. However, it was estimated that the yield of the well under continuous operation probably would not exceed 25 gallons a minute.

Attempts to increase the yield of wells 7 and 8 were made by "shooting" them but they were unsuccessful. These wells have been partly filled in, well 7 being only 371 feet deep and well 8 only 422 feet deep, as shown by measurements made during the investigation.

Well 9, at the pump station, was completed in April 1944 at a depth of 780 feet. A rotary machine was used, and the driller recorded 72 feet of sand from 682 to 754 feet. Casing was set to 680 feet and was cemented from bottom to top. The bottom 100 feet of hole (from 680 to 780 feet) is not cased, and the well has filled in to 727 feet. The well is equipped with a jack pump, and on November 15, 1944, after it had been pumped at the rate of 28 gallons a minute for 24 hours, the pumping level was below the bottom of the air line at 550 feet. On November 17, after the pump had been shut down 48 hours, the water level was 209 feet below the surface. The yield of the well, therefore, was less than one-twelfth of a gallon a minute per foot of drawdown.

According to these data, wells 1, 3, 4, 5, 6, 7, and 8 draw water from several sands between 200 and 600 feet below the surface. Water obtained from these wells is very soft and relatively low in dissolved minerals. The chloride ranges from 9 to 19 parts per million. Well 9, however, which draws from sand below 680 feet, yields water that is somewhat more highly mineralized; the water contains 286 parts per million of chloride and is very high in iron. (See table of chemical analyses.)

Well 10, a city test hole near the east edge of town, was drilled in 1927 by the Layne-Texas Company to a depth of 893 feet. (See log.) It was abandoned for reasons not fully known to the writers. Wells 5 and 6 nearby, about 525 and 600 feet in depth, yield 12 and 17 gallons a minute, respectively.

Wells adjacent to Nocona. - Wells 11 and 12, east of town, belonging to Lesh-McCall and Whaley, and wells 15 and 18, west of town, belonging respectively to the Highlander Gasoline Plant and R. W. Berry (see map), range from 270 to 570 feet in depth. When pumped each well yields about 20 gallons a minute. The water is soft and is relatively low in dissolved minerals.

Wells 14 and 16, west of town, belonging respectively to the Sunray Oil Corporation and the Highlander Gasoline Plant, are about 800 feet deep and yield rather highly mineralized water. Well 17, belonging to O. V. Beck and located near the west edge of town on the bank of Pecan Creek, was drilled to a depth of 752 feet. It is unused but is reported to have been a "strong" well. The casing was perforated opposite all

important water-bearing sands, but the quality of the water from the well is not known. An oil test on the Berry place, 300 feet north of well 18, which is somewhat down dip from the wells listed above, encountered the last fresh-water sand between 780 and 820 feet below the surface.

Wells 19 and 20, about 4 miles southwest of town, belonging to the Sinclair-Prairie Oil Company, are 240 and 259 feet deep, respectively. Well 19, which is unused, is reported to be a "strong" well, whereas well 20 yields only 12 gallons a minute. The water from well 20 is soft and is relatively low in dissolved minerals.

Wells near Belcherville.- Wells that have a natural flow of water have been drilled along the valley of Balknap Creek between Belcherville and Ringgold. Wells 23, 24, and 25 are flowing wells on the Hardy Seay ranch, and they are 240, 263, and 390 feet deep, respectively. The discharge pipes are about 2½ feet above the ground, and the measured flow on November 16, 1944 was 2, 2, and 3¼ gallons a minute, respectively. Well 24, after being shut off for 10 minutes, had sufficient pressure to raise the water 1½ feet above the discharge pipe, or 4 feet above the ground. The water from the wells is soft and comparatively low in dissolved minerals.

According to the report by Gordon 4/ a well at Belcherville was drilled to a depth of 961 feet. Several water-bearing strata were passed through but the principal water-bearing stratum was reached at 600 feet. The water rose within 100 feet of the surface, but it was highly charged with salt and sulphur. Gordon reports also that at Ringgold the water from wells ranging from 20 to 200 feet in depth is predominantly brackish.

Bowie wells.- A flowing well (no. 26) was drilled at Bowie Lake southwest of Stoneburg. The well is 265 feet deep and was put down to supplement the municipal supply which is obtained from the lake. However, it is a weak well and when pumped yields only a few gallons a minute.

Well 27 at Bowie was formerly used to supply the city. According to the record obtained by Gordon, it was finished in 1907 at a depth of 640 feet. The yield of the well is not recorded, but the water was highly mineralized, containing 972 parts per million of chloride.

All the wells discussed above draw water from Carboniferous rocks. In general it may be stated that in the vicinity of Nocona individual wells in these rocks will yield only relatively small quantities of water; the water from sands above 600 feet is very soft and low in dissolved minerals, although the percent of sodium bicarbonate (black alkali) is high; the water from sands below 600 feet becomes more highly mineralized with increased depth; and no fresh-water supplies of importance are to be expected below about 750 or 800 feet.

4/ Gordon, C. H., op. cit. p. 39.

Information regarding the quantity and quality of water that can be obtained from sands of the Trinity within a reasonable distance from Nocona is scanty. A well on the Ed Bell place about 5 or 6 miles southeast of Nocona yields about 70 gallons of water a minute from sand and boulders; but the water is reported to be unfit for drinking. Gordon states that about 4 miles southeast of Nocona a well 73 feet deep yields hard water which is evidently in the basal part of the Trinity. His records of wells at Montague indicate that water from the Trinity in that area is hard and probably would be undesirable for a municipal supply. (See analyses of water from wells 28, 29, and 30).

Pumping tests

The rate at which water can be withdrawn from an aquifer or water-bearing formation depends upon the rate at which water percolates into the aquifer at its outcrop; upon the rate at which the aquifer will transmit water to the wells of the pumped area, expressed by a coefficient of transmissibility; and upon the rate at which water is released from storage in the aquifer when the head is lowered, expressed by a coefficient of storage.

Methods for computing mathematically the coefficients of transmissibility and storage of an aquifer from pumping tests on wells have been devised by the Geological Survey. In making quantitative studies of the ground-water resources in many areas these methods have been used successfully to predict the amount and rate of decline in water levels that results from the withdrawal of a given quantity of ground water.

Pumping tests were made on five of the municipal wells at Nocona. The specific capacity of the wells, it was found, is very low, averaging about one-tenth gallon of water a minute per foot of drawdown. The drawdowns and recoveries of water levels in wells caused by withdrawals during the tests were compiled and analyzed by the Theis graphical method 5/ to determine the coefficients of transmissibility and storage of the water-bearing sands. The equations for non-steady flow that was used is based on the assumptions that the water-bearing formation is homogeneous and of infinite areal extent, that it is bounded above and below by impermeable beds, that the discharge well penetrates the entire thickness of the formation, and that the transmissibility of the formation is constant at all times and all places. The results obtained from the tests show that the transmissibility varies widely from place to place. The drillers' logs show that the formation is not homogeneous, and none of the discharge wells penetrate the entire thickness of the formation. It is concluded, therefore, that

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5/ Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Trans. Amer. Geophys. Union, pp. 519-524, 1935.

no prediction can be made from the tests as to the amount and rate of decline in water levels in the city wells that will result from the withdrawal of a given quantity of ground water. The tests do indicate, however, that the coefficients of transmissibility and storage of the water-bearing sands at Nocona are very low.

Conclusions and recommendations

A study of the information obtained during the investigation indicates that no material advantage will be gained by going several miles from Nocona to develop a ground-water supply from rocks of Carboniferous age. Furthermore, the records show that water below about 800 feet at Nocona is unsuitable for a municipal supply. The sands of the Trinity group to the southeast of Nocona, (see map), might yield a sufficient quantity of water to meet the demand, but in areas along the west border of the outcrop within a few miles from Nocona the water in these sands is hard and somewhat highly mineralized.

The water in the sands and sandstones that supplies the city wells is under artesian pressure and will rise in wells above the point at which it is struck by the drill. The level to which the water would rise in the wells when they were first drilled is not known, but evidently there has been considerable reduction in artesian pressure and consequently the water levels in the city wells have declined. The decline is indicated by the higher water levels in wells surrounding Nocona. However, this in itself is not alarming because a decline in water levels is expected to accompany a large withdrawal of ground water.

Although records of the total decline of water levels in wells at Nocona are not available, it appears that the ground-water supply has not been seriously depleted and that a supply sufficient to meet the present demand can be obtained from wells. If, however, a large increase in water requirements is anticipated, steps should be taken immediately to develop a surface-water supply.

Primary factors affecting the present water system are lack of adequate surface storage and improper operation of the pumping units. It is reported that even during periods of heavy demand the pumps are shut off at night because there is no place to store the water. Consequently during the day the pumps are operated at excessively high speeds, the water is withdrawn at rates exceeding the maximum efficiency of the wells, and as a result the pumps are constantly breaking down and the city is out of water.

During the tests made by the writers the total pumpage from all nine wells amounted to about 170 gallons a minute, but at that rate wells 2, 7, 8, and 9 apparently were being pumped too hard. On the basis of this information it is believed that the total combined rate of pumping should be limited to about 150 gallons a minute divided as follows: well 1, about 30 gallons a minute; wells 2, 3, 4, and 5 about 10 gallons a minute each; wells 6 and 7 about 15 gallons a minute each; and wells 8 and 9 about 25 gallons a minute each. More accurate figure on the maximum practicable rate of pumping from the individual wells can be obtained by pumping each well continuously, at various speeds, for several days during which a systematic record is kept of the yields and pumping levels.

The city needs at least 200 gallons a minute or 288,000 gallons a day during periods of peak demand in summer. An additional development must be made. But ground water in the sands of Carboniferous age apparently is the only source available at a moderate cost. Therefore, it is suggested that an additional well be put down at a conveniently located site at least one-fourth mile from any existing heavily pumped well. According to the meager information available none of the present wells draw from more than one water-bearing sand zone whereas at least three such zones are encountered above a depth of 750 feet. It is suggested, therefore, that a new well be drilled to a depth of about 750 feet and that screens be set opposite all the important sands. Such a well, it is believed, should yield 50 gallons a minute, if the pump is set low. The position of the important sands usually can be determined from an electrical survey made in the drill hole before casing is set, supplemented by the driller's log. A competent well driller who is familiar with constructing, developing, and operating wells that draw water from sands and sandstone such as those at Nocona, should be employed.

The most urgent immediate need is more storage.

Records of wells in Montague County, Texas,
including measurements of water levels and yields made during November 8 to 16, 1944
(See fig. 1 for locations of wells)

Well	Owner	Date completed	Depth of well (ft.)	Diameter of well (in.)	Water level: Below land surface (ft.)	Water level: Date of measurement	Yield (gallons a minute)	Remarks
1	City of Nocona	Old	388	-	--	--	32	Sand from 375 to 388 feet.
2	do.	1926, 1944	712	8, 5-3/16	268.5	Nov. 17, 1944	19	Sand from 682 to 704 feet.
3	do.	1926	600±	12	--	--	10½	
4	do.	1926	600±	12	--	--	6½	
5	do.	1943	525	8, 5-3/16	320.7	Nov. 16, 1944	12	See log.
6	do.	1942	600±	8	306.5	Nov. 19, 1944	17	
7	do.	1938	371	10	182.0	Nov. 10, 1944	23	See log.
8	do.	1939	422	10,	140.9	do.	25	Do.
9	do.	1944	727	8-5/8	206.3	Nov. 8, 1944	28	Casing cemented to 680 feet, open bottom. See log.
10	do.	1927	893	-	--	--	--	Abandoned. See log.
11	Lesh & McCall	1941	558	6-5/8, 5-3/16	--	--	20	See log.
12	-- Whaley	1939	308	8	114.8	Nov. 15, 1944	20	
13	Ward & Cullum	--	325	--	--	--	--	See log.
14	Sunray Oil Corp.	1939	800±	10	50	1939	45	Water reported unfit for drinking.
15	Highlander Gasoline Plant	1942	570	8	--	--	20	Casing cemented and gun perforated between 196 and 568 feet. See log.
16	do.	1944	795	8¼	--	--	10	Casing cemented and gun perforated between 573 and 772 feet. See log.
17	O. V. Beck	--	752	8	--	--	--	Reported strong supply. Casing perforated between 200 and 752 feet.
18	R. W. Berry	1944	270	7	40	Oct. 1944	20	Cased to bottom, lower 60 feet perforated. See log.
19	Sinclair-Prairie Oil Co	1943	240	6-5/8	10.3	Nov. 15 1944	--	Reported strong supply. See log.
20	do.	1943	259	8	--	--	12	See log.
21	Mark Freeman	1943	315	--	--	--	--	Reported strong supply.
22	Hardy Seay	1895	50	6	25	1944	2	
23	do.	1940	240	6	+2.5	Nov. 16, 1944	2, Flows	Casing perforated from 225 to 240 feet.
24	do.	1939	263	6	+2.5	do.	2, Flows	See log.
25	do.	1940	390	6	+2.5	do.	3¼, Flows	Casing perforated from 312 to 390 feet. See log.
26	City of Bowie	1944	265	8	+	1944	Flows	Sands at 155-172 and 190-205 feet.
27	do.	1907	620	--	--	--	--	Abandoned. See log.
28	Montague County	Old	60	--	--	--	--	See table of analyses.
29	Parsonage	Old	60	--	--	--	--	Do.
30	"Wagon House"	Old	40	--	--	--	--	Do.

Drillers' logs of wells in Montague County, Texas

Well 5, partial log

City of Nocona, ¼ mile east of pump station.

	Thickness (feet)	Depth (feet)
Surface material	10	10
Yellow clay	15	25
Shale	15	40
Brown shale	10	50
Sandy gray shale	44	94
Water sand	7	101
Gray shale	39	140
Red shale	10	150
Blue shale	25	175
Black shale	11	186
Gray shale	4	190
Red shale	125	315
Sandy gray shale	25	340
Water sand	6	346
Sandy gray shale	9	355
Water sand	15	370
Sandy gray shale	4	374
Water sand	21	395
Blue shale	5	400
Red shale	5½	405½

Well 7, partial log

City of Nocona, ¼ mile southeast of pump station.

Red clay	25	25
Sand rock	10	35
Red clay	13	48
Sand rock	12	60
Water sand	12	72
Red clay	33	105
Water sand	40	145
Blue shale	20	165
Sandy shale	12	177
Water sand	25	202
Blue shale	28	230
Water sand	32	262
Red clay	3	265
Blue shale	7	272
Red clay	43	315
Gray shale	7	322
Red clay	9	331
Sandy shale	15	346
Water sand	31	377

Well 8, partial log

City of Nocona, ¼ mile southeast of pump station.

Red clay	16	16
Sand rock	12	28
Red clay	20	48
Sand rock	15	63
Green shale	17	80
Red clay	38	118
Sandy shale	24	142
Gray shale	8	150
Red clay	30	180
Blue shale	5	185
Water sand	23	208
Red clay	10	218
Sandy shale	13	231
Water sand	51	282
Red clay	12	294
Gray shale	28	322
Red clay	23	345
Sandy shale	25	370
Water sand	12	382
Gray shale	16	398
Water sand	24	422
Sandy shale	4	426

Well 9

City of Nocona, at pump station.

Sand, gravel, and shale	204	204
Sand, shale and shells	123	327
Clay, shale and broken sand	92	419
Sand, shale, and shells	231	650
Sandy shale, lime, shells and sand	32	682
Sand	72	754
Lime shells, and white sand	26	780

Well 10

City of Nocona, 35 feet east of well 5 and 1,200 feet east of pump station.

Surface clay	4	4
Hard sand	3	7
Brown clay	10	17
Hard sand	22	39
Sand rock	3	42
Hard sand	51	93
Sand rock	1	94
Hard sand	98	192
Sand rock	2	194
Gumbo	7	221
Shale and lignite	44	265
Shale and streaks of hard sand	27	292
Shale	15	307
Gummy shale	9	316
Hard sand rock	2	318
Sand	3	321
Hard sand	20	341
Sand rock	1	342
Hard sand	6	348
Gumbo	7	355
Hard sand	16	371
Sandy lime	4	375
Hard sand rock	1	376
Hard sandy shale	21	397
Hard sand and shale	18	415
Hard sandy shale	10	425
Gumbo	23	448
Hard shale	6	454
Hard sandy shale	12	480
Gumbo	34	514
Sand	7	521
Hard sand and shale	7	528
Hard sand rock	1	529
Shale	8	537
Gumbo	7	544
Sand	3	547
Gumbo	36	583
Sand rock	2	585
Gumbo	4	589
Sand	5	594
Gumbo	24	618
Hard shale	5	623
Gumbo	8	631
Sand, lime and boulders	7	638
Hard sandy lime	17	655
Hard sand	1	656
Sand rock	3	659
Shale and gravel	13	672
Packsand	6	678
Hard sandy lime	4	682
Gumbo and lime	12	694
Hard sand and shale	10	704
Gumbo	17	721
Hard packsand	11	732
Hard sand and shale	21	753
Gumbo	22	775
Hard sand	5	780
Gumbo	53	833

(Continued on next page)

Drillers' logs of wells in Montague County -- Continued

	Thickness (feet)	Depth (feet)
Well 10 -- Continued		
Gyp rock	8	841
Hard sand	2	843
Lime rock	2	845
Gumbo	32	877
Hard sand	5	882
Gumbo	11	893
Well 11		
Lesh and McCall, ¼ mile east of Nocona.		
Red shale	75	75
Gray shale and sand (very little water)	45	120
Red shale	25	145
Gray shale	10	155
Red shale	32	187
Lime and shale	13	200
Blue shale	15	215
Water sand	10	225
Red sand and shale	5	230
Water sand	33	263
Red shale	32	295
Water sand	20	315
Brown shale	10	325
Red shale	13	338
Water sand	2	440
Blue shale	20	460
Water sand	20	480
Blue shale	25	505
Water sand	50	555
Shale	3	558
Well 13		
Ward and Cullum, 2¼ miles northeast of Nocona.		
Red clay	95	95
Sand rock	43	138
Red clay	32	170
Shale	5	175
Water sand	15	190
Shale	40	230
Water sand	25	255
Shale	30	285
Water sand	25	310
Red clay	15	325
Well 15		
Highlander Gasoline Plant well no. 2, ¼ mile west of Nocona.		
Surface material	3	3
Sandstone	27	30
Red beds	45	75
Green shale	10	85
Sandy shale	21	106
Dry sand	9	115
Sandy shale	10	125
Red beds	35	160
Not recorded	15	175
Green shale	21	196
Water sand	25	221
Red beds	5	226
Green shale	24	250
Red beds	70	320
Sandy shale	15	335
Water sand	25	360
Red beds	2	362

	Thickness (feet)	Depth (feet)
Well 16		
Highlander Gasoline Plant well no. 3, ¼ mile west of Nocona.		
Surface material	35	35
Clay and sand	55	90
Shale and sand	98	188
Water sand	30	218
Shale	10	228
Water sand	27	255
Shale and shells	71	326
Water sand	29	355
Shale and shells	53	408
Hard sand	22	430
Water sand	16	446
Hard sand and shale	13	459
Shale	3	462
Shale and sand	19	481
Water sand	30	511
Hard water sand and shale	28	539
Water sand	9	548
Shale and shells	5	553
Sand and shale	20	573
Soft water sand	30	603
Shale and shells	24	627
Sandy shale and sand	35	662
Shale and broken sand	6	668
Sand, hard and soft streaks	27	695
Water sand	14	709
Lime and shells	4	713
Shale and shells	17	730
Water sand	42	772
Shale and shells	23	795
Well 18		
R. W. Berry, 2 miles northwest of Nocona.		
Sand	3	3
Sand rock	22	25
Red bed	13	38
Sand rock	9	47
Red bed	71	118
Sand rock	19	137
Red bed	33	170
Shale	15	185
Water sand	12	197
Red bed	11	208
Shale	27	235
Water sand	35	270
Well 19		
Sinclair-Prairie Oil Company, 4½ miles southwest of Nocona.		
Red clay	26	26
Sand rock	12	38
Red clay	74	112
Gray shale	8	120
Water sand	8	128
Red clay	30	158
Sandy shale	7	165
Water sand	50	215
Gray shale	10	225
Red clay	15	240

Drillers' logs of wells in Montague County -- Continued

	Thickness (feet)	Depth (feet)

Well 20

Sinclair-Prairie Oil Company, 4½ miles southwest of Nocona.

Soil	4	4
Sand rock	12	16
Red clay	200	216
Sandy shale	10	226
Water sand	27	253
Shale	6	259

Well 24

Hardy Seay, 2¾ miles west of Belcherville.

White sand	35	35
White clay	8	43
White sand	11	54
Sand rock	6	60
Gray shale	6	66
Red clay	6	72
Water sand	13	85
Blue shale	5	90
Red clay	64	154
Blue shale	24	178
Water sand	12	190
Red clay	28	218
Sandy shale	22	240
Water sand	23	263

Well 25

Hardy Seay, 3 miles southwest of Belcherville.

Red clay	24	24
Red sand	10	34
Gray shale	6	40
Sandy shale	32	72
Red clay	33	105
Sandy shale	13	118
Water sand	20	138
Black shale	2	140
Water sand	12	152
Red clay	13	165
Sandy shale	29	194
Red clay	10	204
Sandy shale	12	216
Red clay	22	238
Shale	30	268
Red clay	30	298
Blue shale	14	312
Water sand	78	390

	Thickness (feet)	Depth (feet)

Well 27 1/

City of Bowie, in Bowie.

Trinity sand (Cretaceous)		
Soft sandy soil with some gravel and water	30	30
Hard yellow clay	10	40
Cisco group (Carboniferous)		
Hard sandstone	38	78
Hard soapstone rock	18	96
Slate, traces of coal	4	100
Hard soapstone or fire clay	8	108
Conglomerate (concrete rock)	132	240
Shale	11	251
Hard concrete	54	305
Gritty shale, "hardpan"	75	380
Hard concrete rock	55	435
Red shale	13	448
Sandstone	32	480
Red shale	18	498
Hard shale, "hardpan"	12	510
Sandstone	9	519
Sand with water	9	528
Sandstone	4	532
Soapstone, shale, and slate	69	601
Sand with water	19	620

1/ Gordon, C. H., Geology and underground water of the Wichita Region, North-Central Texas, U. S. Geol. Survey Water-Supply Paper 317, p. 42, 1913.

Chemical analyses of water from wells in Montague County, Texas

Analyzed at The University of Texas under the direction of W. W. Hastings, Chemist, U. S Department of the Interior, Geological Survey. Results are in parts per million. Well numbers correspond to numbers in table of well records.

Well	Owner	Depth of well (ft.)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total hardness as $CaCO_3$	pH
1	City of Nocona	388	Nov. 17, 1944	532	13	0.03	2.6	0.7	210	503	30	12	1.6	1.5	10	8.4
3	do.	600±	do.	574	-	-	2.7	2.1	221	542	34	11	-	1.2	15	8.4
4	do.	600±	July 7, 1944	-	-	-	-	-	-	566	42	13	-	-	6	-
5	do.	525±	do.	-	-	-	-	-	-	551	44	13	-	--	8	-
6	do.	600±	Nov. 17, 1944	708	18	0.34	3.8	0.8	282	647	53	19	4.0	1.8	13	8.4
7	do.	371	Nov. 10, 1944	518	-	-	2.1	0.4	205	498	20	16	-	1.2	6	8.4
8	do.	422	July 7, 1944	-	-	-	-	-	-	-	-	9	-	-	-	-
9	do.	727	July 8, 1944	1,210	11	16	4.6	1.4	487	736	53	286	3.0	1.2	18	8.4
11	Lesh & McCall	558	Nov. 9, 1944	694	-	-	-	-	-	610	46	14	-	1.8	16	-
12	-- Whaley	308	Nov. 15, 1944	-	-	-	-	-	-	485	22	59	-	-	22	-
15	Highlander Gasoline Plant	570	Nov. 9, 1944	727	-	-	-	-	-	667	56	21	-	1.8	16	-
16	do.	795	do.	1,410	13	0.47	6.6	1.9	557	636	44	465	4.4	1.8	24	8.0
18	R. W. Berry	270	Nov. 17, 1944	-	-	-	-	-	-	541	35	14	-	-	10	--
20	Sinclair-Prairie Oil Co.	259	Nov. 15, 1944	-	-	-	-	-	-	390	35	52	-	-	26	-
22	Hardy Seay	50	Nov. 16, 1944	-	-	-	--	-	-	243	9	11	-	-	118	-
23	do.	240	do.	-	-	-	--	-	-	668	60	103	-	-	12	-
24	do.	263	do.	-	-	-	--	-	-	536	70	108	-	-	12	-
25	do.	390	do.	-	-	-	-	-	-	537	70	92	-	-	21	-
1/27	City of Bowie	620	Mar. --, 1907	2,119	5.4	0.3	21	9.5	772	382	129	972	-	1.9	-	-
1/28	Montague County	60	Dec. --, 1906	2,075	19	Tr	327	74	284	442	262	653	-	102	-	-
1/29	" Parsonage Well"	60	Dec. --, 1906	446	26	26	96	27	27	334	54	43	-	Tr.	-	-
1/30	" Wagon House Well"	40	Dec. --, 1906	1,272	21	21	270	29	29	249	104	186	-	334	-	-

1/ Gordon, C. H., Geology and underground waters of the Wichita Region, north-central Texas: U. S. Geol. Survey Water-Supply Paper 317, pp. 42 and 44, 1913.

Figure I
Plate III

GEOLOGIC MAP
OF
MONTAGUE COUNTY, TEXAS

BY
FRED M. BULLARD AND ROBERT H. CUYLER

Assisted by the students of the University of Texas Geology Camp summer of 1928

WATER WELLS
● Flowing
○ Non Flowing

See inset for wells in this area

PENNSYLVANIAN CRETACEOUS RECENT
CISCO GROUP

CITY OF NOCONA
CITY HALL

SCALE
0 1000 2000 3000 Feet