GROUND WATER SUPPLY FOR THE CITY OF SCOTLAND

by

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Science Center
University of South Dakota
Vermillion, South Dakota
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GROUND WATER SUPPLY FOR THE
CITY OF SCOTLAND

by

Cleo M. Christensen

INTRODUCTION

Present Investigation

This report contains the results of a special investigation for the
city of Scotland by the South Dakota State Geological Survey during the
period July 23-August 12, 1962, in Bon Homme and Hutchinson counties, South
Dakota (fig. 1), for the purpose of assisting the city in locating future
water supplies. Scotland now receives its water supply from two wells which
do not supply the quantity and quality of water needed by the community.
The two wells produce from the Niobrara Formation at a depth of about 125
feet and are located within the city limits (fig. 2).

A survey of the ground water possibilities was made of a 64 square
mile area around the city, and consisted of geologic mapping, a well inventory,
the drilling of 23 rotary test holes to an average depth of 132 feet and 10
auger holes to an average depth of 39 feet, and the taking of 16 water
samples for analysis. As a result of this survey it is recommended that the
city drill several more test holes 2-2 1/2 miles east of the city, because
in this area as much as 60 feet of saturated sand and gravel was penetrated,
and the quality of the water is good.

The field work and preparation of this report were performed under the
supervision of Merlin J. Tipton, Assistant State Geologist. The aid of
Robert Schoon, geologist-driller, and his assistant, Keith Munroe, who
drilled test holes with the Survey's Bucyrus Erie 10-8 rotary rig, is grate-
fully acknowledged. Richard Brown and Steve Potratz drilled test holes with
a Geological Survey jeep-mounted auger drill, and test pumped several holes
to obtain water samples for analysis. Loren Rukstad gave helpful advice
throughout the project. The writer also wishes to thank Nat Luftin of the
Geological Survey and the members of the State Chemical Laboratory for
analyzing the water samples collected for this project.

The cooperation of the residents of Scotland, especially Mayor M. T.
Sweet, and LaRoy Gimbel, Water and Sewer Superintendent, is greatly appre-
ciated. Special thanks are due to well drillers Art and Otto Bjornum for
making their well records available.

Location and Extent of Area

The city of Scotland is located in southeastern South Dakota and has a
population of 1,077 (1960 census). The area is in the James Basin division
of the Central Lowland physiographic province (fig. 1).

Climate

The climate is continental temperate with large daily fluctuations in
temperature. The average daily temperature is 48.8 degrees F., and the average
annual precipitation is 22.86 inches at the U. S. Weather Bureau Station in
Menno, 13 miles northeast of Scotland.
Figure 1. Major Physiographic Divisions of Eastern South Dakota showing location of the Scotland Area
Topography and Drainage

The topography of the Scotland area is typical youthful glacial moraine-rolling hills and valleys with knobs and kettles. The drainage in the area flows northeasterly to the James River (fig. 3).

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Scotland area are chiefly the result of glaciation late in the Pleistocene Epoch. The glacial deposits, collectively termed drift, can be divided into till and outwash. Till consists of a jumbled mixture of clay, silt, sand, pebbles, and boulders carried and deposited by the ice itself. Outwash material, which consists primarily of sand and gravels, was deposited by meltwater streams from the retreating glaciers. Surface outwash deposits, with the exception of small terraces along the tributaries of the James River (fig. 3), are lacking in the mapped area.

Alluvial material has been deposited along the James River and its tributaries (fig. 3) since the retreat of the glaciers. The alluvium consists of clay and silt with minor amounts of fine to medium sand.

An older buried alluvium was penetrated in rotary test holes 16 and 17. This alluvium is as much as 50 feet thick (Test Hole R. 12) and consists of fine brown silt and clay.

Exposed Bedrock

The Niobrara Formation, which is the only bedrock exposed in the Scotland area, crops out in several places east of the city of Scotland. Where the Niobrara formation is exposed, it consists of a massive, cream-colored chalk which locally contains layers of dark-gray shale.

Subsurface Bedrock

Stratified rocks of Cretaceous age lie beneath the surface deposits in the Scotland area. The Niobrara Formation lies directly beneath the glacial drift and is underlain in descending order by the Carlile, Greenhorn, and Graneros Formations, and the Dakota Group.

The Niobrara Formation, in the subsurface consists of light-gray chalk and light to medium blue-gray shale which contains numerous microscopic white calcareous spores. At the base of the Niobrara Formation is the Cedell Sandstone Member of the Carlile Shale. This member consists of gray to green, fine- to medium-grained, poorly cemented glauconitic sandstone.

The Carlile Formation is medium- to dark-gray bentonitic shale with pyrite concretions and layers of fine brown siltstone.

The Greenhorn Formation consists of a hard layer of white to cream limestone containing numerous fossil fragments. This limestone is overlain (and possibly underlain) by a layer of dark-gray shale containing numerous small white calcareous specks.

The Graneros Formation is hard light- to dark-gray siliceous shale.

The Dakota Group contains layers of alternating shales and sandstones.
OCCURRENCE OF GROUND WATER

Principles of Occurrence

Contrary to popular belief, ground water does not occur in "veins" that criss-cross the land at random. Instead it can be shown that water occurs nearly everywhere beneath the surface, but at varying depths. The top of this zone of saturation is known as the water table.

Nearly all ground water is derived from precipitation. Rain or melting snow either percolates downward to the water table and becomes ground water, or drains off as surface water. Surface water may percolate downward and become ground water, or it may evaporate or drain to the sea by means of streams. In general, ground water moves laterally down the hydraulic gradient, and is in transient storage.

Recharge is the addition of water to an aquifer (water-bearing material) and is accomplished in a number of ways: (1) by downward percolation of precipitated water from the land surface, (2) by downward percolation from surface bodies of water such as lakes and streams, and (3) by lateral movement of water in transient storage.

Discharge of ground water from a water-bearing material is accomplished in four main ways: (1) by evaporation and transpiration of plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water in transient storage, and (4) by pumping.

The amount of water which can be stored in a saturated material is equal to the amount of voids or pore spaces in that material. A measurement of the capability of a material to store water (or any other liquid) is called porosity. Porosity depends entirely on the shape and arrangement of the particles in a material, and is not affected by size. Sands and gravels usually have porosities of 20-40 percent, whereas sandstones normally have porosities of 15-25 percent; this lower porosity of sandstones is due to closer packing and to cementation of the particles.

Permeability is the rate at which a fluid will pass through a substance. If the pore spaces of a material are connected, the permeability of that material will be high. If the pore spaces are not connected, the permeability will be low. Thus, a material may have high porosity and still not yield water readily because of low permeability. Sands and gravels, however, tend to have both high porosity and high permeability. Thus the geologist is not concerned with finding a "vein" when looking for a good water supply; but because water occurs almost everywhere in the ground, he is searching instead for a sand or gravel or another similarly porous and permeable deposit that lies beneath the water table.

Ground Water in Alluvium

Alluvium is present along the James River and its tributaries in the Scotland area (fig. 3). This alluvium contains large amounts of water where it is below the water table, but because of its low permeability it does not yield water readily. The alluvium along Dawson Creek (fig. 3) was test-drilled with the Survey's jeep-mounted auger drill, but the deposits are too thin and too fine to support a city water supply.
Ground Water in Glacial Deposits

As was stated earlier, glacial deposits can be divided into till and outwash. Till, because of its unsorted nature and the larger amount of clay, usually does not yield water readily. Outwash, on the other hand, is a good source of ground water because of its high porosity and high permeability. The outwash deposits in the Scotland area include the patches of terraces along the tributaries of the James River mentioned earlier, and two buried outwashes.

Outwash terraces are not considered to be a potential source of water for the city because they cover a relatively small area and for the most part are above the water table and are therefore dry. A lower buried outwash occurs about two miles northeast of Scotland and is overlain by 200-250 feet of glacial till. These lower buried outwash sediments have an average thickness of 19 feet and a maximum thickness of 31 feet (see Appendix A; Test Hole R. 4). The lower buried outwash has an extent of about three square miles in the mapped area (fig. 3) and trends northeast-southwest.

An upper buried outwash in the northeastern part of the mapped area covers about eight square miles and is overlain by 30-115 feet of glacial till. The outwash sands and gravels average about 48 feet thick and have a maximum thickness of more than 120 feet (Test Hole R. 1). The apparent trend of this outwash in the limited area it was mapped is northwest-southeast (fig. 3). The relative thickness of the outwash sediments are shown on figure 4. The outwash sediments have an uneven surface and appear to slope to the east (fig. 5).

Both the upper and lower buried outwashes were test-drilled with the Survey's rotary drilling rig. The test holes were drilled with natural mud, using a 4 1/2-inch drag bit.

The areal extent of the buried outwash and was mapped as accurately as possible from these test holes and from a well inventory of the area.

Ground Water in Bedrock

Both the Niobrara Formation and the Dakota Group supply water to wells in the Scotland area (Appendix C). The Niobrara Formation lies at depths of 0-180 feet in the Scotland area and water can be obtained from this formation where it is below the water table. Some water is obtained directly from the main body of the formation, which is chalk, however, more and slightly better water is obtained from the Cudell Sandstone Member of the Carlile Formation, which is directly below the Niobrara. The chalk and sandstone constitute a single aquifer even though they belong to two different formations and this aquifer supplies water to numerous wells in the Scotland area (see Appendix C).

The sandstones of the Dakota Group are the only other bedrock from which water is readily obtained in the Scotland area. These sandstones are at a depth of 500-600 feet in the Scotland area and their waters are under artesian pressure.

The recharge for these Dakota sandstones in South Dakota is said to come from the Rocky Mountains or the Black Hills, where they crop out a much higher elevation than in the Scotland area. The overlying Cretaceous shales provide the imperious material that confines the water to the sandstones.

One well in the area is producing water from the Greenhorn Limestone but it is not considered to be a major aquifer.
Figure 4. Map Showing Thickness of Upper Buried Outwash Sediments, in the Scotland Area

- Lines of equal thickness
- Test hole showing thickness of sand and gravel
  Contour interval: 20 feet

Scale

0 1/8 1 2 miles

C. M. Christensen, 1962
Figure 5. Map of Surface of Upper Buried Outwash, in the Scotland Area

Contour on surface of upper buried outwash deposit, interval 10 feet

Test hole showing elevation of surface of upper buried outwash deposit.

Scale

0

1

2 miles

by

C. M. Christensen, 1962
Quality of Ground Water

Precipitated water is nearly pure before it reaches the ground, however, all ground water contains minerals which are obtained (1) from the atmosphere, (2) from soil and underlying deposits as the water percolates downward to the water table, and (3) from deposits below the water table in which the water is circulating. In general it can be said that the more minerals a water contains, the poorer its quality. The water in the Niobrara Formation and the Dakota Sandstone is generally of a poorer quality than that in the buried outwash deposits.

Table 1 is a comparison of various waters in the Scotland area with the present city water and with the Public Health Standards for drinking water. It can be seen that both present city wells exceed the Public Health Standards in sulfates, iron, manganese, and total solids. Both wells also contain a very large amount of CaCO₃ which accounts for the extreme hardness of the water, in most cases the water taken from the buried outwash deposits is much better than the water from the present city wells. Sample 4, which was pumped from Rotary Test Hole 16 has the best quality water taken from the upper buried outwash deposits. Although this water exceeds the standards for iron, it is otherwise acceptable.

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the city of Scotland drill several test holes for future water supplies between Rotary Test Hole 16 (SE 1/4 SE 1/4 sec. 3, T. 96 N., R. 58 W.) and Rotary Test Hole 17 (SE 1/4 SW 1/4 sec. 2, T. 96 N., R. 58 W.). Although this is not the thickest area of the buried outwash, it does contain 97-60 feet of sand and gravel (fig. 6) and the water is of a good quality. It would be advisable for the city to obtain a sample of water from each of these test holes in order to find the area within the aquifer which has the best quality water. After a well site is chosen on the basis of the quality of the water a test well should be installed and test-pumped. This test pumping should be conducted by licensed engineers and should be run for a minimum of 7/2 hours to determine yield, drawdown, and recovery of the aquifer.

It is suggested that the city contract with a commercial drilling company licensed by the State of South Dakota to test-drill the area recommended. The city officials should consult the State Water Resources Commission with regard to obtaining a water right and a permit to drill a city well, and the State Department of Health with regard to the biological and chemical suitability of the water. A consulting engineering firm licensed in the State of South Dakota should be hired to design the well and adjoining water system.
### Table 1. Chemical Analyses of Water Samples in the Scotland Area

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*Modified for South Dakota by the State Department of Health (written communication, February 5, 1962)*

*Optimum

*Lower Buried Outwash*
Locations of Water Samples

A  U. S. Public Health Standards for Drinking Water

B  City Well #1

C  City Well #2

1  S.D.G.S. Rotary Test Hole #16 SESE Sec. 3, T. 96 N., R. 58 W.
2  Art Handel SESE Sec. 29, T. 97 N., R. 58 W.
3  Ward Asche (farm) HESW Sec. 18, T. 97 N., R. 58 W.
4  Otto Bietz (farm) HESW Sec. 33, T. 97 N., R. 58 W.
5  S.D.G.S. Rotary Test Hole #14 NWNW Sec. 10, T. 96 N., R. 58 W.
6  Ross Habbert (farm) SENE Sec. 4, T. 96 N., R. 58 W.
7  R. Buechler (farm) NWSW Sec. 21, T. 97 N., R. 58 W.
8  C. Nuemeister (farm) SWSW Sec. 3, T. 96 N., R. 58 W.
9  S.D.G.S. Rotary Test Hole #4 SESE Sec. 6, T. 97 N., R. 58 W.
10  Bill Engel (farm) SSW Sec. 34, T. 97 N., R. 58 W.
11  D. Hebbert (farm) SENW Sec. 3, T. 96 N., R. 58 W.
12  S.D.G.S. Rotary Test Hole #2 NWNW Sec. 34, T. 97 N., R. 58 W.
13  Lake Henry SE Sec. 9, T. 96 N., R. 58 W.
14  Deutsher (farm) NWNW Sec. 12, T. 96 N., R. 58 W.
15  H. Schlechter (farm) SESE Sec. 26, T. 97 N., R. 59 W.
16  Burke SWSW Sec. 32, T. 97 N., R. 58 W.
Figure 6. Geologic Cross-section showing Upper Buried Outwash Sediments, in the Scotland Area

EXPLANATION
- Glacial till
- Upper buried outwash
- Older alluvium?
- Niobrara chalk
- Cadell sandstone member
- Carliie shale

Scale: 0

1/2

1 mile

by

C.M.Christensen, 1962
REFERENCE CITED

### APPENDIX A

**Logs of Rotary Test Holes in the Scotland Area**

Test Hole R. 1  
**Location:** ESWW Sec. 28, T. 37 N., R. 58 W.  
**Elevation:** 1330 feet  
0- 25 clay, buff, sandy  
25- 33 clay, gray, sandy  
33-105 sand, fine to granular

---

Test Hole R. 2  
**Location:** INNW Sec. 3a, T. 97 N., R. 58 W.  
**Elevation:** 1293 feet  
0- 15 clay, buff, silty  
15- 20 clay, gray, sandy  
20- 25 gravel, pea to nut-size  
25- 35 clay, gray, sandy  
35-110 sand, fine to coarse  
110- plugged bit

---

Test Hole R. 3  
**Location:** SESE Sec. 27, T. 97 N., R. 58 W.  
**Elevation:** 1290 feet  
0- 15 clay, buff, sandy, pebbly  
15- 20 clay, gray, sandy, very pebbly  
20- 34 clay, buff, sandy  
34- 76 clay, gray, sandy  
76- 92 gravel, pea-sized  
92-120 clay, gray, sandy  
120-150 gravel, fine to pea-size  
150-280 clay, gray, pebbly  
280- hit boulder at 280 feet

---

Test Hole R. 4  
**Location:** SESE Sec. 26, T. 97 N., R. 58 W.  
**Elevation:** 1281 feet  
0- 30 clay, buff, sandy  
30- 35 sand, fine to medium-grained  
35-115 clay, gray, sandy  
115-125 gravel, pea to nut-size  
125-140 clay, gray, sandy  
(continued on next page)
Test Hole R. 4—continued

140-150 sand, medium to coarse-grained
150-199 clay, gray, sandy
199-230 gravel, fine to pea-size; medium to coarse sand
230-240 clay, gray, sandy (older alluvium?)
240-250 shale (Carilite)

Test Hole R. 5
Location: NWNE Sec. 33, T. 67 N., R. 58 W.
Elevation: 1305 feet

0- 21 clay, buff, sandy
21- 35 clay, gray, sandy
35- 45 sand, coarse
45-122 clay, gray, sandy
122— Codell or a hard rock. Could not advance drill

Test Hole R. 6
Location: SESE Sec. 32, T. 67 N., R. 58 W.
Elevation: 1305 feet

0- 18 clay, buff, sandy
18-230 clay, gray, sandy
230-235 gravel, pea-size
235— Codell Sandstone

Test Hole R. 7
Location: SESE Sec. 35, T. 67 N., R. 58 W.
Elevation: 1295± feet

0- 35 clay, buff, sandy
35- 50 sand, very fine
50- 95 clay, gray, sandy
95-118 sand, gravel, coarse, nut-size
118-130 clay, gray, sandy
130-160 sand, medium to very coarse; fine gravel

Test Hole R. 8
Location: NESE Sec. 5, T. 66 N., R. 58 W.
Elevation: 1325 feet

0- 15 clay, light-gray to light-buff, sandy and pebbly
15- 85 clay, medium gray, sandy and gritty
85-103 gravel, pea to nut-size
(continued on next page)
Test Hole R. 8--continued

100-107  clay or silt
107-130  sandstone, brown and green (Codell)
130-140  shale

Test Hole R. 9
Location:  SE1/4 Sec. 33, T. 97 N., R. 58 W.
Elevation:  1318 feet

1- 15  clay, buff, sandy
15- 23  gravel and sand (non water-bearing)
23- 49  clay, gray, sandy
49- 56  sand and fine gravel
56- 65  clay, gray, sandy
65- 78  sand, coarse and fine gravel
78-220  clay, gray, sandy and a few gravel stringers
220-241  sand and gravel, nut-size
241-265  clay, gray, sandy

Test Hole R. 10
Location:  1/2 SW1/4 S5, T. 97 N., R. 58 W.
Elevation:  1395 feet

0- 28  clay, buff, sandy
28- 40  clay, gray, sandy
40- 46  sand, medium to coarse; pea-size gravel
46-150  clay, gray, sandy and pebbly with occasional thin gravel lenses
150-210  sand, medium-grained at top becoming coarse-grained to gravel at base
210-215  clay, gray, sandy
215-235  gravel, pea to nut-size
235-240  clay, gray, sandy

Test Hole R. 11
Location:  SE1/4 Sec. 2, T. 96 N., R. 58 W.
Elevation:  1290+ feet

0-  5  topsoil
5- 25  clay, buff, sandy
25- 33  clay, gray, sandy, pebbly
35- 40  gravel, nut-size
40- 80  clay, gray, sandy, thin gravel lenses
80-150  gravel, pea to nut-size, coarse sand
130-140  Carlile Shale
Test Hole R. 17
Location: SW1/4 Sec. 4, T. 96 N., R. 58 W.
Elevation: 1355 feet

0-31 clay, buff, sandy
31-55 clay, gray, sandy
55-70 Niobrara Chalk (lost circulation at 65 feet)

Test Hole R. 13
Location: SSW1/4 Sec. 3, T. 96 N., R. 58 W.
Elevation: 1397 feet

0-26 clay, buff, sandy
26-55 clay, gray, sandy; many thin sands and gravels
55-78 clay, gray, sandy
78-115 Niobrara Chalk (?) — samples badly mixed
115-125 Codell Sandstone

Test Hole R. 14
Location: NNE1/4 Sec. 10, T. 96 N., R. 58 W.
Elevation: 1325 feet

0-25 clay, buff, silty, sandy
25-37 clay, gray, sandy
37-40 gravel, pea-size
40-68 clay, gray, sandy
68-75 gravel, pea-size
75-83 clay, gray, sandy
83-140 gravel, fine to nut-size (hole binding badly)

Test Hole R. 15
Location: SSE1/4 Sec. 3, T. 96 N., R. 58 W.
Elevation: 1273 feet

0-18 clay, buff, sandy
18-58 clay, gray, sandy
58-98 sand, coarse
98-200 clay, gray, sandy (till)

Test Hole R. 16
Location: S1/2 SE1/4 Sec. 3, T. 96 N., R. 58 W.
Elevation: 1227 feet

0-5 alluvium
(continued on next page)
Test Hole R. 16--continued

5-20 clay, buff, sandy
20-39 sand, very coarse; fine gravel
39-46 alluvium (?)
45-82 gravel, pea to nut-size; sand
82-95 Carlile Shale

Test Hole R. 17
Location: SESE Sec. 2, T. 96 N., R. 58 W.
Elevation: 1285 feet

0- 35 clay, buff, sandy
25- 90 clay, gray, sandy
90-150 gravel, pea to nut-size; sand
150-200 alluvium (?)

Test Hole R. 18
Location: SESE Sec. 2, T. 96 N., R. 58 W.
Elevation: 1295 feet

0- 31 clay, buff, silty, sandy
31- 55 clay, gray, silty and sandy
55- 61 gravel, pea-size
61-111 clay, gray, sandy
115-125 gravel, pea-size; coarse-grained sand
125-137 clay, gray, very sandy
137-190 sand, medium to coarse-grained; pea-size gravel
190-227 clay, very sandy (clay alluvium?)
227-286 Codell Sandstone (?) (getting poor returns)
286-306 Carlile Shale

Test Hole R. 19
Location: SESE Sec. 1, T. 96 N., R. 58 W.
Elevation: 1280 ft.

0- 25 clay, buff, sandy
25-105 clay, gray, sandy
105-110 sand, coarse
110-170 clay, gray, sandy
Test Hole R. 20
Location: SESE Sec. 11, T. 96 N., R. 58 W.
Elevation: 1290 feet
0- 25  clay, buff, sandy
25- 35  gravel, nut-size
35-107  clay, gray, sandy
107-200  sand, few streaks of gravel

Test Hole R. 21
Location: SESE Sec. 10, T. 96 N., R. 58 W.
Elevation: 1290 feet
0- 17  clay, buff, sandy
17- 25  clay, gray, sandy
25- 29  gravel, nut-size
29-110  clay, gray, sandy
110-137  sand, medium to coarse
137-170  clay, gray, sandy

Test Hole R. 22
Location: SWSW Sec. 14, T. 96 N., R. 58 W.
Elevation: 1290 feet
0- 25  clay, buff, sandy
25- 36  clay, gray, sandy
36- 44  sand, fine
44- 90  clay, gray, sandy
90-185  sand, medium to coarse; some fine gravel

Test Hole R. 23
Location: NESE Sec. 17, T. 95 N., R. 58 W.
Elevation: 1350 feet
0-24  clay, buff, sandy
24-40  sand, gravel, dry
40-58  clay, gray, silty and sandy; a few thin gravels
58-80  Pikovara Chalk
APPENDIX B

Logs of Auger Test Holes in the Scotland Area

Test Hole A. 1
Location: NNW Sec. 32, T. 97 N., R. 58 W.,
0-9 clay, brown, silty and sandy
9-29 clay and sand about half and half; some gravel. Water at 17 feet,
29-34 no cuttings, only water and a trace of silt
34-39 clay, blue-brown, sand, fine (25%); hard drilling
39-49 no cuttings; very slow, hard drilling

Test Hole A. 2
Location: SENE Sec. 32, T. 97 N., R. 58 W.,
0-24 clay, brown, sandy; some gravel from 14 to 19 feet
24-39 clay, blue-brown, silty, hard drilling; water at 26 feet
39-69 no cuttings, only water and a trace of sand, easier drilling,
bit sample was blue clay

Test Hole A. 3
Location: SESE Sec. 3, T. 96 N., R. 58 W.,
0-4 clay, brown, silty
4-9 clay, sandy, brown, damp; fine sand (50%)
9-24 sand, fine to medium; brown clay (60%) water at 16 feet
24-44 few cuttings, very hard drilling

Test Hole A. 4
Location: SESE Sec. 8, T. 96 N., R. 58 W.,
0-4 topsoil
4-24 clay, brown, hard, layer of pea gravel at 5 feet; light-gray sand
24-34 clay, blue-gray, sandy, very hard drilling

Test Hole A. 5
Location: NESW Sec. 10, T. 96 N., R. 58 W.,
0-9 few cuttings, some topsoil
9-14 clay, brown, sand from 10 to 11 feet
14-19 clay, dark blue, dense, hard drilling
19-24 clay, dark gray, dense, hard drilling
Test Hole A. 6
Location: MENE Sec. 24, T. 96 N., R. 37 W.
0- 9  clay, brown, silty and sandy, sand, coarse (5-10%)
  9-24  clay, brown; sand, coarse (20%); pea-size gravel
  24-39  clay and sand about half and half; some gravel
  39-40  no cuttings, very hard drilling

Test Hole A. 7
Location: SSWW Sec. 17, T. 96 N., R. 58 W.
0- 4  clay, dark brown, sandy, sand (25%)
  4- 9  clay, light brown, sandy; sand (50%)
  9-17  no cuttings, very hard drilling, bit sample was Niobrara Chalk

Test Hole A. 8
Location: NNSW Sec. 16, T. 96 N., R. 38 W.
0- 4  clay, dark brown, sandy
  4- 9  clay, light brown, sand (50%); some pea-size gravel
  9-13  sand, medium; gravel, pea size, clayey. Water at 12 feet.
  13-24  few cuttings, some silt and clay, hard drilling
  24-36  few cuttings, some blue-brown clay, very sandy; may be
          Niobrara Chalk at 36 feet. Could not advance.

Test Hole A. 9
Location: SWNW Sec. 15, T. 96 N., R. 58 W.
0- 9  clay, brown, sandy
  9-24  clay, brown, sandy; water at 12 feet; some fine sand
  24-29  clay, dark brown and gravel, pea-size; some coarse sand
  29-39  clay, blue-gray, hard drilling, sandy, few cuttings after 34 feet

Test Hole A. 10
Location: SESE Sec. 15, T. 96 N., R. 58 W.
0- 4  clay, brown, very silty, sandy
  4-14  sand, fine, silty; and clay (35%), brown. Water at 11 feet.
  14-29  clay, blue-brown, sandy and silty
  29-35  few cuttings, some blue silt and sand, hard drilling. Could not
          advance past 35 feet.
## APPENDIX C

### Record of Wells

**Well location:** Letters stand for quarter section, first number for section, second for township north, third for range west

**Use of Water:** S, stock; D, domestic

**Character of material:** s1, sand lens; ss, sandstone

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<th>Well Location</th>
<th>Owner or Tenant</th>
<th>Geologic Source</th>
<th>Character of Material</th>
<th>Use of Water</th>
<th>Depth of Well (feet)</th>
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### Appendix C - Record of Wells—continued

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