STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

SPECIAL REPORT 24

GROUND WATER SUPPLY FOR THE CITY OF REDFIELD AND THE REDFIELD STATE HOSPITAL AND SCHOOL

by
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Science Center
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GROUND WATER SUPPLY FOR THE CITY OF
REDFIELD AND THE REDFIELD STATE HOSPITAL AND SCHOOL

by

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INTRODUCTION

Present Investigation

This report contains the results of a special investigation made by the South Dakota State Geological Survey from June 18 to July 20, 1962 in and around the city of Redfield, Spink County, South Dakota (fig. 1), for the purpose of assisting the city and the Redfield State Hospital and School in locating future water supplies. The city and the Hospital and School receive their water supplies from four wells which in recent years have not supplied the quantity and quality of water desired. The four wells produce from the Dakota Sandstone at a depth of about 1050 feet. Two of these wells are located within the city limits and the other two are located on the grounds of the State Hospital and School (fig. 2).

A survey of the ground-water possibilities was made of a 56 square-mile area around the city, and consisted of geologic mapping, the making of a well inventory, the drilling of 21 rotary test holes to an average depth of 65 feet and the drilling of 31 auger test holes to an average depth of 46 feet, and the taking of 15 water samples for analysis.

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 field assistants Kieth Munneke, Richard Brown, Steve Pottratz and Alan Wood is gratefully acknowledged. Loren Rukstad acted as assistant geologist to the writer throughout the project.

The cooperation of the residents of Redfield, especially Mayor Charles Woodland and State Hospital and School Superintendent, Howard Chinn, is greatly appreciated. Special thanks are due to Arthur Larson and the staff of Larson Drilling Company for their helpful advice.

No adequate supply of water was found above the Dakota Sandstone, and it is recommended that the city of Redfield and the Redfield State Hospital and School continue to use the waters of the Dakota Sandstone.

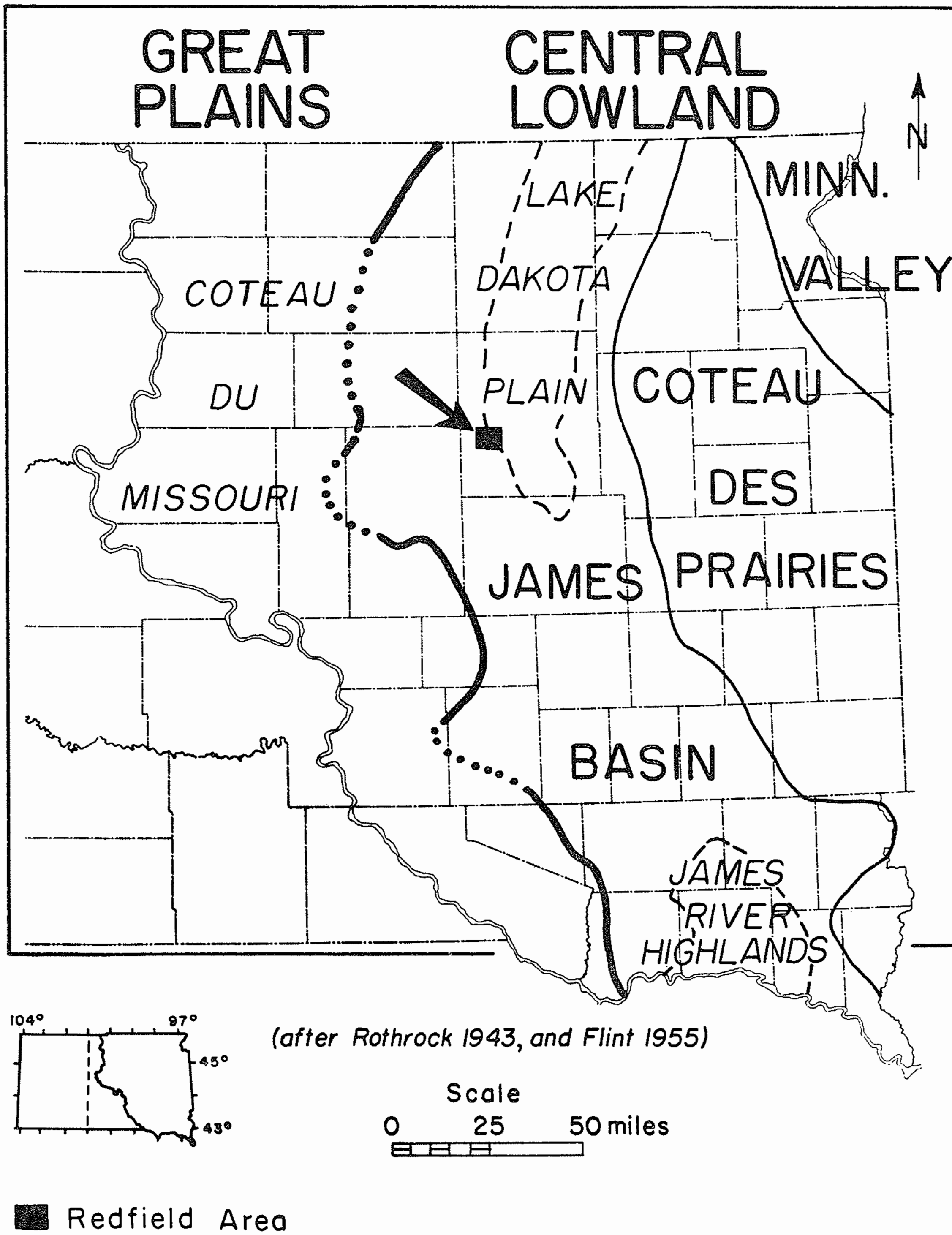
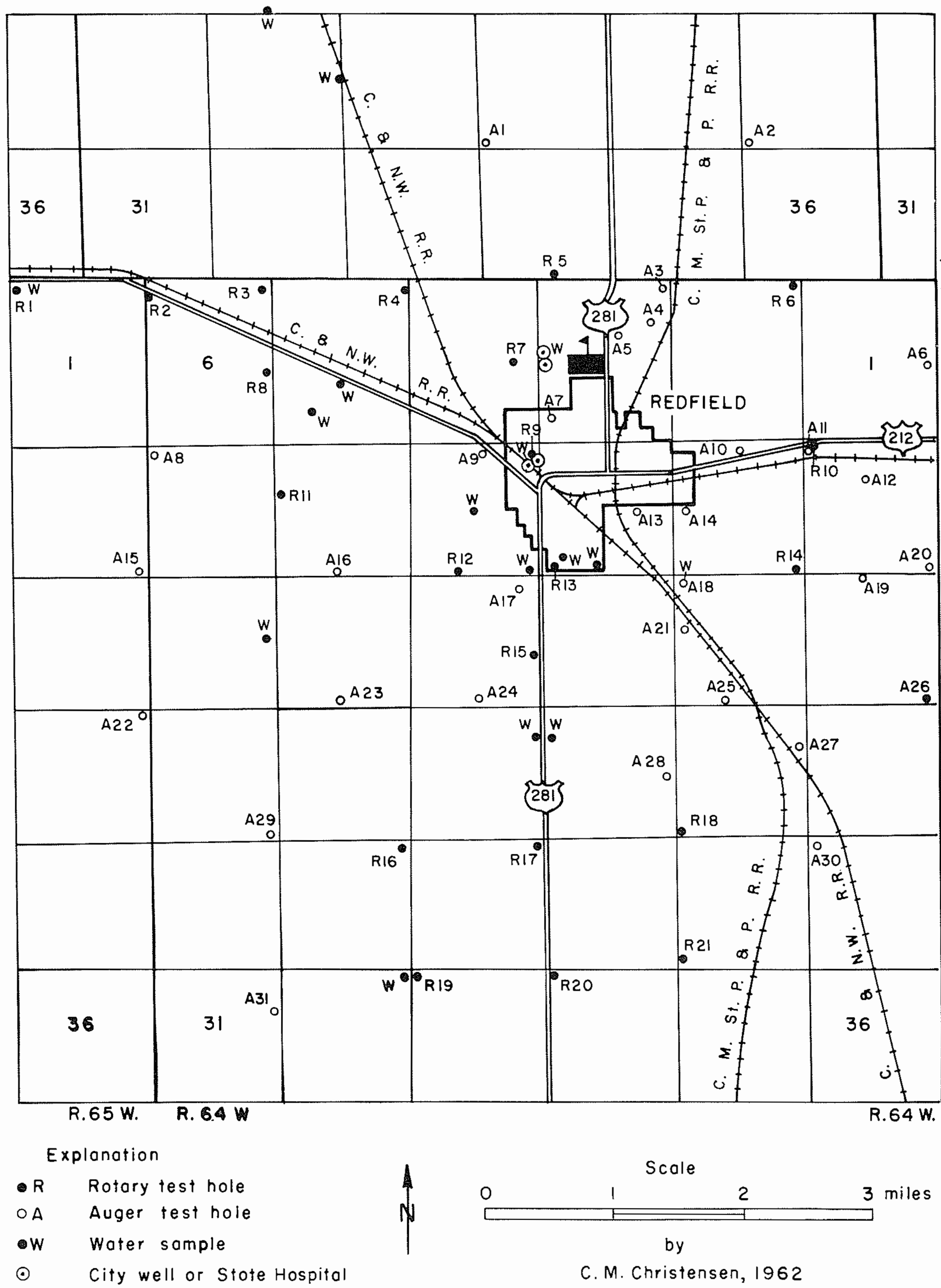


Figure I. Major Physiographic Divisions of Eastern South Dakota and location of the Redfield Area

Figure 2. Data Map of the Redfield Area



drafted by Elizabeth Garnos

Location and Extent of Area

The city of Redfield is located in east-central South Dakota and has a population of 2,952 (1960 census). The area is in the James Basin 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 45.9 degrees F., and the average annual precipitation is 17.35 inches at the U. S. Weather Bureau Station in Redfield.

Topography and Drainage

The topography of the Redfield area is mainly dissected glacial moraine, with the flat Lake Dakota in the northeastern part of the mapped area (fig. 3). The drainage in the area is in a northeasterly direction (fig. 3), where the James River is located.

Well-Numbering System

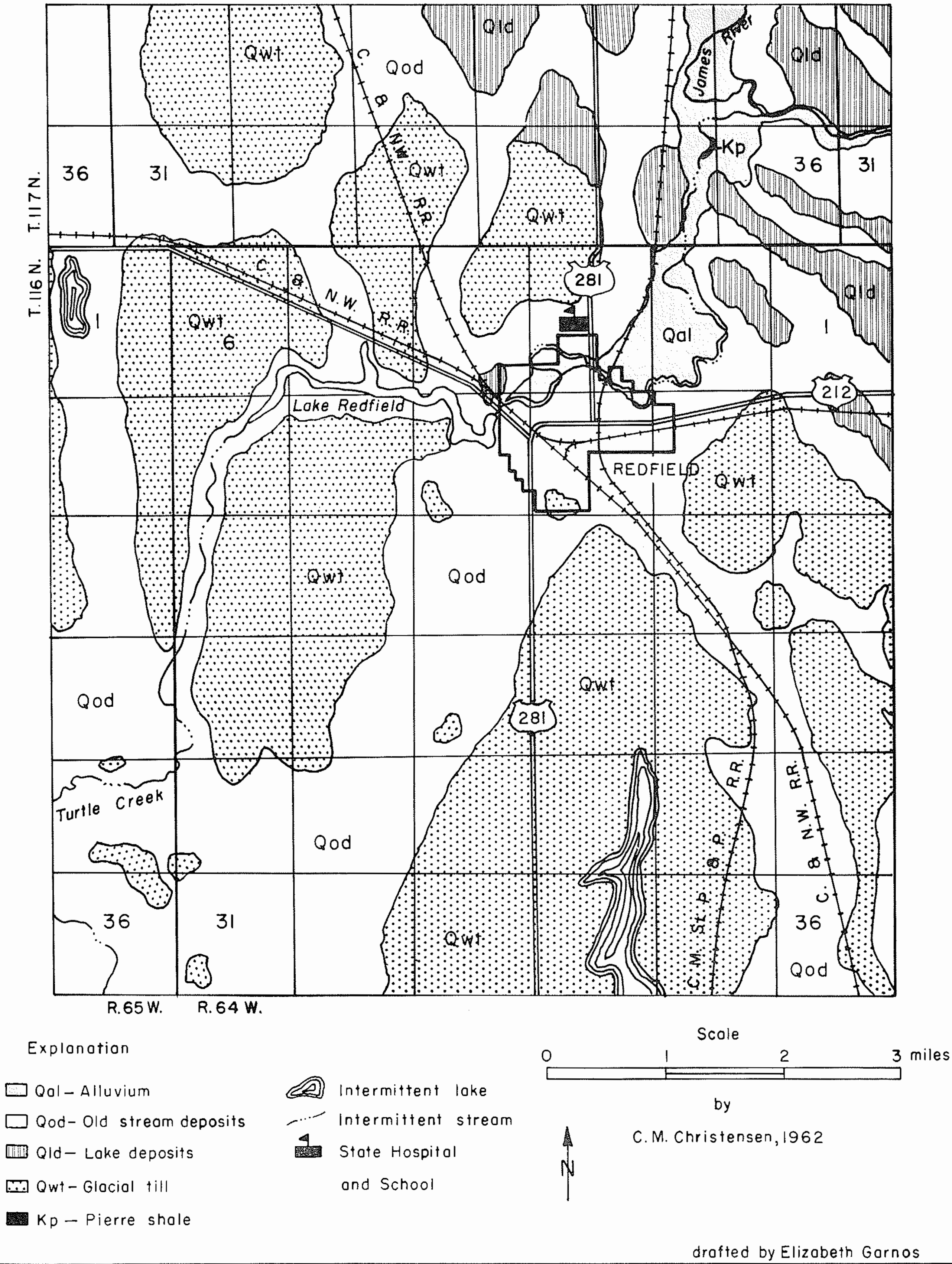
Wells in this report are numbered in accordance with the U. S. Bureau of Land Management's system of land subdivision. The first numeral of a well designation indicates the township, the second the range, and the third the section in which the well is situated. Lowercase letters after the section number indicate the well location within the section. The letters a, b, c, d, are assigned in a counterclockwise direction, beginning in the northeast corner of each tract. The first letter denotes the 160-acre tract, the second the 40-acre tract, the third the 10-acre tract, and the fourth the $2\frac{1}{2}$-acre tract. To distinguish between two or more wells situated within the same tract, consecutive numbers beginning with 1 are added as a suffix to each well designation. Rotary Test Hole R 15 (fig. 2), 116-64-16dadb is the one located in the NW$\frac{1}{4}$SE$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 16, T. 116 N., R. 64 W.; the method of designation is shown in figure 4.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Redfield area are chiefly the result of glaciation late in the Pleistocene Epoch, and of glacial Lake Dakota. Other surficial deposits include those of post-Lake Dakota streams. The glacial deposits, collectively termed drift, can be divided into till,

Figure 3. Geologic Map of the Redfield Area
(modified from Todd, 1909)



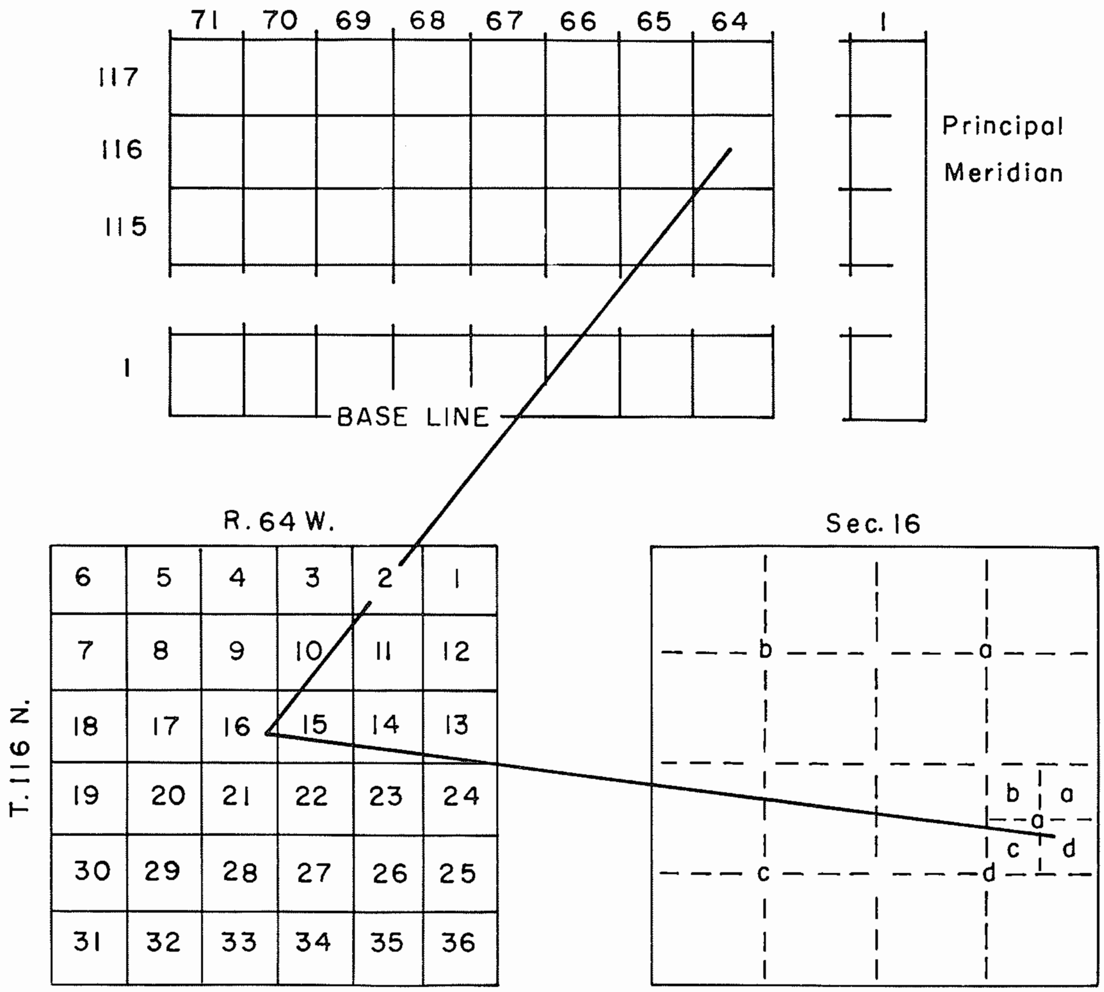


Figure 4. Well-numbering System

outwash and lake deposits. 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 the meltwater streams from the wasting glaciers. Outwash deposits in the Redfield area are thin and non-continuous. The lake deposits consist primarily of silts and fine sands deposited in glacial Lake Dakota (fig. 3). Many old stream channels, filled with silts and fine- to medium-grained sands, cut the Lake Dakota Plain (fig. 3).

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

Subsurface Bedrock

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

The Pierre has a thickness of about 160 feet in the Redfield area, and consists of light-gray fissile shale with bands of iron concretions. A small exposure is present along Turtle Creek in NE¼ sec. 35, T. 117 N., R. 64 W., 2 miles northeast of Redfield.

The Niobrara Formation consists of approximately 125 feet of light to medium blue-gray shale which contains numerous microscopic white calcareous specks.

The Carlile Formation is medium- to dark-gray bentonitic shale with pyrite concretions and layers of fine brown siltstone. This formation has a thickness of about 200 feet.

The Greenhorn Formation is about 25 feet thick and 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 having a thickness of approximately 250 feet.

None of the above formations will yield water readily in this area.

The Dakota Group has a thickness of over 300 feet and contains layers of sandstone and shale. The sandstones supply water to numerous wells in the Redfield area (see Appendix C), from a depth of 800-1200 feet; their waters are under artesian pressure, and some of the wells flow.

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 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 precipitation 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 an aquifer 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 cementation of the grains.

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 a 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 ground water supply, but he is searching instead for a sand or gravel deposit that lies beneath the water table.

Ground Water in Alluvium

Alluvium is present along Turtle Creek and the James River in the Redfield 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 Turtle Creek was test drilled (see Appendix B) but the sediments were too fine and the deposit too thin to provide an adequate amount of water for the city or the State Hospital and School.

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 large 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 permeability. Extensive deposits of glacial outwash, however, are lacking in the Redfield area.

Ground Water in the deposits of glacial Lake Dakota and post-Lake Dakota streams

The deposits of glacial Lake Dakota and the numerous post-Lake Dakota streams in the Redfield area contain large amounts of water where they are below the water table. These deposits were test drilled and found to be too fine-grained to be of any significant value as a source of water for either the city of Redfield or the State Hospital.

Ground Water in Bedrock

The sandstones of the Dakota Group are the only known bedrock in the Redfield area from which water is being produced. These artesian sandstones are at a depth of 800-1200 feet. Many farm wells, the city wells, and the wells at the State Hospital, produce from these sandstone layers. The amount of water yielded by the Dakota varies; some of the artesian wells in the Redfield area flow but others do not, depending on the surface elevation of the wells.

The recharge of these sandstones in South Dakota is said to come from the Rocky Mountains or the Black Hills where these rocks are exposed at the surface and are at much higher elevations than in the Redfield area. This difference in elevation provides the pressure which causes the water to rise in the wells in the Redfield area. The overlying Cretaceous shales provide the impervious material which confines the water to the sandstones.

Quality of Ground Water

Precipitated water is nearly pure before it reaches the ground. However, all ground water contains minerals that 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 the more minerals a water contains, the poorer its quality.

Table 1 is a chemical comparison of waters from several wells and test holes in the Redfield area, with the present city water and water from the State Hospital and School; the table also gives the U. S. Public Health Standards for drinking water. It can be seen that the city wells and the one well tested from the State Hospital and School exceed the standards set by the U. S. Public Health with the exception of nitrate, chloride, and in some wells, iron. Only samples Q and R are within the standard set for total solids and only samples L, N, O, Q, and R are within the standard set for sulfate. As a whole the water found in the Redfield area is of poor quality. Only samples O, Q, and R can be considered good quality water.

CONCLUSIONS AND RECOMMENDATIONS

Since no abundant supply of good-quality water was located in the surficial deposits of the Redfield area, it is recommended that the city and the State Hospital continue to use the waters of the Dakota sandstones. Although some better-quality water was located in the post-Lake Dakota stream deposits in the Redfield area (sample Q, Table 1) it is doubtful that these deposits would support a well of the capacity needed by the city or the State Hospital.

Table 1.--Chemical Analyses of Water Samples
from the Redfield Area

Sample	Parts Per Million											
	Calcium	Sodium	Mag-nesium	Chloride	Sulfate	Iron	Man-ganese	Nitrate	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A	---	---	---	250	500*	0.3	0.05	10	0.9-1.7**	---	----	1000*
B	45	685	13	191	1103	1.1	0	0	2.7	7.8	166	2161
C	31	736	9	226	1097	0.2	0	0	3.0	7.9	116	2232
D	53	480	4	152	1048	0.24	0	3.0	2.8	7.9	147	2084
E	49	400	8	199	1067	0.1	0	1.5	2.4	7.8	156	2184
F	197			240	630					7.8	70	1063
G	903			248	1165					7.2	1670	4450
H	268			324	1260					7.1	660	4260
I	76	460	28	158	1131	0	0	0.2	2.8	7.9	308	2108
J	262	40	106	97	691	0.24	0.26	12.0	0	7.4	1095	1748
K	310	90	164	96	1209	0.28	1.1	8.8	0	7.2	1452	2364
L	135	230	172	132	458	0	0	1.8	0	7.7	1052	2270
M	338		111	200	682					7.0	1290	
N	394			452	486					7.4	320	3180
O	130	175	17	69	372	6.7	1.2	0.8	0.4	7.4	396	1028
P	190	330	173	198	1446	1.6	0.8	0.4	0.4	7.3	1186	2978
Q	168	34	31	3	267	7.8	2.0	0	0.6	7.1	490	822
R	56	66	18	30	112	0.7	0	0.3	0.2	7.6	216	478

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

** Optimum

Location of Water Samples--Redfield Area

A. U. S. Public Health Drinking Water Standards (1961)

B. Redfield City Well (east), 116-64-9aa

C. Redfield City Well (west), 116-64-9aa

D. State Hospital, 116-64-3bc

E. City Ball Park, 116-64-10cc

F. #61 no name (farm), 117-64-29ad

G. Albrecht, J. (farm), 116-64-5ca

H. Harford, C. (farm), 116-64-18ad

I. Devork (farm), 116-64-21ad

J. Jaragoske, J. (farm), 116-64-32aa

K. Akins (farm), 116-64-22bc

L. Seibrecht, W. (farm), 117-64-20cd

M. Huether, E. (farm), 116-64-9dd

N. Marlow, B. (farm), 116-64-9ca

O. Lutheran Church, 116-64-10cd

P. Rotary Test Hole 1, 116-65-1bb

Q. Auger Test Hole 18, 116-64-14bb

R. Redfield Lake, 116-64-5db

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Rothrock, E. P., 1943, A Geology of South Dakota, Pt. 1: The Surface: S. Dak. Geol. Survey Bull. 13, pl. 2.

Todd, J. E., 1909, Aberdeen-Redfield Folio 165: Geologic Atlas of the United States, U. S. Geol. Survey Folio 165.

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

APPENDIX A

Logs of Rotary Test Holes

Test Hole R-1
Elevation: 1304 feet
Location: 116-65-1bb

0-23	clay, buff, silty
23-50	sand, very coarse and gravel, pea-size

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Test Hole R-2
Elevation: 1301 feet
Location: 116-64-6bb

0-15	clay, buff, silty
15-33	clay, gray, sandy
33-65	sand, coarse, gravel, pea-size

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Test Hole R-3
Elevation: 1300 feet
Location: 116-64-6aa

0-25	clay, buff, sandy
25-40	Pierre Shale

* * * * * *

Test Hole R-4
Elevation: 1303 feet
Location: 116-64-5aa

0-17	clay, buff
17-28	gravel, pea to nut-size, and sand
28-34	clay, silty (Lake Deposits)
34-40	Pierre Shale

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Test Hole R-5
Elevation: 1302 feet
Location: 117-64-34dc

0-15	clay, buff, sandy
15-20	clay, gray, sandy
20-26	sand, fine
26-62	clay, gray, sandy and silty
62-64	gravel, pea-size
64-68	Pierre Shale

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Test Hole R-6
Elevation: 1291 feet
Location: 116-64-2aa

0-30	clay, buff, silty and sandy
30-32	gravel, pea-size
32-34	clay, gray, sandy
34-44	sand, gravel, pea-size
44-80	clay, sandy, interbedded with few gravel stringers.

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Test Hole R-7
Elevation: 1299 feet
Location: 116-64-4da

0-15	sand, buff, dry
15-20	gravel, fine to coarse, many limonite concretions
20-44	clay, gray, sandy
44-54	Pierre Shale

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Test Hole R-8
Elevation: 1299 feet
Location: 116-64-6ad

0-17	clay, buff, silty
17-22	sand, coarse
22-30	Pierre Shale

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Test Hole R-9
Elevation: 1275 feet
Location: 116-64-9aa

0-5	clay, buff, silty
5-15	sandy with gravel streaks
15-24	Pierre Shale

* * * * * *

Test Hole R-10
Elevation: 1292 feet
Location: 116-64-12bb

0-15	sand, coarse, no water, some clay at 3 feet
15-30	sand, coarse, and water bearing
30-32	coal, lignite, drills very hard (stops rig in 4th gear)
32-50	sand, coarse
50-59	gravel, pea-size
59-67	Pierre Shale

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Test Hole R-11
Elevation: 1290 feet
Location: 116-64-8bc

0-21	clay, buff, sandy and pebbly
21-32	clay, gray, sandy, few boulders
32-45	Pierre Shale

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Test Hole R-12
Elevation: 1301 feet
Location: 116-64-9cd

0-8	sand, buff, fine
8-42	clay, gray, sandy
42-54	Pierre Shale

* * * * * *

Test Hole R-13
Elevation: 1305 feet
Location: 116-64-10cc

0-6	clay, light buff, silty
6-21	sand, fine, becoming granular
21-44	clay, gray, sandy
44-54	gravel, pea-size, composed of limestone and shale fragments, seems to contain some clay stringers
54-64	gravel, pea-size, interbedded with clay (50%)
64-78	Pierre Shale
78-84	Niobrara Chalk

* * * * * *

Test Hole R-14
Elevation: 1310 feet
Location: 116-64-11dd

0-54	sand, coarse to very coarse, water table 35'

* * * * * *

Test Hole R-15
Elevation: 1302 feet
Location: 116-64-16dadb

0-19	sand, coarse, composed of quartz and feldspar, some gravel stringers, some limonite
19-23	sand, fine, gray, very clayey
23-35	sand, medium to coarse, composed mostly of shale fragments
35-37	clay, gray, sandy (till)
37-52	sand, gravel
52-104	clay, gray, sandy (till?)
104-110	Niobrara Chalk

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Test Hole R-16
Elevation: 1302 feet
Location: 116-64-29aa

0-15	clay, buff, silty and sandy
15-50	clay, gray, sandy

(continued on next page)

Test Hole R-16 (continued)

50-52	gravel, nut-size
52-60	clay, gray, sandy
60-78	clay, gray, sandy, interbedded with nut-size gravel
78-82	sand, very coarse to granular
82-123	clay, gray, sandy with few gravel stringers
123-143	Pierre Shale

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Test Hole R-17
Elevation: 1323 feet
Location: 116-64-28aa

0-10	sand, very fine, clayey
10-23	clay, gray, very sandy
23-54	sand, medium- to coarse-grained
54-69	must be coarse rocks--had trouble penetrating and were stuck in hole

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Test Hole R-18
Elevation: 1309 feet
Location: 116-64-23cc

0-5	sand, medium to coarse
5-22	clay, buff, sandy and silty
22-30	sand, medium to coarse
30-49	clay, gray, very sandy
49-69	sand, very coarse to granular

* * * * * *

Test Hole R-19
Elevation: not measured
Location: 116-64-33bb

0-15	clay, buff, sandy
15-20	clay, gray, sandy
20-25	gravel, pea to nut-size
25-35	clay, gray, sandy

(continued on next page)

Test Hole R-19 (continued)

35-39	gravel, pea to nut-size
39-44	clay, gray, sandy
44-56	alluvium? Lake Deposits?
56-65	sand, very coarse to granular
65-120	clay, gray, sandy--few thin gravel streaks
120-125	Pierre Shale

* * * * * *

Test Hole R-20
Elevation: 1334 feet
Location: 116-64-34bb

0-29	clay, buff, sandy, occasional lenses of gravel
29-34	clay, gray, sandy
34-36	sand, coarse, gravel, pea-size
36-39	alluvium, clayey silt

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Test Hole R-21
Elevation: 1323 feet
Location: 116-64-26cc

0-5	clay, buff, sandy
5-10	gravel, pea-size, dry
10-24	clay, buff, sandy
24-29	sand, coarse to gravel, pea-size
29-30	clay, black, (soil horizon?)
30-39	clay, gray, sand, alluvium
39-47	clay, gray, fine silty alluvium
47-51	sand and gravel, pea-size
51-54	Pierre Shale

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APPENDIX B

Logs of Auger Test Holes

Test Hole A-1
Elevation: 1301 feet
Location: 117-64-34bb

0-4	topsoil, dark brown, some sand, medium-grained
4-14	sand, fine, clayey
14-39	clay, blue-gray, silty and sandy, damp
39-44	As above, water at 41 feet, hard drilling from 42 feet. Bit sample from bottom contained gravel, pea-size.

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Test Hole A-2
Elevation: 1262 feet
Location: 117-64-25cc

0-14	clay, dark brown, silty, some sand and gravel
14-34	clay, blue, trace of sand, very hard drilling

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Test Hole A-3
Elevation: 1298 feet
Location: 116-64-3aa

0-4	clay and silt, brown, some gravel (probably road fill)
4-34	clay, brown, water at 14 feet, sandy from 14 to 19 feet

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Test Hole A-4
Elevation: 1275 feet
Location: 116-64-3ad

0-6	topsoil and clay, dark brown
6-28	clay, light brown
28-36	clay, gray
36-39	clay, blue

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Test Hole A-5
Elevation: 1295 feet
Location: 116-64-3ac

0-5	topsoil and clay, dark brown
5-7	clay, light colored
7-17	clay, silty
17-18	clay, silty, pebbly
18-26	clay, very sandy, saturated (water at 18 feet)
26-41	sand, coarse and clay
41-59	clay, blue, silty, hard drilling

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Test Hole A-6
Elevation: 1289 feet
Location: 116-64-1ad

0-4	no cuttings--hard drilling
4-24	clay, dark brown, sandy, water at 9 feet
24-39	clay, blue, hard drilling

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Test Hole A-7
Elevation: not measured
Location: 116-64-3cb

0-14	clay, brown, silty
14-34	clay, blue, very dark, hard drilling--bit contained Pierre Shale

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Test Hole A-8
Elevation: 1304 feet
Location: 116-64-7bb

0-4	topsoil (1'), clay, dark blue
4-9	clay, dark brown, sandy and silty
9-19	clay, blue-brown, saturated from 12 feet
19-24	drilling hard, no cuttings, could not advance past 24 feet

* * * * * *

Test Hole A-9
Elevation: 1290 feet
Location: 116-64-9aa

0-2	topsoil
2-4	sand, light brown, saturated
4-12	clay, light brown, silty, sandy--hard drilling--unable to advance

* * * * * *

Test Hole A-10
Elevation: 1290 feet
Location: 116-64-11ba

0-9	clay, gray-brown, dry
9-29	clay, brown, sandy, damp
29-34	clay, dark brown, sandy, increase in water
34-59	clay, blue, sandy

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Test Hole A-11
Elevation: 1295 feet
Location: 116-64-12bb

0-14	clay, dark brown, dry, hard drilling
14-34	clay, brown, sandy, saturated from 17 feet
34-39	clay, blue-brown
39-59	sand, fine to coarse, clayey, some gravel present in thin lenses

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Test Hole A-12
Elevation: not measured
Location: 116-64-12ac

4-9	clay, brown, sandy
9-19	clay, light brown, sand, fine (25%), water at 12 feet
19-24	no cuttings, only dirty gray water
24-44	clay, blue, sandy, saturated, hard drilling

* * * * * *

Test Hole A-13
Elevation: not measured
Location: 116-64-10db

0-4	clay, brown, silty, sandy--yellow clay from 3-4 feet
4-9	silt, brown, sandy
9-17	clay, medium brown, silty, dry, hard drilling
17-24	same as above, few cuttings
24-39	sand, brown, fine- to medium-grained, clayey, water at 29 feet
39-49	sand, blue-gray, fine-grained, clay, blue (50-50)

* * * * * *

Test Hole A-14
Elevation: 1305 feet
Location: 116-64-11bc

0-9	sand, fine and silt (50-50)
9-14	silt, brown, powdery, sand, fine
14-19	same as above only darker colored, sand, medium-grained
19-24	same as above, water at 22 feet, sand, coarse-grained
24-69	sand, blue-gray, fine-grained, well rounded--hard layer at 58 feet and again at 69 feet

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Test Hole A-15
Elevation: 1308 feet
Location: 116-65-12dd

0-4	topsoil (1'), clay, dark brown
4-24	clay, gray-brown, water at 17 feet
24-34	clay, blue-brown, gravelly
34-39	no cuttings, hard drilling, unable to advance after 39 feet

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Test Hole A-16
Elevation: 1304 feet
Location: 116-64-8cd

0-4	topsoil (8"), clay, brown, silty, damp
4-24	clay, brown, silty and sandy, some gravel from 14-19 feet
24-44	clay, blue-gray to blue, few cuttings, hard drilling

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Test Hole A-17
Elevation: 1305 feet
Location: 116-64-16aa

0-4	topsoil, sand, medium-grained, clay, brown
4-9	clay, brown-blue and sand, fine-grained (10-15%)
9-29	silt, brown, sand, fine-grained (5-15%)
29-34	clay, dark brown, silty and sandy, water at 32 feet
34-59	clay, blue-gray, sandy, few cuttings

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Test Hole A-18
Elevation: 1287 feet
Location: 116-64-14bb

0-7	clay, brown, sandy, gravelly
7-29	sand, medium-grained, saturated at 10 feet, clay, (15%)
29-49	sand, medium- to coarse-grained, clean, well rounded grains, evidence of shell life

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Test Hole A-19
Elevation: 1299 feet
Location: 116-64-13ba

0-4	topsoil (8"), clay, brown, sandy, silty
4-19	clay, brown, silty, sandy and sand, coarse (50-50) water at 8 feet
19-34	clay, brown, sandy and sand, medium-grained (50-50)
34-44	sand, coarse and clay, blue (50-50)
44-54	clay, blue, very dense, hard drilling

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Test Hole A-20
Elevation: 1295 feet
Location: 116-64-12dd

0-4	topsoil (8"), clay, dark brown, silty
4-9	clay, light brown, silty, very sandy and gravelly
9-14	clay, dark brown, silty, sandy
14-34	clay, light brown, very sandy with thin gravel lenses, water at 33 feet
34-54	sand, coarse, some gravel, clayey, hard drilling

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Test Hole A-21
Elevation: 1290 feet
Location: 116-64-14cd

0-10	topsoil, clay, dark
10-14	clay, light brown
14-17	clay, light brown with some silt and fine sand
17-21	silt and sand, fine, clayey (water at 17 feet)
21-22	clay, brown
22-32	sand, fine, silty, clayey
32-89	silt, sandy, clayey

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Test Hole A-22
Elevation: 1307 feet
Location: 116-65-24aa

0-9	clay, dark brown, silty, dry
9-24	clay, light brown, sandy, silty, saturated
24-29	No cuttings, very hard drilling, bit sample was a dark gray clay with specks of light gray.

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Test Hole A-23
Elevation: not measured
Location: 116-64-17dc

0-3	topsoil
3-5	clay, brown
5-6	silt, brown, sandy, saturated
6-11	sand, fine- to medium-grained
11-15	clay, sandy
15-22	sand, clayey
22-32	silt, sandy, dark colored
32-34	clay, blue, contains some pebbles

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Test Hole A-24
Elevation: 1305 feet
Location: 116-64-16cd

0-5	topsoil and clay, dark brown
5-10	sand, medium-grained (water at 10 feet)

(continued on next page)

Test Hole A-24 (continued)

10-27	sand, medium-grained, saturated
27-30	silt and sand, fine
30-39	clay, blue, silty

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Test Hole A-25
Elevation: not measured
Location: 116-64-14cd

0-5	topsoil
5-8	sand, fine- to medium-grained, clayey
8-25	clay, yellow-brown
25-26	silt, sandy, saturated
26-29	clay, brown
29-35	silt, sandy, saturated
35-39	clay, blue, silty, saturated

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Test Hole A-26
Elevation: 1296 feet
Location: 116-64-13dd

0-4	topsoil (8"), clay, dark brown, some sand and gravel which is probably road fill
4-34	clay, light brown, silty and sandy, water at 20 feet
34-44	clay, light brown, sand, fine (about 10%)
44-59	clay, blue, sandy

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Test Hole A-27
Elevation: 1299 feet
Location: 116-64-23ad

0-4	topsoil (8"), sand, light brown, clayey
4-9	clay, dense, sand, medium-grained (20%)
9-24	clay, blue-gray, sand and silt (20-25%), saturated
24-29	clay, blue-gray, silty and sandy, some coal present
29-44	clay, blue, sandy
44-49	clay, blue, very dense

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Test Hole A-28
Elevation: 1305 feet
Location: 116-64-22ca

0-6	topsoil, sandy
6-7	sand, fine, dark, containing some clay
7-15	sand, light colored, medium-grained
15-19	sand, fine- to medium-grained, saturated
19-23	sand, clayey
23-42	clay, blue, silty with thin lense of gravel--drilling too hard to continue

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Test Hole A-29
Elevation: 1307 feet
Location: 116-64-19dd

0-4	topsoil (1-2"), silt, brown, dry
4-14	sand, fine, and clay, brown, saturated
14-29	clay, brown-blue, sandy
29-34	clay, dark blue

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Test Hole A-30
Elevation: 1301 feet
Location: 116-64-25bb

0-4	clay, dark brown, silty, some medium-grained sand and some pea-size gravel
4-9	clay, gray-brown, little sand
9-14	clay, brown, sand, coarse (10-15%)
14-19	clay, blue-brown, little sand
19-24	clay, dark colored, sandy
24-49	sand, coarse and clay, dark (about 50-50) Last 12 feet of rod contained blue clay with some sand upon recovery of rod.

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Test Hole A-31
Elevation: 1296 feet
Location: 116-64-31ad

0-19	clay, rust-brown, very sandy, gravel, pea-size (10-15%)

(continued on next page)

Test Hole A-31 (continued)

19-29	clay, blue, very sandy, gravel, pea-size
29-49	clay, blue, less sand, hard drilling

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APPENDIX C

Table 2.--Record of Wells

Use of Water: D, Domestic; S, Stock

Geological Source: PLD, Post-Lake Dakota Stream Deposits

Character of Material: Ss, sandstone; S, sand

Location	Name	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)	Depth to Water
116-63-6cd	Brink, R.	Dakota	Ss	D,S	1000+	Flows
116-64-1bc	Schmidt, A.	Dakota	Ss	D,S	950	Flows
116-64-2ad	Guilkey, E.	Dakota	Ss	D,S	1070	Flows
116-64-2cd		Dakota	Ss		1000?	Flows
116-64-5ca	Albrecht, J.	PLD	S	D,S	40	20
116-64-6da	Marlette, C.	Dakota	Ss	D,S	1000+	Flows
116-64-6ca	Craston, R.	Dakota	Ss	D,S	1000+	Flows
116-64-6cd	Kainer, A.	Dakota	Ss	D,S	1000+	Flows
116-64-7db	Schmidt, A.	Dakota	Ss	D,S	1000+	Flows
116-64-9cb	Perry, E.	Dakota	Ss	D,S	1000±	Flows
116-64-9bd	Sante, C.	Dakota	Ss	D,S	1000+	Flows
116-64-9ca	Marlow, B.	PLD	S	D,S	30?	
116-64-9db	Nenaber, D.	Dakota	Ss	D,S	1000?	Flows
116-64-9dd	Huether, E.	PLD	S	D,S	28	20

Appendix C - Record of Wells--continued

Location	Name	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)	Depth to Water
116-64-12cd	Nelson	Dakota	Ss	D,S	900+	
116-64-13cb	Battey, S.	Dakota	Ss	D,S	1000+	Flows
116-64-14ab		Dakota	Ss		900-1000	Flows
116-64-17da	Stammer, M.	Dakota	Ss	D,S	900+	Flows
116-64-18ad	Harford, C.	Glacial	S	D,S		
116-64-18bb	Schmidt, L.	Dakota	Ss	D,S	900+	Flows
116-64-19bb	Crump, E.	Dakota	Ss	D,S	900-1000	Flows
116-64-21ad	Devork	Dakota	Ss	D,S	1050±	
116-64-22bc	Akins, G.	Glacial	S	D,S	65±	50+
116-64-24bb	Bourassa, V.	Dakota	Ss	D,S	900-1000	Flows
116-64-24dd	Davis, C.	Glacial	S	D,S	103	18
116-64-27bc	Hirtzel, F.	Dakota	Ss	D,S	955	120
116-64-32aa	Jaragoske, J.	PLD	S	D,S	20	15
116-65-1cd	Hardie, D.	Dakota	Ss	D,S	900-1000	Flows
116-65-1ac	Buss, A.	Dakota	Ss		900-1000	Flows
116-65-13bb	Olson, O.	Dakota	Ss	D,S	900+	Flows
116-65-13bb	Peterson, L.	Dakota	Ss	D,S	900-1000	Flows
116-65-24ba	Swope, V.	Dakota	Ss	D,S	900-1000	Flows

Appendix C - Record of Wells--continued

Location	Name	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)	Depth to Water
117-63-18cc	Poore, M.	Dakota	Ss	D,S	900-1000	Flows
117-63-18dd	Hekredle	Dakota	Ss	D,S	1000	Flows
117-63-20bb	Authier, L.	Dakota	Ss		1000?	Flows
117-63-31cc	Lundstrom, W.	Dakota	Ss	D,S	900+	Flows
117-64-4ca			S			
117-64-5ac	Corkens, L.	Dakota	Ss	D,S	900-1000	Flows
117-64-14bb	Johnsen, E.	Dakota	Ss	D,S	1000	Flows
117-64-14dc	Miller, T.	Dakota	Ss	D,S	1000±	Flows
117-64-18dd	Willes, L.	Dakota	Ss	D,S	900-1000	Flows
117-64-19aa	Moeller, L.	Dakota	Ss		900-1000	Flows
117-64-20cd	Seibrecht, W.	PLD	S	D	30	25
117-64-21ad	Richmond, B.	Dakota	Ss		1000?	Flows
117-64-22aa	Hillcrest	Dakota	Ss	D,S	1000?	Flows
117-64-24ca	Klebsch, E.	Dakota	Ss	D,S	900-1000	Flows
117-64-35dd	Hagman, D.	Dakota	Ss	D,S	1000±	Flows
117-64-25ca	Dvorak, J.	Dakota	Ss	D	800	Flows
117-64-25bb	Padrnos	Dakota	Ss		840	Flows

Appendix C - Record of Wells--continued

Location	Name	Geologic Source	Character of Material	Use of Water	Depth of Well (feet)	Depth to Water
117-64-26aa	Avery, R.	Dakota	Ss	D,S		Flows
117-64-27aa	Welk, C.	Dakota	Ss	D	1000±	Flows
117-64-28ac	Schutte, D.	Dakota	Ss	D,S	940	Flows
117-64-28da		Dakota	Ss	D,S	1200?	Flows
117-64-33cd	Moore	Glacial	S	S		
117-64-34aa	Pennington, J.	Dakota	Ss		900-1000	Flows
117-64-34cc	Hilkemeyer, A.	Dakota	Ss		900-1000	Flows
117-65-23dd	Esser, M.	Dakota	Ss	D,S	1200?	Flows
117-65-35aa	O'Donnell, W.	Dakota	Ss	D,S	900-1000	Flows