STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

SPECIAL REPORT 20

GROUND WATER SUPPLY FOR THE CITY OF SCOTLAND

by
Cleo M. Christensen

Science Center
University of 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 10, 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 165 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 Munneke, who drilled test holes with the Survey's Bucyrus Erie 10-R rotary rig, is gratefully acknowledged. Richard Brown and Steve Pottratz 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 Lufkin 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 LeRoy Gimbel, Water and Sewer Superintendent, is greatly appreciated. Special thanks are due to well drillers Art and Otto Bjorum 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 48.3 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.

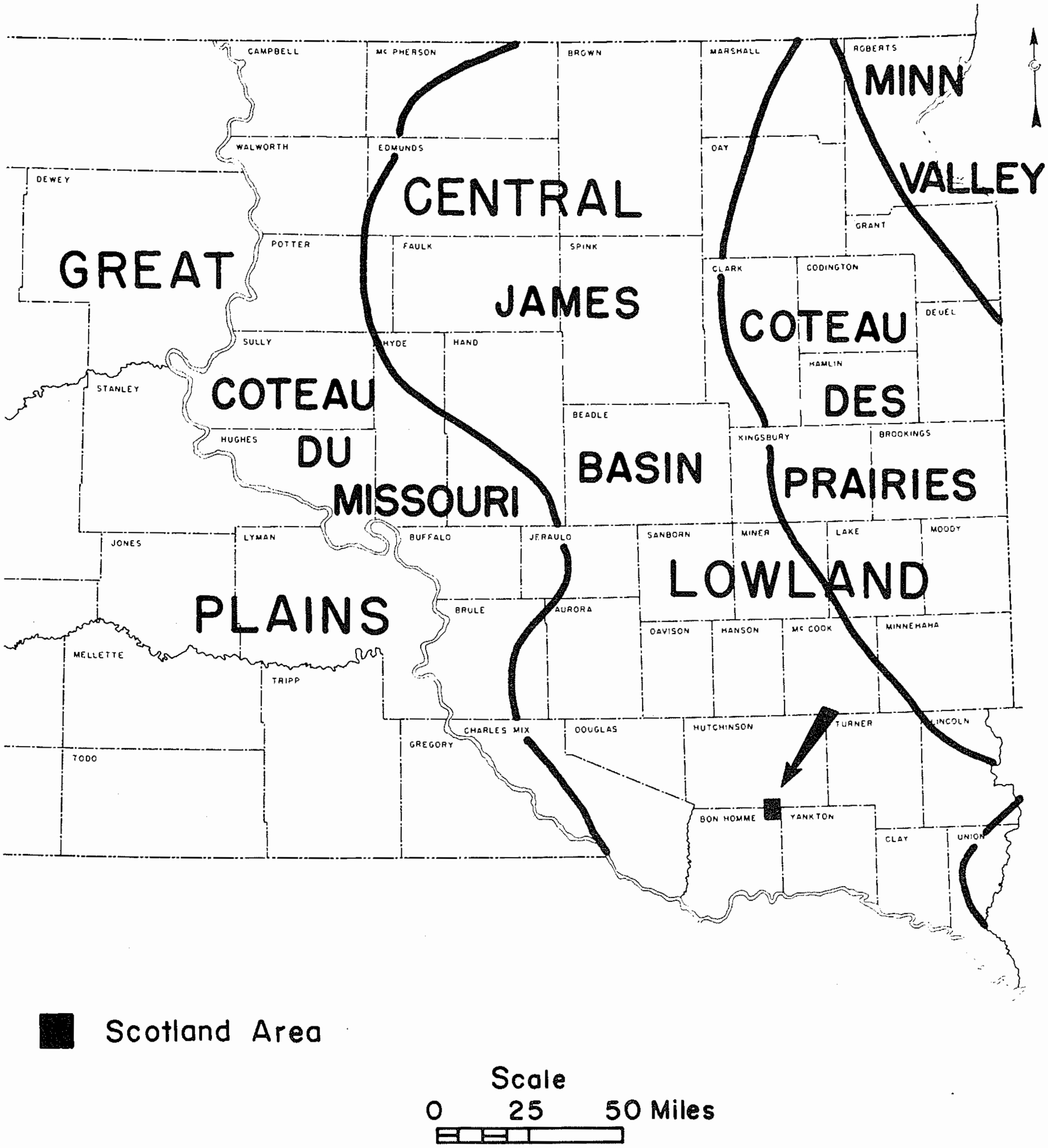
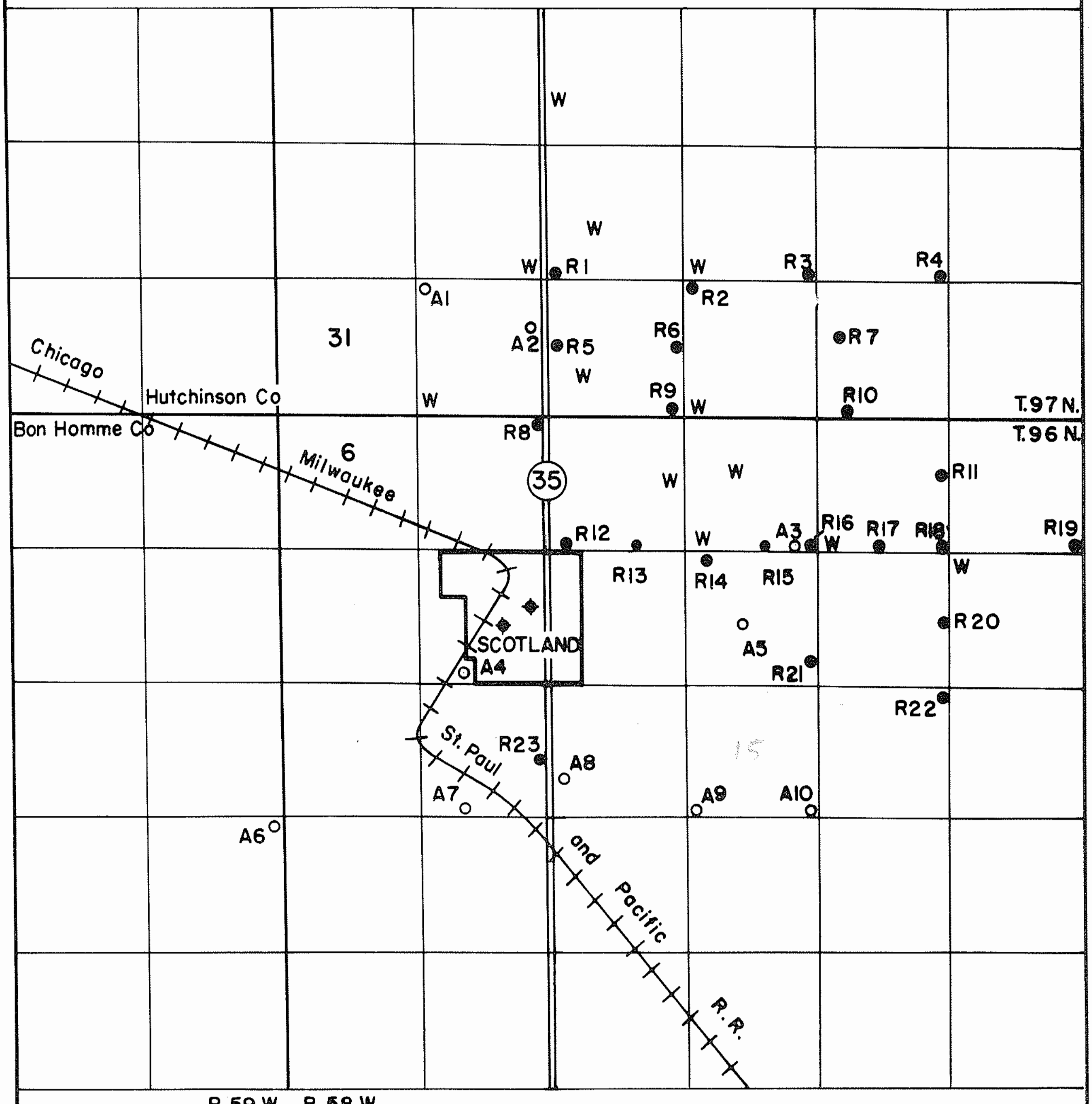


Figure I. Major Physiographic Divisions of Eastern South Dakota showing location of the Scotland Area

Figure 2. Data Map of the Scotland Area



EXPLANATION

- ● R Rotary test hole
- ○ A Auger test hole
- ◆ City well
- W Water sample

N

Scale: 0 ½ 1 2 miles

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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 sands and gravels, was deposited by meltwater streams from the wasting 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 specks. At the base of the Niobrara Formation is the Codell Sandstone Member of the Carlile Shale. This member consists of gray to green, fine- to medium-grained, poorly cemented glauconitic sandstone.

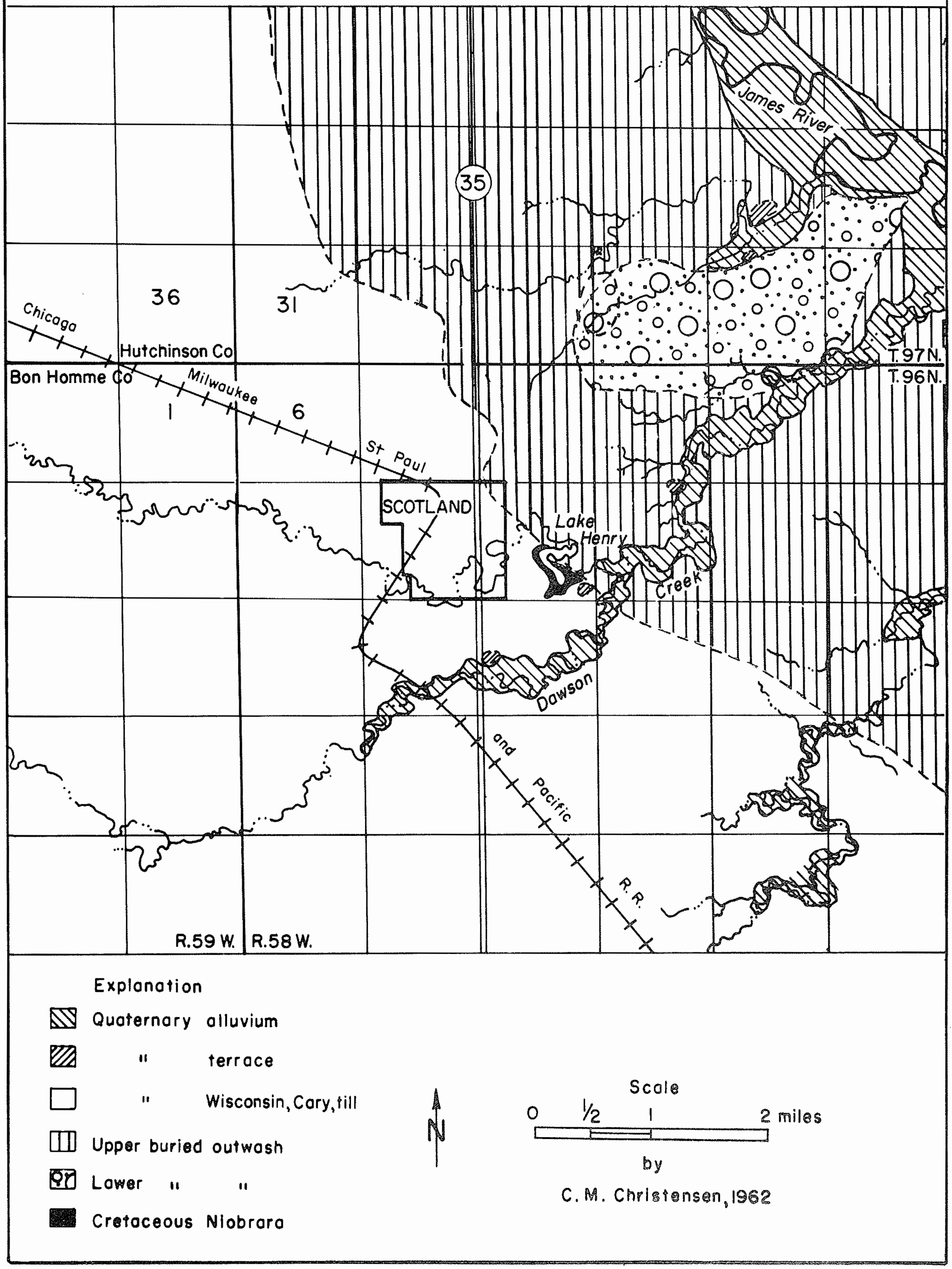
The Carlile Formation is medium- to dark-gray bentonitic shale with pyrite concretions and layers of fine brown siltstone.

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.

Figure 3. Generalized Geologic Map of Scotland Area



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.

The 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 200-230 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 outwashes 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 Codell 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 impervious 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

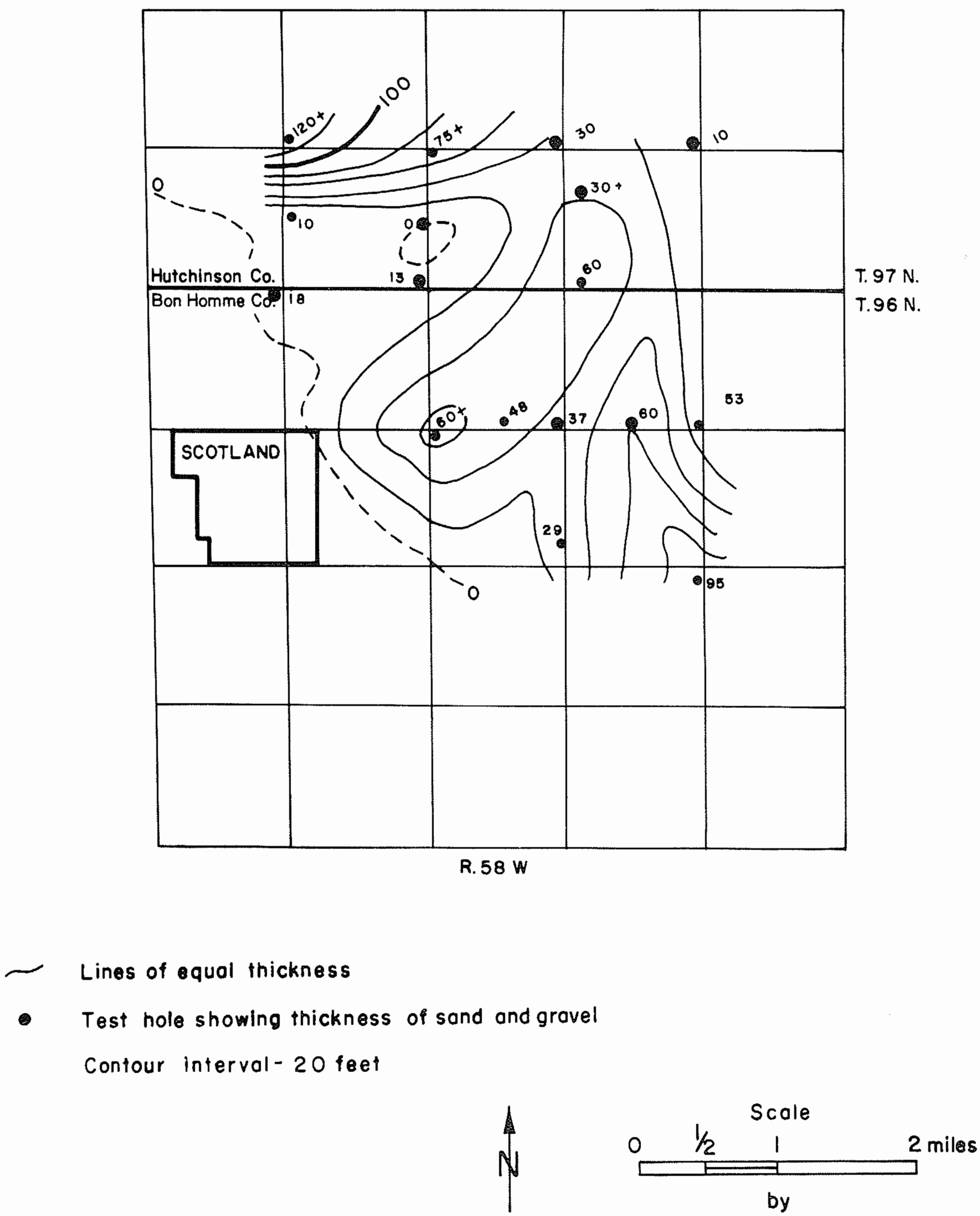


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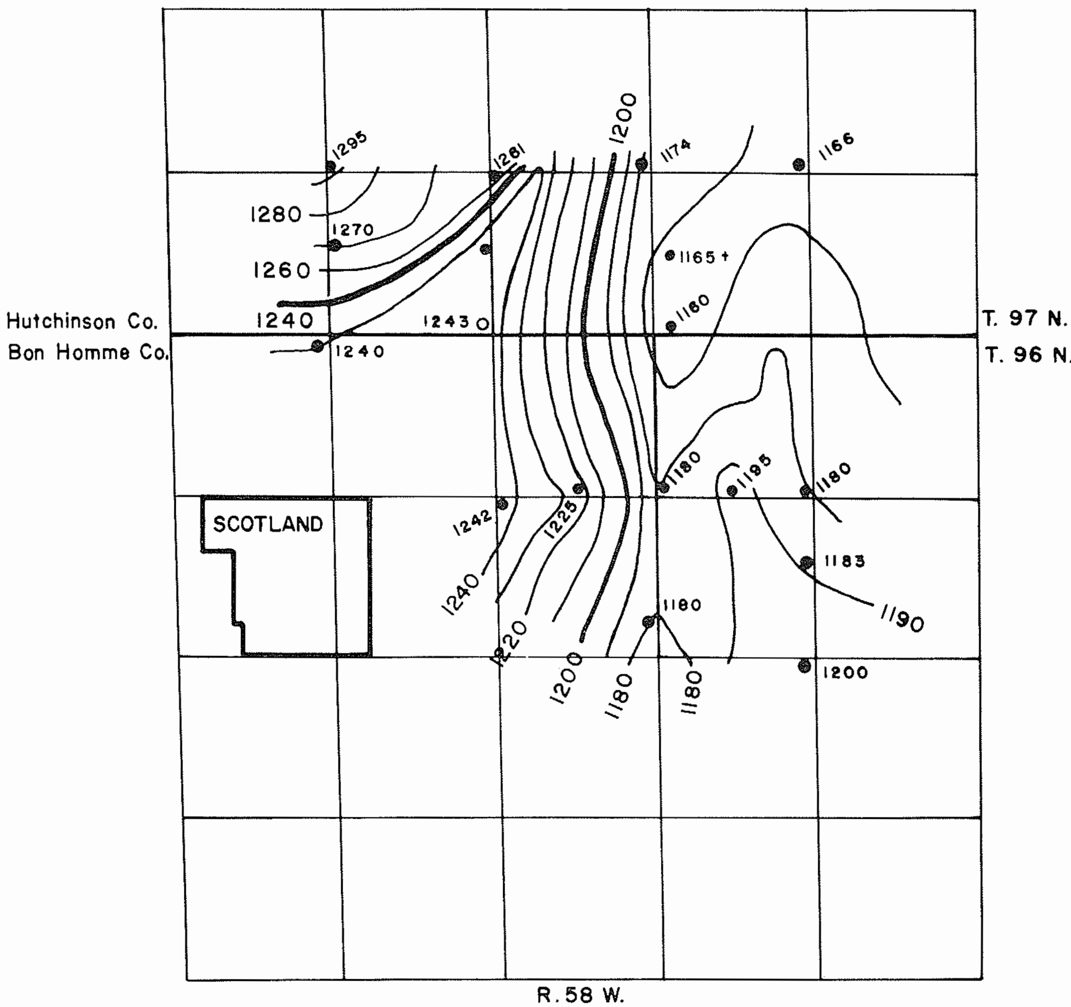
Figure 5. Map of Surface of Upper Buried Outwash, in the Scotland Area



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

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

Scale

0 ½ 1 2 miles

N

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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 Sandstones 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 $CaCO_3$ 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 1 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 37-60 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 72 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

Sample	Source	Parts Per Million											
		Calcium	Sodium	Mag-nesium	Chloride	Sulfate	Iron	Man-ganese	Nitrate	Fluoride	pH	Hard-ness $CaCO_3$	Total Solids
A	Niobrara	---	---	---	250	500*	0.3	.05	10*	0.9-1.7**	---	---	1000*
B	Niobrara	433	101	129	47	1365	2.0	0.1	0	0.8	7.1	1614	2514
C	Niobrara	343	82	108	28	1080	4.4	0.2	0	0.6	7.1	1308	2011
1	Upper Buried Outwash	123	63	60	8	422	0.8	trace	0.5	0.4	7.3	556	946
2	Upper Buried Outwash	215	44	80	10	675	6.2	0	0.6	0.8	7.5	866	1422
3	Upper Buried Outwash	221	200	163	133	1262	3.7	1.6	0.5	1.6	7.4	1472	2766
4	Upper Buried Outwash	227	44	58	9	625	13.0	0	0.1	0.8	7.3	805	1318
5	Upper Buried Outwash	410		119	68	1070					7.5	1500	3100
6	Upper Buried Outwash	286	138	67	24	876	2.0	2.9	0.9	0.4	7.0	991	1820
7	Upper Buried Outwash	569	163	374	11	2946	2.2	1.0	1.3	1.4	7.4	2961	5018
8	Upper Buried Outwash	271	129	77	25	985	0.6	1.7	0.4	0.4	7.3	992	1876
9	Upper Buried Outwash	160	44	39	4	421	5.5	0	0.7	0.4	7.2	556	1054
10	Upper Buried Outwash	319	51	114	1	1091	4.9	0	0	1.4		1268	2036
11	Upper Buried Outwash	251	45	62	8	723	3.3	0.4	0	0.4		880	1484
12	***LBO	181	118	42	50	658	0.4	2.0		0.8	7.7	624	1308
13	Codell	270	248	70	50	1235	2.3	2.0	0.9	1.4	7.5	964	2224
14	Codell	137	300	34	55	958	0.3	0	1.1	1.6		480	1842
15	Dak	423		.5	120	895					7.7	1060	2395
16	Lake	107	40	37	16	308	0.3	0	0	0.2	8.1	420	720

*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) NESW Sec. 28, T. 97 N., R. 58 W.

4 Otto Bietz (farm) NESW 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 Hebbert (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 Emil Engel (farm) SWSW 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.

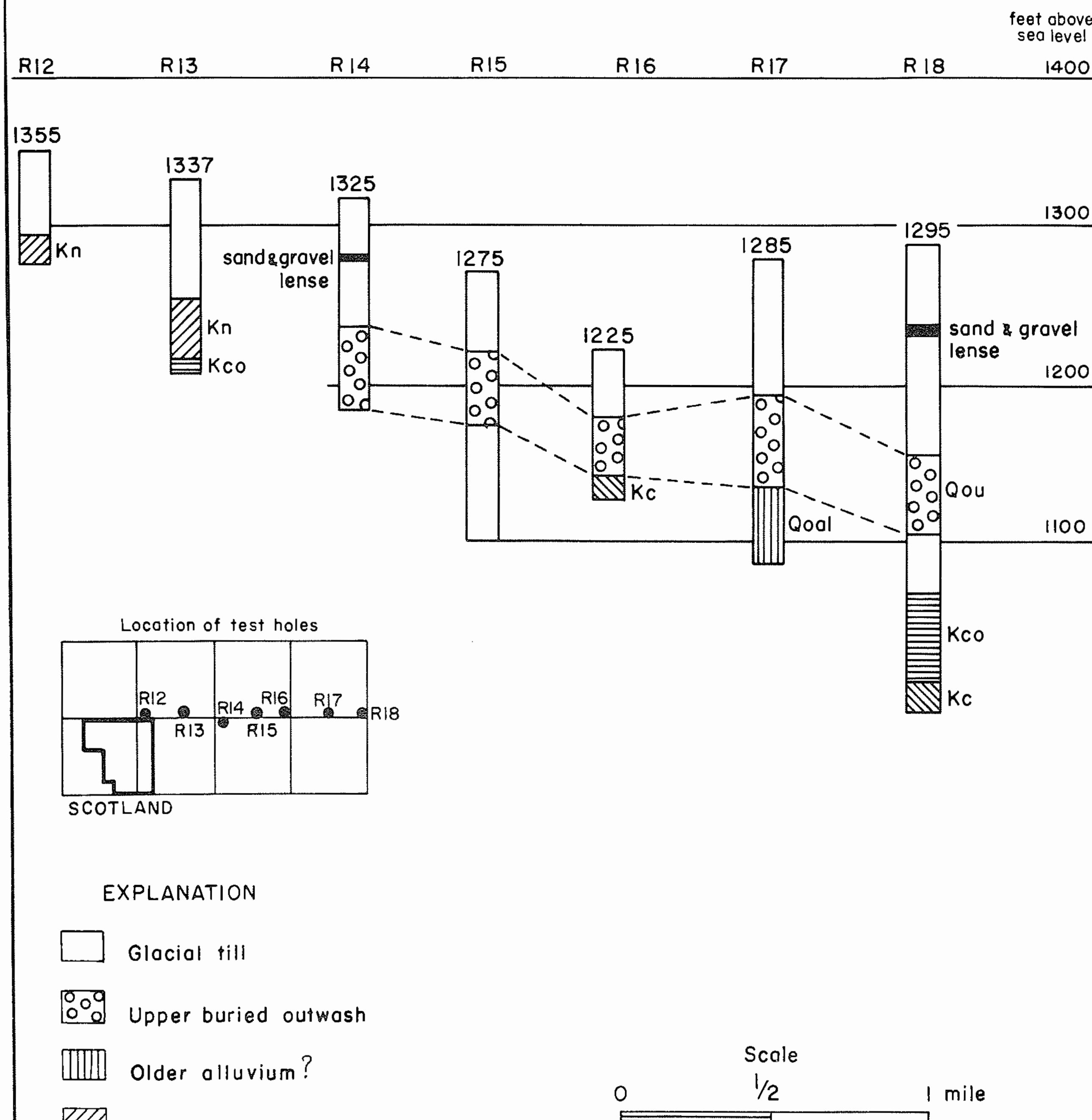
13 Lake Henry SE Sec. 9, T. 96 N., R. 58 W.

14 Deutesher (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



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REFERENCE CITED

U. S. Public Health Service, 1961, Drinking Water Standards: Am. Water Works Assoc. Jour., v. 53, no. 8, p. 935-945.

APPENDIX A

Logs of Rotary Test Holes in the Scotland Area

Test Hole R. 1
Location: SWSW Sec. 28, T. 97 N., R. 58 W.
Elevation: 1330 feet

0- 25	clay, buff, sandy
25- 33	clay, gray, sandy
33-155	sand, fine to granular

* * * * * *

Test Hole R. 2
Location: NWNW Sec. 34, 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
70- 72	gravel, pea-sized
72-120	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 (Carlile)

* * * * * *

Test Hole R. 5
Location: NWSW Sec. 33, T. 97 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: NESE Sec. 33, T. 97 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: SWNW Sec. 35, T. 97 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: NENE Sec. 5, T. 96 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

103-107	clay or silt
107-130	sandstone, brown and green (Codell)
130-140	shale

* * * * * *

Test Hole R. 9
Location: SESE 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 SWSW 35, T. 97 N., R. 58 W.
Elevation: 1295 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

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Test Hole R. 11
Location: SENE Sec. 2, T. 96 N., R. 58 W.
Elevation: 1295+ feet

0- 5	topsoil
5- 25	clay, buff, sandy
25- 35	clay, gray, sandy, pebbly
35- 40	gravel, nut-size
40- 80	clay, gray, sandy, thin gravel lenses
80-130	gravel, pea to nut-size; coarse sand
130-140	Carlile Shale

* * * * * *

Test Hole R. 12
Location: SWSW 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: SESW Sec. 4, T. 96 N., R. 58 W.
Elevation: 1337 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

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Test Hole R. 14
Location: NWNW 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- 69	clay, gray, sandy
69- 75	gravel, pea-size
75- 83	clay, gray, sandy
83-140	gravel, fine to nut-size (hole binding badly)

* * * * * *

Test Hole R. 15
Location: SWSE Sec. 3, T. 96 N., R. 58 W.
Elevation: 1275 feet

0- 18	clay, buff, sandy
18- 50	clay, gray, sandy
50- 98	sand, coarse
98-200	clay, gray, sandy (till)

* * * * * *

Test Hole R. 16
Location: SESE Sec. 3, T. 96 N., R. 58 W.
Elevation: 1225 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
39-45	alluvium (?)
45-82	gravel, pea to nut-size; sand
82-95	Carlile Shale

* * * * * *

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

0- 35	clay, buff, sandy
35- 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
61-115	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 (older alluvium?)
227-286	Codell Sandstone (?) (getting poor returns)
286-305	Carlile Shale

* * * * * *

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

0- 25	clay, buff, sandy
25-105	clay, gray, sandy
105-110	sand, coarse
110-170	clay, gray, sandy

* * * * * *

Test Hole R. 20
Location: SENE 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

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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

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Test Hole R. 22
Location: NENE 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

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Test Hole R. 23
Location: NESE Sec. 17, T. 96 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	Niobrara Chalk

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APPENDIX B

Logs of Auger Test Holes in the Scotland Area

Test Hole A. 1
Location: NWNW 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

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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

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Test Hole A. 4
Location: SESW 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

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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

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Test Hole A. 6
Location: NENE Sec. 24, T. 96 N., R. 57 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

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Test Hole A. 7
Location: SESW 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: NWSW Sec. 16, T. 96 N., R. 58 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.

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Test Hole A. 9
Location: SWSW 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

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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.

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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: sl, sand lense; ss, sandstone

Well Location	Owner or Tenant	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)
SW-26-97-59	R. Schlechter		Sand		
SE-26-97-59	H. Schlechter	Codell	ss		140
NW-26-97-59	R. Schlechter	Codell	ss		155
NW-26-97-59	R. Schlechter	Niobrara	Chalk	S	80
NE-25-97-59	M. Brown	Codell	ss	S,D	180±
SE-25-97-59	Abandoned	Codell	ss	S	150?
SE-24-97-59	L. Conrad	Codell	ss	S,D	175±
SW-24-97-59	R. Frier	Codell	ss	S,D	175±
NW-35-97-58	F. Muhmel	Glacial	Outwash		50
NE-35-97-58	L. Hess	Glacial	Outwash	S,D	51
SW-34-97-58	E. Engel	Glacial	Outwash	S,D	235
NE-34-97-58	F. Muhmel	Dakota	ss	S,D	550
SW-33-97-58	O. Bietz	Glacial	Outwash	S,D	90±
SE-33-97-58	P. Engel	Dakota	ss		564
NE-33-97-58	Petzoldt	Glacial	Outwash	S	70±
SE-32-97-58	F. Burke	Codell	ss	S,D	147

Appendix C - Record of Wells--continued

Well Location	Owner or Tenant	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)
NE-31-97-58	T. Schneider	Glacial	Outwash	S	80
SE-30-97-58	A. Nieman	Glacial	Outwash	S	165
NE-30-97-58	O. Dean	Glacial	sl		33
NE-30-97-58	O. Dean	Glacial	sl		68
NE-30-97-58	O. Dean	Greenhorn	sl	S,D	415
SW-30-97-58	M. Simantel	Codell	ss		120
SE-29-97-58	A. Handel	Glacial	Outwash		205
NW-29-97-58	L. Popma	Glacial		S,D	50
SE-28-97-58	H. Muhmel	Glacial	Outwash	S,D	85
NE-28-97-58	C. Muhmel	Glacial	Outwash	S	40
SW-28-97-58	W. Asche	Glacial	Outwash		60
SW-27-97-58	E. Serr	Glacial		S	40
SW-23-97-58	E. Schatz	Glacial	Outwash	S,D	70
SW-23-97-58	E. Schatz	Dakota?	ss	S,D	430
SW-22-97-58	L. Buechler	Glacial	Outwash	S,D	48
SW-22-97-58	L. Buechler	Glacial	Outwash	S,D	165
SW-21-97-58	R. Buechler	Glacial	Outwash	S,D	40
SE-20-97-58	E. Oehsner				20
NE-35-96-59	E. Buechler	Glacial	sl	S,D	60±
SW-24-96-59	A. Suess	Niobrara	Chalk		100±
SE-25-96-59	M. Haase	Niobrara	Chalk	S,D	100

Appendix C - Record of Wells--continued

Well Location	Owner or Tenant	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)
SW-24-96-59	Machacher				280?
SE-24-96-59	V. Cap	Glacial	sl	S,D	50±
NE-24-96-59	R. Cass	Niobrara	Chalk	S	65
SW-14-96-59	A. Thum	Glacial	Till	S	48
NE-14-96-59	F. Goreck	Niobrara	Chalk		100±
NW-14-96-59	C. Kowalski	Niobrara	Chalk	S	104
NW-13-96-59	J. Sedlacek	Codell	ss	S,D	160
SW-13-96-59	R. Kokesh	Niobrara	Chalk	S	130
NW-12-96-59	George Kirtz	Glacial	sl		35
NE-11-96-59	J. Cary	Niobrara	Chalk		110
NE-2-96-59	E. Conrad	Codell (?)	ss	S,D	
SW-1-96-59	Buecher	Codell (?)	ss	S,D	
SE-1-96-59	V. Behl	Codell	ss	S,D	172
NW-31-96-58	H. Nyhouse	Niobrara	Chalk	S	90
NW-30-96-58	A. Woehl	Niobrara	Chalk		95±
NE-30-96-58	K. Ireland	Codell	ss	S,D	
NW-29-96-58	K. Ireland	Niobrara	Chalk	S	100+
NW-29-96-58	K. Ireland	Codell	ss		160+
SE-29-96-58	M. Nelson	Niobrara	Chalk	S	120+
NW-28-96-58	E. Dingman	Niobrara	Chalk	S	80±
NE-27-96-58	A. Klink	Codell	ss	S,D	123

Appendix C - Record of Wells--continued

Well Location	Owner or Tenant	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)
NW-23-96-58	W. Ireland	Codell	ss		128
NW-23-96-58	W. Ireland	Glacial	Till		50
NW-22-96-58	G. Gemar	Niobrara	Chalk	S	100
SE-21-96-58	E. Burke			S	100+
SE-20-96-58	M. Bainbridge	Niobrara	Chalk	S,D	
SW-19-96-58	Nyhouse	Glacial	Till		45
SW-18-96-58	Soukup	Niobrara	Chalk		119
SE-17-96-58	H. Goeken	Alluvium	Sand	S	30
SW-17-96-58	C. Eisemann	Codell	ss	S	165
NW-15-96-58	A. Thunker	Niobrara	Chalk		80
NW-15-96-58	A. Thunker	Niobrara	Chalk		75
NE-14-96-58	M. Gunn	Glacial	Outwash	S	85
NE-14-96-58	G. Gunn	Glacial	Outwash	S,D	125
NE-14-96-58	G. Gunn	Glacial	Outwash (?)	S,D	60
NW-12-96-58	Deutcsher	Dakota	ss	S	600+
NW-11-96-58	Jonda	Glacial	Outwash		152
NW-10-96-58	T. Buechler	Codell	ss		135
NW-8-96-58	H. Gunn	Codell	ss	S,D	126
SW-7-96-58	L. Bjorum	Codell	ss	S,D	166
NW-7-96-58	T. Ireland	Niobrara	Chalk	S	170
NW-6-96-58	D. Behl	Niobrara	Chalk		175

Appendix C - Record of Wells--continued

Well Location	Owner or Tenant	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)
SE-6-96-58	L. Muhmel			S,D	200+
SW-5-96-58	B. Burke	Codell	ss	S	158
SE-5-96-58	L. Gemar	Codell	ss		146
NE-4-96-58	R. Hebbert	Glacial	Outwash	S,D	150
NW-4-96-58	G. Mach	Niobrara	Chalk		130
SW-3-96-58	C. Neumeister	Glacial	Outwash	S,D	130
NW-3-96-58	D. Hebbert	Glacial	Outwash	S,D	115
SW-2-96-58	G. Deutcsher		ss	S,D	354