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GROUND WATER IN THE NEWCASTLE AREA, WYOMING

By

Charles C. Williams

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INTRODUCTION

This report summarizes the ground-water conditions in the vicinity of Newcastle, Wyoming, with reference to the availability of water for municipal, industrial, and domestic use. The investigation was made as a part of the cooperative ground-water investigation now being made in Wyoming.

The City of Newcastle (population about 2,400) is situated on the west edge of the Black Hills in eastern Weston County, Wyoming. The city is served by the Chicago, Burlington, and Quincy Railroad, and by U. S. Highways 16 and 85. Newcastle is the trade center for a large area devoted mainly to stock raising. The principal industries are the railroad and two small oil refineries. The recently renewed drilling activity in the Mush Creek oil field near the city has contributed to the increasing population and trade, and industrial expansion is anticipated.

The present city water supply serves industrial as well as municipal needs. It is derived principally from springs issuing from the zone of contact between the Minnelusa and Pahasapa formations (described below) along the east side of Stockade Beaver Creek Valley, but in part directly from the creek during late summer months. The springs, known as Parmalee and Bear Canyon Springs, are located in Tps. 46 --- 47 N., R. 60 W., near the Wyoming-South Dakota boundary. The flow from the springs is intercepted several hundred feet below the point of issue and the water is conducted about 15 miles through a wooden pipe line to Newcastle. The flow of Stockade Beaver Creek above Parmalee and Bear Canyon Springs is taken directly into the city pipe line when needed.

For several years, during summer months, the supply from these sources has been inadequate for the needs of the city, and water rationing and conservation measures have been practised. According to Mr. L. C. Williams, Wyoming State

Sanitary Engineer, contamination of the water supply occurs during the late summer months, especially when water is taken directly from the creek. The chemical quality of the present city supply is satisfactory. Owing to recurrent annual water shortage and warnings from the State Board of Health, the officials of the City of Newcastle have recognized the need for a larger supply of water of better bacteriological quality; also, further city plans for a sewer system, and anticipated industrial expansion in the area, will require an additional quantity of water that the present source will not supply and that the present pipe line apparently will not deliver.

The quantity of water used at present by the City of Newcastle is not known, but is estimated by Mr. Carl Kugland, City Clerk, to have been about 6 million gallons in November 1947. Mr. Kugland further estimated that of this amount about 3 million gallons, or one-half of the supply, is being used by the industrial establishments in and near the city. The last available records are for the month of August 1945 when 6 million gallons was consumed for all purposes. The increasing population and industrial expansion in this area indicate the present need for an average monthly supply of at least 7 1/2 million gallons. Installation of a sewer system would increase this average requirement considerably. It appears that a supply of about 15 million gallons a month (350 gallons a minute) is needed for the anticipated water use for all purposes at and near Newcastle.

In November 1947 the Mayor of Newcastle, Mr. Charles Martens, the City Attorney, Mr. Rodney Guthrie, and other interested citizens, asked Dr. H. D. Thomas, State Geologist of Wyoming, to arrange for a preliminary geological investigation of the ground-water possibilities in the Newcastle area. The State Engineer of Wyoming and the Wyoming State Board of Control cooperate with the Ground Water Division of the U. S. Geological Survey in the study of the occurrence, availability, and chemical quality of ground water in Wyoming. Accordingly

Dr. Thomas made sufficient funds available, with approval of the State Engineer and the Director of the U. S. Geological Survey, for the Ground Water Division to make an examination of conditions in the vicinity of Newcastle in connection with other ground-water studies in Wyoming.

In December 1947 the writer visited wells and springs in the Newcastle area, collected samples of water, made a geological reconnaissance, and assembled logs and other records pertaining to water wells. The water samples were analyzed by D. E. Weaver in the Lincoln, Nebraska, Laboratory of the U. S. Geological Survey, and are given in the table at the end of this report. In addition to the field work, several days were spent assembling and interpreting published and unpublished reports pertinent to the possible development of a ground-water supply in this area. These sources of information have proved most helpful and include:

Darton, N. H., 1904, Description of the Newcastle quadrangle: U. S. Survey Geol. Atlas of the United States, Newcastle folio (No. 107) (including maps and sections).

Darton, N. H., 1905, Preliminary report on the geology and underground resources of the Central Great Plains: U. S. Geol. Survey Prof. Paper 32, pp. 1-409, figs. 1-18, pls. 1-72.

Knight, S. H., and Beckwith, R. H., 1934, The municipal water supply of Newcastle, Wyoming: Unpublished report in the files of the Geological Survey of Wyoming, Laramie.

Robinson, T. W., and Foley, F. C., 1941, The artesian well near Osage, Wyoming (Jones No. 1): Unpublished report in the files of the U. S. Geological Survey, Cheyenne, Wyoming, and Washington, D. C.

Thomas, H. D., 1941, Memorandum to State Engineer concerning city-supply springs near Newcastle, Wyoming: Unpublished memorandum in the files of State Engineer, Cheyenne, and Geological Survey of Wyoming, Laramie.

Evans, Vincent, 1944, Water well at the Newcastle refinery: Unpublished report in the files of the Carter Oil Company, Denver, Colorado.

Dobbin, C. E., Northrop, G. D., and Horn, G. H., 1947, Geologic and structure contour map of the Osage-Mule Creek area, Weston and Niobrara Counties, Wyoming: U. S. Geol. Survey, Oil and Gas Investigations Preliminary Map. __ .

Geologic and hydrologic setting

The stratified rocks appearing at the surface along the west flank of the Black Hills east of Newcastle are a succession of shales, sandstones, and limestones exhibiting many differences in their general character. The older rocks that have been penetrated by the drill in the vicinity of Newcastle (Pahasapa and Minnelusa formations) are exposed over a wide area in the western half of the Black Hills. These beds form an extensive plateau and dip gently westward from South Dakota into Wyoming a short distance west of the State line, and then dip rapidly beneath the surface and are deeply buried near Newcastle. Rocks successively younger than the Pahasapa and Minnelusa crop out westward toward Newcastle, and the differences in the character of the steeply dipping rocks have resulted in a distinctive topographic expression of each formation.

The geology of this area has been described in detail by Darton and others, and is not repeated here. The following log of the deep well at Osage is presented, however, to show the character and thickness of the rocks beneath the surface near Newcastle. In addition to the rocks described in this log about 50 feet of sandstone (Newcastle sandstone) and about 200 feet of shale (Mowry shale) would be encountered in a well at Newcastle above the upper rocks described in the log.

Sample log (driller's log to 800 feet) of the deep water well at Osage, Wyoming, NE SW SE sec. 10, T. 46 N., R. 63 W.
(Authority, driller and M. W. Krampert)

	Thickness, feet	Depth, feet
Cretaceous, Upper		
Skull Creek shale member of Graneros shale		
Soil and shale	68	68
Shale	52	120
Shale, sandy	80	200
Cretaceous, Lower; Inyan Kara group		
Fall River sandstone		
Sand and sandstone, first water	110	310
Fuson shale		
Shale	60	370
Lakota sandstone		
Sand and sandstone	90	460
Jurassic, Upper		
Morrison (to about 640 feet) and Sundance formations		

	Thickness, feet	Depth, feet
Shale	50	510
Shale, sandy	12	522
Shale and sandy shale (no detail)	278	800
Sundance formation		
Shale, limy, dark; laminated with streaks of white, dense, glauconitic sand	40	840
Sand, fine, shaly, salmon colored	40	880
Sand, light gray and pink	10	890
Sand, red, containing streaks of light gray and red shale	60	950
No samples	20	970
Clay, light gray, shale, limy, and some fine white sand	10	980
Shale, light gray to red, containing streaks of sand	20	1,000
Shale, sandy, limy	40	1,040
Triassic (?)		
Spearfish formation		
Silt and shale, bright red	60	1,100
Shale and silt, red	70	1,170
Shale, red, containing trace of anhydrite	10	1,180
Shale, dark red	20	1,200
Shale, red, containing gypsum	20	1,220
Shale, red	80	1,300
Shale, red, containing traces of gypsum	30	1,330
Shale, red, containing about 10 percent anhydrite	30	1,360
Shale, red, containing some anhydrite	20	1,380
Shale, red and gray	10	1,390
Shale, red and gray, containing about 40 percent anhydrite	10	1,400
Anhydrite, white, containing minor red shale streaks	40	1,440
Shale, red, containing anhydrite	40	1,480
Anhydrite, white, containing streaks of red shale	60	1,540
Shale, red, containing traces of anhydrite	60	1,600
Anhydrite, white	15	1,615
Permian (?)		
Minnekahta limestone		
Limestone, pink, and anhydrite, pink	5	1,620
Limestone, pink, white, and gray, containing traces of anhydrite	50	1,670
Opeche formation		
Shale, red, and lime, pink	10	1,680
Shale, red	30	1,710
Shale, red, containing some anhydrite	15	1,725
Shale, red and gray, containing embedded grains of coarse sand	5	1,730
Pennsylvanian		
Minnelusa sandstone		
Dolomite, pink, containing some red shale and coarse-grained sand	10	1,740
Dolomite, pink	40	1,780
Sand, medium, rounded grains, pink	35	1,815
Dolomite, pink	45	1,860
Dolomite, pink, and sand, pink, containing some red shale	30	1,890
Dolomite, pink	10	1,900

	Thickness, feet	Depth, feet
Dolomite, pink, containing some red shale and sand	10	1,910
Dolomite, sand, and anhydrite	10	1,920
Sand, dense, hard, pink	10	1,930
Dolomite, pink, containing red shale, anhydrite, and pink sand	30	1,960
Sand, very dense, red, containing some red shale	30	1,990
Dolomite and pink sand	10	2,000
Dolomite, pink and gray	10	2,010
Dolomite, pink and gray	10	2,020
Anhydrite, gray dolomite, and trace of sand	30	2,050
Sand, pink	10	2,060
Dolomite, gray, anhydrite, and shale, red	30	2,090
Sand, shaly, red	10	2,100
Shale, red, containing anhydrite	15	2,115
Sand, dense, white, with streaks of red shale	30	2,145
Dolomite, gray, containing some anhydrite	15	2,160
Sand, very dense	70	2,230
Shale, dark, containing sand	10	2,240
Sand and dolomite	25	2,265
Dolomite, gray, containing anhydrite and few thin sandy streaks	45	2,310
Shale, red and gray, with thin streaks of dolomite	30	2,340
Dolomite, gray, with streaks of red sandy shale	20	2,360
Shale, red, and sand	30	2,390
Shale, red, and dolomite	40	2,430
Limestone, with streaks of red shale	90	2,520
Shale, red, with streaks of dolomite	20	2,540
Mississippian, lower		
Pahasapa (Madison) limestone		
Limestone, dolomitic, porous and cavernous in part (Bit dropped without circulation or weight from 2,580 feet to 2,592 feet)	52	2,592

The formations described in the log of the well at Osage include several beds of water-bearing sandstone and limestone that receive water at the surface of the high plateau and along the ridges and slopes bordering the Black Hills. The principal water-bearing formations crop out over a wide area and receive a large amount of water, not only from rainfall on their surfaces, but from streams that at many points lose all or part of their flow in crossing the outcrops. These waters are trapped in the rocks as the porous beds pass beneath the surface, and are available under artesian pressure to wells drilled along the edge of the hills.

Water in younger rocks

Analysis of the data collected and the information assembled leads to the conclusion that the only rocks likely to yield usable water to a well drilled in the vicinity of Newcastle are the Pahasapa and Minnelusa formations. Therefore, in considering the possibilities of municipal and industrial ground-water supplies in this area it is convenient to discuss the younger rocks (those above the Minnelusa) and the older rocks separately.

Fall River (Dakota) and Lakota sandstones

The Fall River (Dakota) and Lakota sandstones probably would yield the first water encountered in any volume in a well drilled near Newcastle. These sandstones vary in porosity, and the chemical quality of the water derived from them ranges widely. In the Newcastle folio (see reference above) Darton described several wells drilled into these rocks near Newcastle that yielded water too highly mineralized for use. In 1946, twelve wells producing water from the Fall River and Lakota sandstones in the Osage oil field northwest of Newcastle (T. 46 N., R. 63 and 64 W.) were sampled by C. M. Nickerson, geologist, and analyzed by G. D. Clark, chemist, of the Casper office of the Geological Survey, Conservation Branch. Total dissolved solids in the water ranged from 648 to 5,003 parts per million and averaged 1,725 parts per million, principally sodium sulfate.

Carter refinery well.--A well was drilled several years ago by the Consumer's Oil and Refining Co. at the refinery now owned by the Carter Oil Co. This well is located at the west edge of Newcastle and was drilled to a depth of 778 feet. Water under artesian pressure was encountered at 720 feet, and a small quantity of highly mineralized water flowed from the Lakota sandstone. The quality of the water was not suitable even for cooling purposes at the refinery and the well was abandoned and plugged. No chemical analysis of this water is available, but presumably the water would be unsatisfactory for ordinary uses.

Grayco refinery well.--In 1941 a well was drilled for water at the west edge of Newcastle by the Grayco refinery (near the Carter refinery). This well was 830 feet deep and had a small flow of highly mineralized water from the Lakota sandstone. A partial analysis of this water was made in 1941 by J. G. Crawford, U. S. Geological Survey, and the results are given in the table of analyses (Analysis A). This analysis indicates that water in the Fall River-Lakota sandstones is unfit for municipal or industrial use at this location.

Sundance formation

The well at the Grayco refinery was deepened in 1946 and drilled to a depth of about 930 feet. At this depth the well probably had penetrated the upper beds of the Sundance formation, but had not reached the principal sand of the formation which would have been encountered at about 1,150 feet at this location. On December 10, 1947, the Grayco well was flowing about 15 gallons a minute to waste, principally from the Lakota sandstone, but perhaps in part from sandy beds in the upper part of the Sundance. The water issuing from the well had a temperature of 61° F., and a deposit of iron oxide was observable over the discharge area around the well. The analysis (Analysis B - see table) indicates the undesirable chemical quality of this water.

Records are not available of wells penetrating the principal sands of the Sundance formation in the vicinity of Newcastle. These sands may contain water, and if so, the water should be under artesian pressure; but it seems very probable that water in sands of the Sundance is of poor chemical quality and undesirable for most uses.

Water in older rocks

The Spearfish formation, Minnekahta limestone, and Opeche formation comprise about 700 feet of rocks between the base of the Sundance formation and the top of the Minnelusa sandstone. In general these rocks contain only small amounts of water, but locally along the east side of Stockade Beaver Creek, a few miles

north of the L A K Ranch, small springs yielding hard water issue from the Opeche formation. The salt springs at the head of Salt Creek north of Newcastle flow from the upper part of the Spearfish formation.

Minnelusa sandstone

The Minnelusa sandstone is about 600 feet thick in the area of outcrop east of the upper part of the Stockade Beaver Valley, and consists mainly of calcareous sandstone. The formation apparently becomes thicker and changes character westward and southward from the hills. At Cambria, Darton reported 850 feet of tightly cemented sandstone and shale in the Minnelusa. At the Osage well the formation is 610 feet thick and is composed of sandstone and dolomite with minor amounts of shale. The Minnelusa yields water to some of the wells in this area, but at some wells is so tightly cemented that it contains no water. The quality of the water also seems to be variable.

Martens shallow well.--A stock well was drilled in 1933 on the Charles Martens Ranch in the NE 1/4 sec. 3, T. 45 N., R. 61 W. The well is 720 feet deep and 6 inches in diameter, and flows about 20 gallons a minute. The flow is reported to come from the upper sand of the Minnelusa, other formations being cased off. The well begins near the base of the Sundance formation, and the driller logged 60 feet of surface material and sandy shale, and 10 feet of sand above the redbeds of the Spearfish formation. The driller reported 470 feet of red shale, followed by 45 feet of impure lime (Minnekahta). The next 37 feet was logged "Opeche," and the last 98 feet was logged "sand." The casing was set at 619 feet, 2 feet above the top of the "sand," and the well flowed after development.

The interval logged as "Opeche" appears not to be thick enough for the Opeche formation in this area. The lower Opeche contains beds of sandstone from which springs issue along the Stockade Beaver Valley. It seems likely, therefore, that water from this well may be a mixture of waters from the lower Opeche

and the upper Minnelusa, and that the analysis (analysis C - see table) may not represent the true chemical character of water from the upper sand of the Minnelusa.

L A K Ranch well (shallow zone).--A deep well (1,300 feet) was completed in 1945 on the L A K Ranch a few miles southeast of Newcastle. The well was started in the lower part of the Spearfish formation and reached the top of the Minnelusa sandstone at 252 feet (see log below). It appears that the Minnelusa is about 860 feet thick at this location. The top of the Pahasapa (Madison) limestone was reached at a depth of 1,152 feet.

The casing record of this well is as follows: 61 feet of 12-inch casing, cemented; 305 feet of 10-inch casing, cemented (extends to surface); 1,045 feet of 6-inch casing set from the surface to 1,045 feet, cemented from 1,010 to 1,045 feet. This record shows that all water above 305 feet is sealed from the well. Water encountered in the Minnelusa between 305 feet and 1,010 feet flows from the well through the annular space between the 10-inch and 6-inch casings. This quantity is about 50 gallons a minute and flows to waste in a small ravine. This water comes principally from the intervals between 310 and 488 feet, and 675 and 800 feet. The water above 1,010 feet was excluded from that encountered below because of its hardness. The analysis (analysis D - see table) indicates the chemical character of the water from the upper and middle sandstones of the Minnelusa at this location.

Driller's log of the L A K Ranch well in SE NE sec. 6, T. 44 N., R. 60 W., Weston County, Wyoming. (Authority, driller).

	Thickness, feet	Depth, feet
Triassic (?)		
Spearfish formation		
Surface material	25	25
Redbeds	34	59
Lime (?)	6	65
Redbeds	40	105
Permian (?)		
Minnekahta limestone		

	Thickness, feet	Depth, feet
Limestone, hard. Water rose 60 feet in hole.	25	130
Limestone, very hard	15	145
Limestone, hard	20	165
Opeche formation		
"Opeche" redbeds	33	198
"Opeche" redbeds with streaks of hard white limestone	54	252
Pennsylvanian		
Minnelusa sandstone		
Sandstone, red, and limestone	52	304
Sandstone, hard, buff and white	4	308
Sandstone, hard. Well started to flow	4	312
Sandstone, buff to pink	33	345
Sandstone, hard, pink. More water	15	360
Sandstone, hard, coarse. More water	15	375
Sandstone, pink	25	400
Shale, sandy, red	7	407
Sandstone, pink, hard	30	437
Shale, sandy, soft	5	442
Shale, soft, with streaks of gypsum	36	478
Sandstone, hard, pink	22	500
Sandstone, very hard, buff	8	508
Shale, soft, red	8	516
Sandstone, white to buff	9	525
Shale, red, with streaks of gypsum and sand	5	530
Sandstone, hard, pink	16	546
Sandstone, soft, pink, with layers of red shale	24	570
Sandstone, hard, pink	20	590
Sandstone and limestone, pink with layers of red shale and gypsum	20	610
Sandstone and limestone, pink	10	620
Limestone, pink	20	640
Shale, sticky, red	31	671
Shale, black	4	675
Shale, sandy, gray	7	682
Shale, sandy, varicolored	28	710
Sandstone, gray	20	730
Shale, black	5	735
Sandstone, hard, gray	55	790
Sandstone, gray, with thin streaks of black shale	15	805
Limestone, dark gray, and sandstone	10	815
Sandstone, gray, with streaks of yellow shale	15	830
Sandstone, chocolate colored	5	835
Sandstone, gray and buff, with thin streaks of yellow shale	10	845
Sandstone, hard, pink. More water	20	865
Sandstone, light gray to buff	75	940
Limestone, hard, gray and pink	15	955
Sandstone, hard, pink	13	968
Clay, very sticky, light green and brown	3	971
Sandstone, soft, gray	9	980
Clay, very sticky, brown	10	990
Sandstone, hard, gray	5	995

	Thickness, feet	Depth, feet
Clay, sandy, brick red	5	1,010
Limestone, very hard, gray	9	1,019
Sandstone, hard, white	21	1,040
Limestone, hard, pink and white	30	1,070
Limestone, firm, purple	10	1,080
Clay, sandy, red	2	1,082
Sandstone, hard, white and pink. Water started flowing inside 6-inch casing at 1,105 feet	63	1,145
Clay, red	3	1,148
Shale, dark red, with streaks of white and pale green shale	4	1,152
Mississippian		
Pahasapa (Madison) limestone		
Limestone, hard	8	1,160
Shale, red and green (Driller's note: "May be caving from above.")	8	1,168
Limestone, hard, white	32	1,200
Limestone, hard, white and yellow	13	1,213
Limestone, hard, white. Some increase in water at 1,230 feet	27	1,240
Limestone, hard, pink and white. Some increase in water at 1,252 feet	30	1,270
Limestone, firm, gray, somewhat sandy. Some increase in water	5	1,275
Limestone, hard, gray	25	1,300

Pahasapa (Madison) limestone

The Pahasapa (Madison) limestone is a massive gray limestone and is about 500 feet thick in this area. The Pahasapa is notably cavernous in the Black Hills, and some zones in the limestone are porous and cavernous in the subsurface in the Newcastle area. Numerous springs flow from the Pahasapa along the west edge of the hills where the beds dip steeply beneath the surface. Water of good chemical quality is obtained from several wells penetrating the upper part of the Pahasapa limestone in the vicinity of Newcastle.

L A K Ranch well (deep zone).--The L A K Ranch well, described above, penetrates the Pahasapa limestone and produces some water from it (see log). As noted above hard water from the upper and middle sands of the Minnelusa flows to waste, while water from the lower Minnelusa and upper Pahasapa flows into the ranch supply line. The producing zone in the Pahasapa is from 75 to 100 feet below the top of the formation at this location. The analysis indicates that

the mixture of the waters from the lower Minnelusa and upper Pahasapa formations is of comparatively good chemical quality (analysis E - see table).

Martens deep well.- In 1941 a well was drilled on the Charles Martens Ranch in the W 1/2 SE 1/4 sec. 31, T. 46 N., R. 60 W. to a depth of 1,178 feet. The well began in the Spearfish formation, and according to the driller's record, the top of the Pahasapa limestone was reached at 1,097 feet. The Minnelusa sandstone was 857 feet thick, but apparently did not produce water. The well flows about 150 gallons a minute from a porous zone 80 feet below the top of the Pahasapa. The water has been used for stock, but at present is flowing to waste in Stockade Beaver Creek. The chemical character of the water from this well is given in the table of analyses (analysis F).

Osage well.--In 1941 an oil test well was drilled by Mr. E. B. Jones in the NE SW SE sec. 10, T. 46 N., R. 63 W. near Osage, Wyoming. The well was drilled to a depth of 2,592 feet where a large cavern was encountered (see log above). Originally the producing formation was thought to be the sand at the base of the Minnelusa formation and possibly some water is derived from this sand. However, the correlation by Mr. Krampert, consulting geologist of Casper, Wyoming, who has examined cuttings from the well, and a study of the driller's log, indicate that most of the water was encountered in cavernous limestone at the top of the Pahasapa (Madison) limestone. The cavernous character of this zone is indicated by the fact that the rotary drill dropped without circulation, rotation, or weight, from a depth of 2,580 to 2,592 feet.

Forty feet of 10-inch casing had been set in the top of the hole when water was encountered, the remainder of the hole being open. An attempt was made to shut the well in, but water broke through and came to the surface 600 feet north of the well. Eight-inch casing was then set to 412 feet and cemented, and 6-inch casing was set to 2,485 feet and cemented. The well has flowed to waste since

April 1941; however, the Black Hills Power & Light Company is now constructing a steam-turbine plant for generation of electric power at Osage and plans to use this flowing well as a source of water supply.

On June 12, 1941, two current-meter measurements of the discharge were made by Mr. N. B. Bennett, Jr., Assistant State Engineer of Wyoming, at a point 600 feet downstream from the well. These measurements were 1.76 and 1.78 cubic feet per second. The average of these two measurements, 1.77 cubic feet per second, is equivalent to 800 gallons a minute, or 1,150,000 gallons a day. In the fall of 1946, engineers of the Black Hills Power & Light Company measured the flow of the well using a V-shaped weir, and found the flow to be 720 gallons a minute. This measurement shows a decrease of about 10 percent of the original flow in five years; however, the difference in yield possibly could be explained by the difference in methods of measurement. No measurements of the pressure head have been made, but the water appears to be under considerable pressure.

The temperature of the water was 75° F. on July 12, 1941, and was 76° F. on December 9, 1947. The analysis indicates the comparatively low mineral content of the water from the Osage well (analysis G - see table).

Cambria well.--Many years ago a deep well was drilled at the Cambria mines about 6 miles north of Newcastle. This was the first deep well to be drilled in this area, and the drill cuttings from the well were studied by N. H. Darton and described in the Newcastle folio (see reference above). As described by Darton, "The deep boring at Cambria was begun just below the base of the Lakota sandstone and continued to a depth of 2,345 feet ***. When the boring was at 2,345 feet the owners concluded to test a water supply found at 2,115 feet before going farther. The water at that depth was found to yield 200 gallons a minute and its quality was entirely satisfactory, so that it has been adequate for the needs of the town." The top of the Pahasapa was reached at 1,947 feet and the producing zone was found about 165 feet below the top of the formation. The Minnelusa

sandstone was so tightly cemented that it yielded no water to the Cambria well.

Deadwood formation

Beneath about 600 feet of Pahasapa limestone is a series of massive sandstones, shales, and beds of conglomerate comprising the Deadwood formation. These beds crop out high in the Black Hills and probably contain water in the subsurface beneath Newcastle. The Deadwood formation has not been reached by drilling in this area, and the quantity and quality of the water in the sandstones is not known.

Possibilities of a water well in the Newcastle area.

Depth and construction of wells

The available data pertinent to the development of municipal, industrial, or other comparatively large ground-water supplies near Newcastle all indicate that wells should be drilled at least to the lower part of the Minnelusa sandstone and probably into the Pahasapa (Madison) limestone. The analyses of water samples from the shallower rocks indicate that the chemical character of the water from those beds is not suitable for municipal or industrial use, although some small domestic and stock wells derive highly mineralized water from them.

The top of the Pahasapa limestone is estimated to be about 2,760 feet below land surface at Newcastle. This estimate has been reached by comparison of land-surface elevation at the Osage well (4,350 feet above sea level) and land-surface elevation at the U. S. C. and G. S. bench mark at the railroad-main street crossing in Newcastle (4,317 feet above sea level), together with the fact that the bench mark in Newcastle is about 250 feet structurally lower than the land surface at the Osage well. Mr. Vincent Evans, formerly of the Carter Oil Company, estimated that the top of the Pahasapa would be about 2,830 feet below land surface at the refinery at the west edge of Newcastle (see reference above). In the Newcastle folio (see reference above), Darton estimated that the top of the

Pahasapa would be 2,740 feet below the surface at Newcastle, basing his estimate on the well at Cambria. The depth of the top of the Pahasapa at Newcastle probably will be within the range of these estimates, and will depend on the location of wells within the city and variation in thickness of some of the beds, especially the Minnelusa sandstone. The productive zone may be at the top of the Pahasapa or may be as much as 170 feet below the top, as may be noted from records of the several wells drilled in this area. The depth of the producing zone in a water well at Newcastle may be expected to range from about 2,740 feet (minimum estimate) to about 3,020 feet (maximum estimate).

The analyses of water from formations above the Minnelusa sandstone indicate the necessity for casing the well at least to the top of that formation. The upper part of the Minnelusa may or may not yield fresh water in the Newcastle area, and if the water is of poor quality the casing should be extended to the lower part of the sandstone. Some of the upper formations contain water that might corrode casings and grouting would appear to be advisable.

Yield of wells

The quantity of water flowing from the several deep wells in the vicinity of Newcastle ranges between wide limits, being about 20 gallons a minute at the L A K well, 150 gallons a minute at Martens deep well, 200 gallons a minute at the Cambria well, and 720-800 gallons a minute at the Osage well. None of the wells in this area have failed to encounter some water in either the Minnelusa or Pahasapa formations, or in both, even though some of them may have been improperly finished. It appears reasonably certain that a well drilled in Newcastle, for example, at an elevation of 4,320-4,350 feet above sea level would flow from these formations. The static heads of the producing wells in the area have not been measured, but it appears likely that a well drilled at the city reservoir, several hundred feet above the town, may not flow and hence may require pumping. The yield of a well drilled in the vicinity of Newcastle

cannot be predicted, but if properly finished and developed it appears possible that a single well may yield a quantity of water sufficient for the needs of the city.

Elsewhere the yield of wells penetrating formations similar to the Minnelusa and Pahasapa has been increased by acid treatment. The sandstones in the Minnelusa are partly cemented by calcium carbonate, and acidizing increases the effective diameter of wells in such rocks. The Pahasapa is a limestone having porous and cavernous zones within it. Application of acid to rocks of this character allows many more of the small passageways entrance to the drill hole and generally results in increased yield. It is suggested that acid treatment may increase the yield of wells penetrating the Minnelusa and Pahasapa formations near Newcastle, especially if the original yield does not meet requirements.

Economic considerations

Analysis of the costs involved in drilling and properly finishing one or more successful water wells in the Newcastle area is beyond the scope of this report. However, it is noted that the costs of drilling to the deep aquifers will be large, and that while such drilling appears to be a reasonable risk for cities and industrial plants, there is no positive assurance that large water supplies can be obtained. It would appear logical that engineering advice be sought and comparative estimates of costs of all sources of a good water supply be made before expending the funds necessary to drill 2,800 feet.

Chemical analyses of water from wells near Newcastle, Wyoming

Dissolved constituents given in parts per million[a] reacting values (underlined) given in equivalents per million[b]

Reference letter, this report	Name of well	Geologic source	Date of collection Dec. 1947	Temperature (°F.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness calculated as $CaCO_3$		pH
																		Total	Noncarbonate	
A[c]	Grayco refinery	Lakota	8/15/41	—	—	Present	308. 15.37	138. 11.35	128. 5.57		140. 2.30	1413. 29.42	21. .59	—	—	—	2077			
B	Grayco refinery	Lakota - Sundance	10	61	3.0	54.[d]	286. 14.27	118. 9.70	59. 2.55	14. .36	24. .39	1250. 26.02	14. .39	1.8 .09	0	—	1760	1200	1180	5.5
C	Martens shallow well	Opeche - Minnelusa	10	58	6.0	.05	504. 25.16	148. 12.17	29. 1.26	8.4 .21	136. 2.23	1720. 35.81	3.8 .11	2.4 .13	1.8 .03	—	2480	1860	1730	7.5
D	L A K Ranch (Shallow zone)	Upper and middle Minnelusa	10	57	5.0	.05	474. 23.65	84. 6.91	9.7 .42	14. .36	222. 3.64	1310. 27.27	11. .31	1.8 .09	2.2 .04	—	2020	1530	1350	7.2
E	L A K Ranch (deep zone)	Lower Minnelusa and Pahasapa	10	58	7.6	0	55. 2.75	13. 1.07	37. 1.61	7.6 .19	300. 4.92	27. .56	2.8 .08	.7 .04	1.8 .03	0.14	298	191	0	7.2
F	Martens deep well	Pahasapa	9	60	11.	.05	58. 2.89	9.8 .81	36. 1.58	6.6 .17	306. 5.02	16. .33	1.8 .05	.5 .03	1.5 .02	.1	290	185	0	7.1
G	Osage well	Lower Minnelusa and Pahasapa	9	76	5.6	.05	70. 3.49	19. 1.56	18. .78	2.4 .06	296. 4.85	47. .98	1.2 .03	.6 .03	1.3 .02	.07	346	252	9	7.1

a/ One part per million is equivalent to one pound of substance per million pounds of water, or 8.33 pounds per million gallons of water.

b/ An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution.
Concentration in equivalents per million is calculated by dividing the concentration in parts per million by the chemical combining weight of the substance or ion.

c/ Partial analysis.

d/ Precipitated iron.