STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

SPECIAL REPORT 26

GROUND WATER SUPPLY FOR THE CITY OF HARRISBURG

by
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Science Center
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Vermillion, South Dakota
1964

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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 16 to July 16, 1963, in and around the city of Harrisburg, Lincoln County, South Dakota (fig. 1). The purpose of the investigation was to assist the city in locating future water supplies. Harrisburg now obtains its water from one well which produces about 50 gallons per minute. The present well is 418 feet deep and obtains water from Pleistocene gravels and sands, the Dakota Sandstone, and the Sioux Quartzite and is located within the city limits (fig. 2). The quantity and quality of water produced is not adequate for the city's needs and for this reason the services of the State Geological Survey were requested.

A survey of a 56 square mile area was made around Harrisburg in an effort to locate possible future water supplies. The survey consisted of obtaining well interviews, drilling fourteen rotary test holes to an average depth of 191 feet and fifteen auger test holes to an average depth of 81 feet, and the taking of sixteen water samples for analyses.

As a result of this survey it is recommended that the city establish a well either in the Dakota Sandstone or the Sioux Quartzite in order to obtain water of adequate quality. The Pleistocene gravels overlying the quartzite in the Harrisburg area contain extremely poor quality water, and for this reason must be disregarded as possible water sources. In drilling to the quartzite a sample of the water contained in the sandstone immediately overlying the quartzite should be taken, as it has been shown to contain water of good quality. If the water contained in the sandstone proves to be of poor quality, then drilling would have to proceed into the quartzite in order to find acceptable water.

The field work and preparation of this report were performed under the supervision of Cleo M. Christensen, ground water geologist. The aid of Robert A. Schoon, geologist-driller, and his assistants Lloyd R. Helseth and John A. Moore, who drilled the rotary test holes in the area is gratefully acknowledged. The aid provided by Lynn Huenemann and Harry Haywood, operator of the jeep auger drill, is also acknowledged. 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. Special thanks go to Mayor Clayton Fink and the other residents in and around Harrisburg, who provided helpful information throughout the project.

Location and Extent of Area

The city of Harrisburg is located in Lincoln County in southeastern South Dakota, and has a population of 313 (1960 census). The area is in the James Basin of the Central Lowland physiographic province (fig. 1).

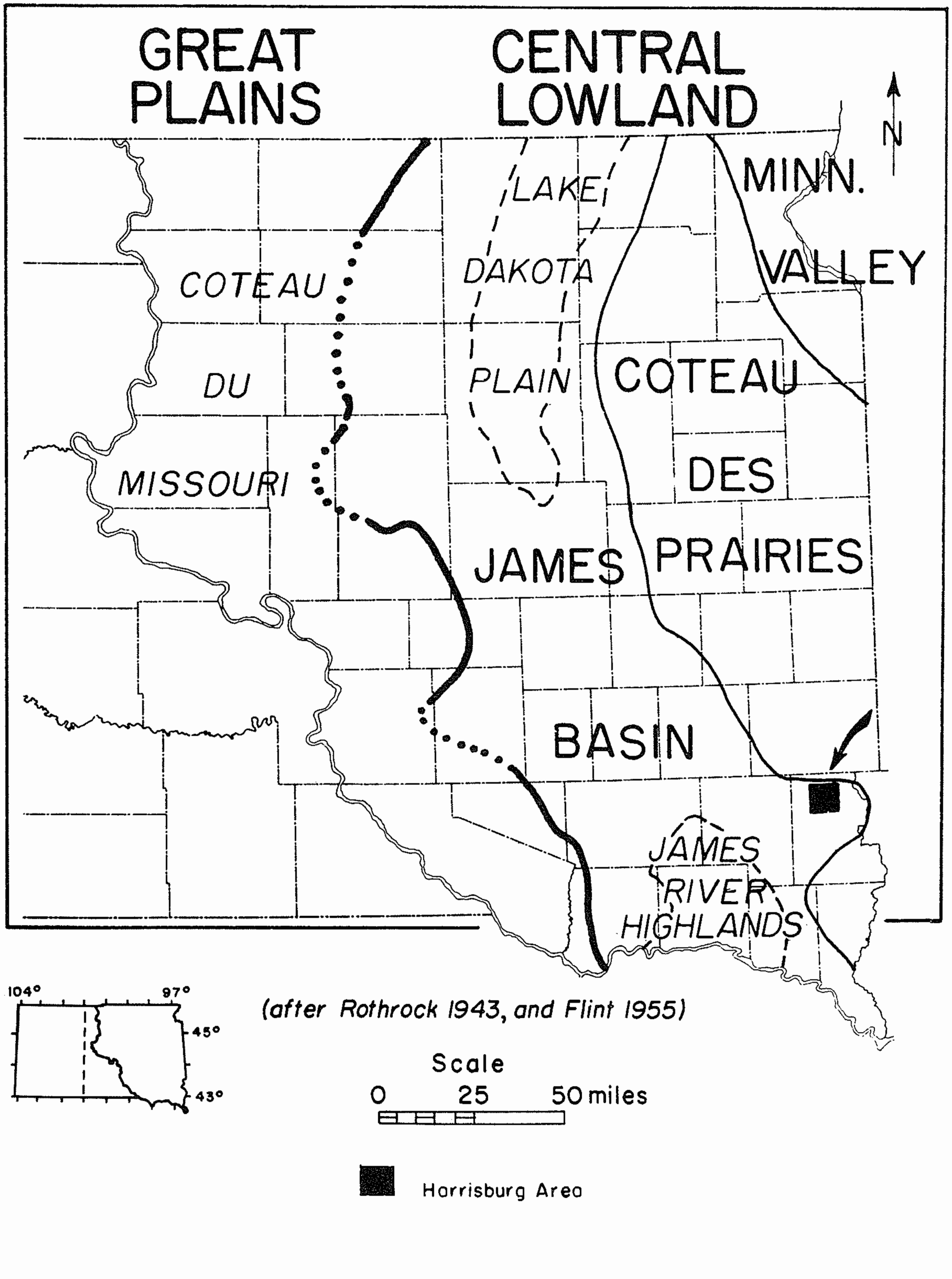
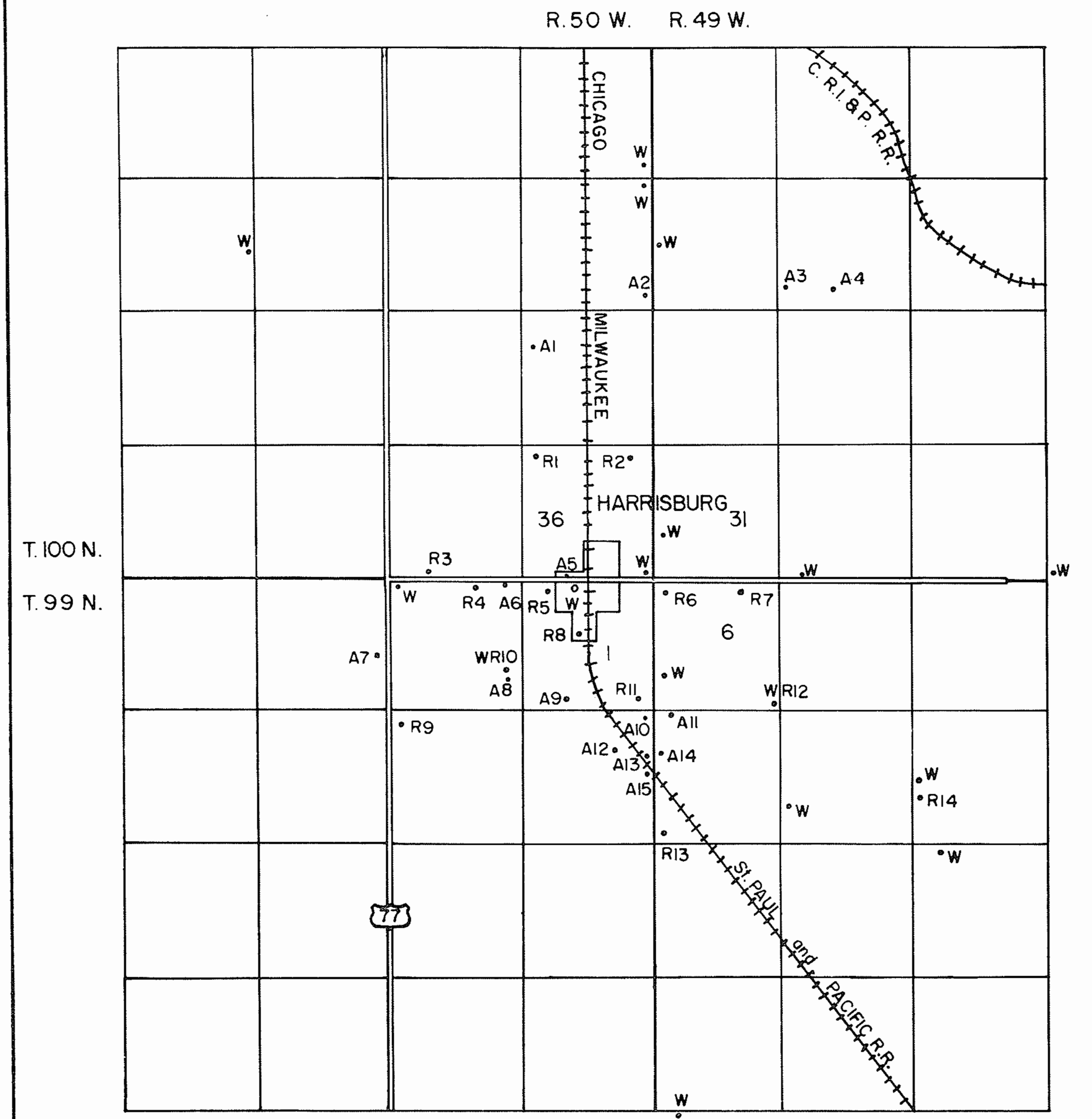


Figure I. Major Physiographic Divisions of Eastern South Dakota, and location of the Harrisburg area.

Figure 2. Data Map of the Harrisburg area.



Explanation

A. Auger test hole

R. Rotary test hole

o. City Well

W. Water sample

Scale

0 1 2 3 Miles

N

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Climate

The climate is continental temperate, with large daily and seasonal fluctuations.

The average daily temperature is 45.8^{o} F. and the average annual precipitation is 25.24 inches at the U. S. Weather Bureau Station at Sioux Falls, about eight miles northwest of Harrisburg.

Topography and Drainage

The topography of the Harrisburg area is typically youthful glacial moraine--rolling hills and valleys with numerous knobs and kettles. The main drainage is Ninemile Creek (fig. 3) south of Harrisburg, and Spring Creek north of Harrisburg, both of which flow easterly into the Big Sioux River.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Harrisburg area chiefly are the result of glaciation late in the Pleistocene Epoch. The glacial deposits are collectively called drift, and can be divided into till and outwash deposits. Till consists of clay and silt randomly mixed with boulders, pebbles, and sand, which were carried and deposited by the ice itself. Outwash is better sorted and consists mainly of pebbles and sand with minor amounts of silt and only a few cobbles and boulders. Outwash is the material deposited by meltwater streams from the wasting glaciers. No surface outwash material is present in the mapped area.

Alluvium consists of silt- and clay-size particles with minor amounts of sand, deposited by recent streams since the retreat of the glaciers. Alluvium is found mainly along Ninemile Creek south of Harrisburg (fig. 3).

Subsurface Bedrock

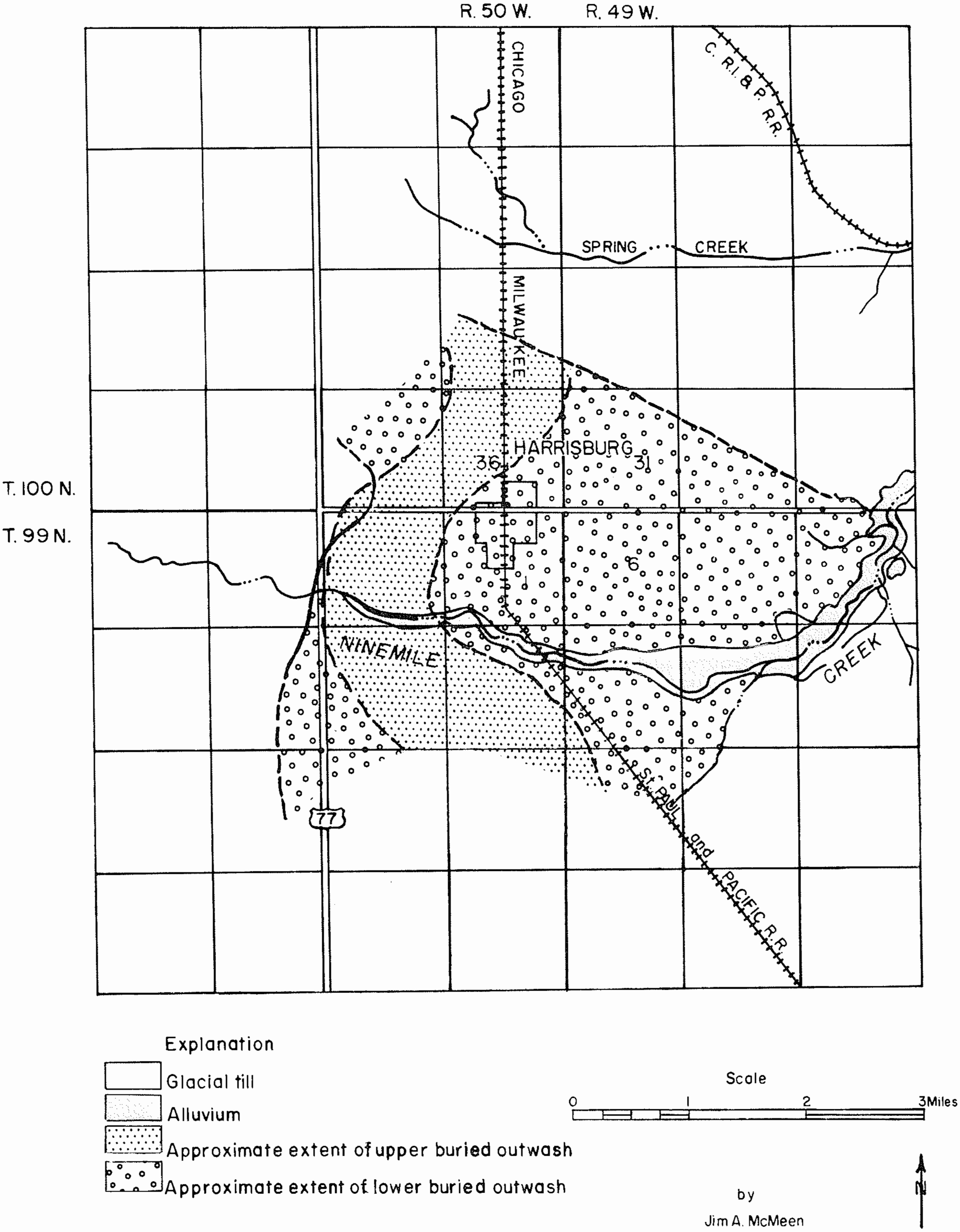
Stratified rocks of Cretaceous age lie beneath the surface deposits in the Harrisburg area. The Niobrara Formation is found immediately beneath the glacial drift in some parts of the area, and the Carlile Formation is the first Cretaceous formation encountered below the drift where the Niobrara is absent. The Carlile is underlain in descending order by the Greenhorn and Graneros Formations, and the Dakota Group, which are all of Cretaceous age, and the Precambrian Sioux Quartzite.

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

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

The Greenhorn Formation consists of a layer of hard cream to white limestone containing numerous fossil fragments. This limestone layer is

Figure 3. Geologic Map of the Harrisburg area. (modified from Steece 1956-7)



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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 consists of a series of alternating sandstones and shales.

The sediments of the Dakota Group are underlain by the Sioux Quartzite of Precambrian age which crops out at Sioux Falls, about six miles north of Harrisburg. In the Harrisburg area the Sioux Quartzite is at a depth of 170-500 feet.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Despite the common belief that ground water is found in veins crisscrossing the land in a discontinued maze, it is known that water occurs almost everywhere in the ground, at a depth below the surface which varies from a few feet to several tens or even hundreds of feet. The top of this zone of water saturation is known as the water table, and in the Harrisburg area it is 14-54 feet below the surface.

Almost all ground water is derived from precipitation. Rain or melting snow either percolates directly downward to the water table and becomes ground water, or drains off as surface water. Surface water either evaporates, escapes to the ocean by streams, or percolates downward to the ground water table.

Recharge is the addition of water to an aquifer (water bearing material), and is accomplished by downward percolation from the ground surface, downward percolation from surface bodies of water, and lateral underflow of water in transient storage.

Discharge, the removal of ground water from an aquifer, is accomplished by evaporation and transpiration of plants, seepage upward or laterally into surface bodies of water such as springs, lateral underflow of water in transient storage, and pumping.

The volume of water capable of being stored in a saturated material is equal to the volume of voids or pore space of the material. A measurement of the capability of a material to store water is called porosity. Porosity is the ratio of volume of voids to the volume of the rock. The shape and arrangement of grains in a material affects the porosity greatly, but size of the grains has little effect. Therefore, if two identical containers are considered, one filled with sand and the other filled with gravel, and if the sand and gravel have the same shape and packing, both would hold approximately the same quantity of water. Sands and gravels usually have porosities that range from 20-40 percent; whereas, sandstones normally have porosities of 15-25 percent. The lower porosity results from closer packing and cementation of the grains.

The rate by which water will drain or pass through material is a function of the permeability of the substance. Water will pass through a material with interconnected pores, but will not pass through material with unconnected pores even if the latter material has a higher porosity. Therefore, permeability and porosity are not synonymous terms. As an example, till has high porosity but will yield only small amounts of water because it has low permeability.

The ratio of the volume of water that will drain from a material by gravity, to the volume of the material is called specific yield. Values for specific yields vary from zero for plastic clays to nearly the total value of the porosity for coarse sands and gravels.

Ground Water in Alluvium

Alluvium is present along Ninemile Creek in the Harrisburg area (fig. 3). The alluvium was deposited by Recent streams, and consists of clay and silt with minor amounts of sand and gravel. That part of the alluvium that is below the water table holds large quantities of water, but yields the water very slowly because of low permeability.

Ground Water in Glacial Deposits

Glacial outwash deposits, because they are better sorted and contain less clay and silt-size particles, yield water much more readily than till.

Two buried outwashes exist in the Harrisburg area (fig. 3). The uppermost of these two outwashes is a rather restricted channel-like deposit of sand and gravel. This deposit appears to have an undulating surface and the thickness of sand and gravel varies considerably (see Appendix A; test holes R-1 and R-10).

The lower buried outwash is more extensive than the upper buried outwash (fig. 3). The depth to this outwash ranges from 120 feet in the southern part of the Harrisburg area to 170 feet in the northern part of the area, and the deposits contained in the outwash are of varying thicknesses (fig. 4), ranging from 45 feet in test hole R-13 to 0 feet in test hole R-14.

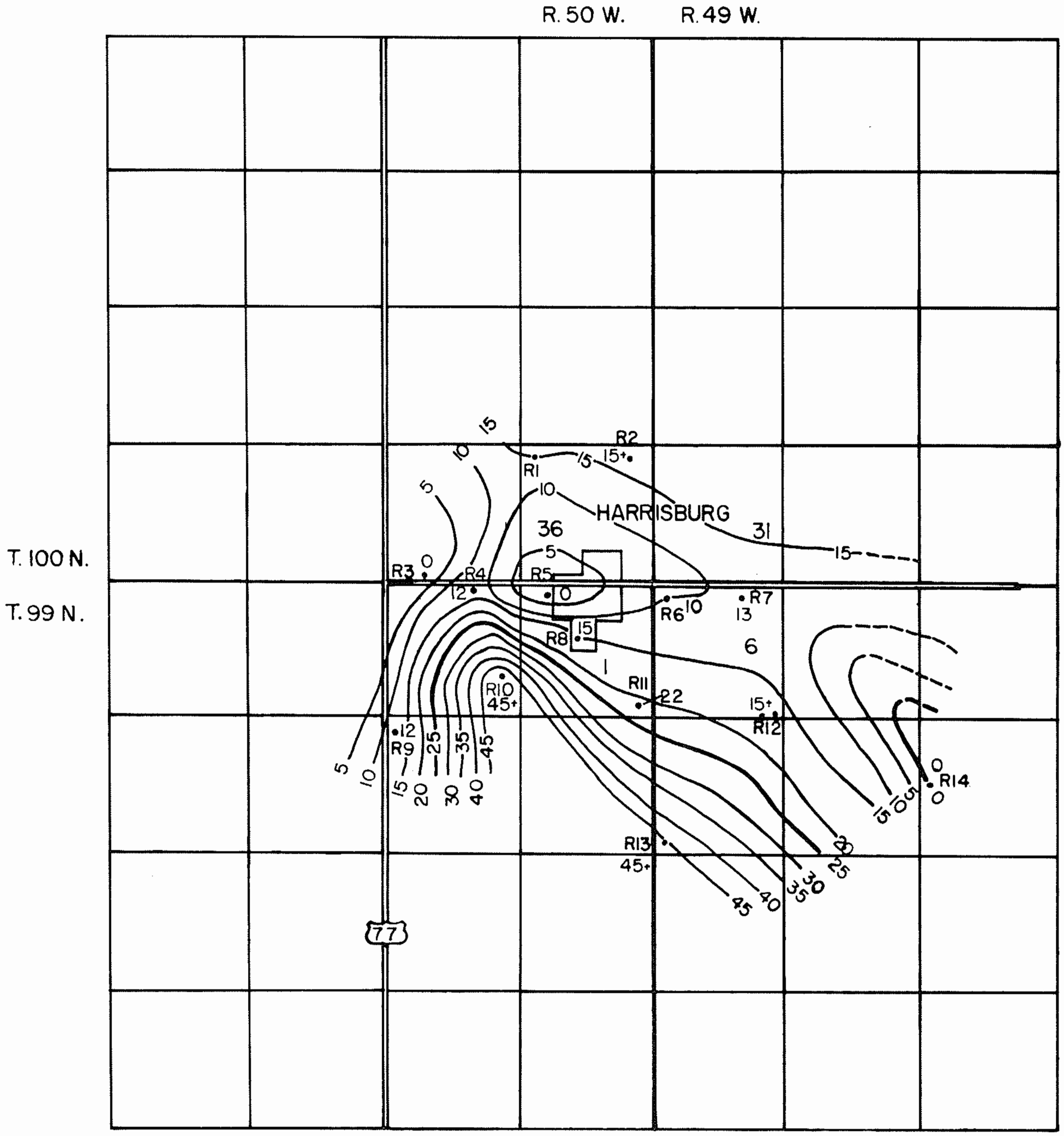
Ground Water in Bedrock

The Niobrara Formation is a known water-producer in some areas of the State and in the Harrisburg area it supplies water to several farm wells. The water from the Niobrara is generally of poor quality and the wells producing from this formation usually have a relatively low yield.

Sandstones of the Dakota Group constitute an aquifer in the area a few miles south and west of Harrisburg. In this area these sandstones contain a fair quality of water under artesian pressure.

A number of farm wells in the Harrisburg area are producing water from the Sioux Quartzite. The quality of the water was found to be fairly good but the yield of the wells varies greatly. Since the water in the Sioux Quartzite is contained in cracks and fissures this variation in yield is

Figure 4. Isopach Map of lower buried outwash in the Harrisburg area.



Explanation

Contour lines show the thickness of the outwash in feet.

Thickness Interval 5 feet.

• Test hole

Lines of equal thickness

Scale

0 1 2 3 Miles

N

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due to the amount of fractures encountered in the formation in any particular well. Records of some of the wells producing from the various formations discussed above are tabulated in Appendix C.

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. Table 1 is a comparison of various waters in the Harrisburg area with the present city water and with the Public Health Standards for drinking water. It can be seen that the waters from the present city well (which produces from the Pleistocene sands and gravels as well as the Niobrara Formation, Dakota Sandstone, and Sioux Quartzite) exceeds the Public Health Standards for drinking water in the amounts of magnesium, sulfate, iron, manganese, and total solids. The samples of water taken from the buried sands and gravels are in general of a poorer quality than the water obtained from the city. (See samples 1-11, Table 1.)

CONCLUSIONS AND RECOMMENDATIONS

Because of the poor quality of water obtainable from the Pleistocene gravels and sands in the area and the relatively low yield and poor quality water of wells in the Niobrara Formation, it must be recommended that the city consider the Sioux Quartzite as a possible source of water. The water analyzed from farm wells in the Sioux Quartzite was of a better quality than that analyzed from the city well. However, in drilling to the Sioux Quartzite it would be wise to test the sandstone immediately above it as this sandstone was found to contain fairly good quality water in one farm well. (See sample 16, Table 1.) Acceptable water is also being taken from a sand and gravel at a depth of 80 feet by the dance hall about one-fourth mile west of test hole R-3. At the present it would be too expensive for the city of Harrisburg to pipe water such a distance, but if it should become necessary in the future to explore this possibility, more test holes should be drilled in this immediate area in order to determine the potential of this aquifer. After a well site is chosen, 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. When a permanent city well is constructed, cement should be placed around the outside of the well casing from the top of the quartzite to ground level. This will prevent the poorer quality water of the overlying formations from being incorporated into the city water supply.

The city officials should consult the State Water Resources Commission to obtain a permit to drill a well and the State Department of Health with regard to biological and chemical acceptability of the water.

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

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate	Fluoride	pH	$CaCO_3$ Hardness	Total Solids
A				50	250	500*	0.3	0.05	10.0	0.9-1.7**			1000*
B	***	433	152	151	11	1382	1.8	0.2	0.0	0.4	7.2	1706	2783
1	Buried Outwash	452		110	20	1020	3-5				7.3	1570	2800
2	Buried Outwash	407	105	154	5	1575	1.2	0.7	0.8	0.4	7.3	1649	2728
3	Buried Outwash	536		350	56	1455	1.0				6.9	2740	3320
4	Buried Outwash	650		130	8	1310	20+				6.8	2140	2605
5	Buried Outwash	592			8	632	0.25				7.0	1070	1525
6	Buried Outwash	246		81	8	364	1.75				7.3	940	1212
7	Buried Outwash	635		78	8	1118	6.0				6.9	1898	2470
8	Buried Outwash	592			36	1069	11.6				7.0	1430	2100
9	Buried Outwash	508		22	68	681	0.12				7.2	1360	1720
10	Buried Outwash	670			8	875	0.30				7.2	1470	1800
11	Buried Outwash	564		160	24	1261	0.85				7.1	2050	2620
12	Sand Lens	282			8	243	0.10				7.2	400	856
13	Quartzite	650		54	8	1069	10.6				7.0	1840	2190
14	Quartzite	535			8	486	1.0				7.2	940	1440
15	Quartzite	268			16	243	0.02				7.3	600	1000
16	Dak.	268			8	97	0.30				7.3	270	950

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

** Optimum

*** Buried outwash, Niobrara Chalk, Dakota Group, Sioux Quartzite

Locations of Water Samples

A. U. S. Department of Public Health Drinking Water Standards (1961)
B. Harrisburg City Well
1. Rotary test hole #10, SE$\frac{1}{4}$ sec. 2, T. 99 N., R. 50 W.
2. Rotary test hole #12, SE$\frac{1}{4}$ sec. 6, T. 99 N., R. 49 W.
3. A. Hart (farm), SW$\frac{1}{4}$ sec. 32, T. 100 N., R. 49 W.
4. C. Osthus (farm), NW$\frac{1}{4}$ sec. 19, T. 100 N., R. 49 W.
5. B. Nielsen (farm), NW$\frac{1}{4}$ sec. 24, T. 100 N., R. 50 W.
6. M. W. Stofferahn (farm), SE$\frac{1}{4}$ sec. 21, T. 100 N., R. 20 W.
7. E. Sproul (farm), SW$\frac{1}{4}$ sec. 6, T. 99 N., R. 49 W.
8. L. Johnson (farm), SE$\frac{1}{4}$ sec. 36, T. 100 N., R. 50 W.
9. A. McGee (farm), SW$\frac{1}{4}$ sec. 8, T. 99 N., R. 49 W.
10. E. G. Hanson (farm), SW$\frac{1}{4}$ sec. 34, T. 100 N., R. 49 W.
11. P. Paulson (farm), NW$\frac{1}{4}$ sec. 30, T. 99 N., R. 49 W.
12. B. Souvignier (farm), NW$\frac{1}{4}$ sec. 9, T. 99 N., R. 49 W.
13. W. F. Urban (farm), NE$\frac{1}{4}$ sec. 20, T. 100 N., R. 50 W.
14. O. Sievers (farm), SE$\frac{1}{4}$ sec. 13, T. 100 N., R. 50 W.
15. N. Enger (farm), SW$\frac{1}{4}$ sec. 31, T. 100 N., R. 49 W.
16. G. Gilbertson, NW$\frac{1}{4}$ sec. 16, T. 99 N., R. 49 W.

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

Flint, R. F., 1955, Pleistocene Geology of Eastern South Dakota: U. S. Geol. Survey, Prof. Paper 262, fig. 1.

Rothrock, E. P., 1943, A Geology of South Dakota, Pt. 1, The Surface: S. Dak. Geol. Survey, Bull. 13., 3 maps, 30 figures, 85 p.

APPENDIX A

Logs of Rotary Test Holes in the Harrisburg Area

(for location see figure 2)

Test Hole R-1
Location: NW$\frac{1}{4}$ sec. 36, T. 100 N., R. 50 W.
Surface elevation: 1448.1 feet

0-5	clay, buff, sandy
5-62	clay, gray, sandy, thin gravels at 30 feet and 40 feet
62-93	gravel, pea size
93-170	clay, buff, sandy
170-185	gravel, pea size
185-190	clay, white
190-	could not penetrate

* * * * *

Test Hole R-2
Location: NE$\frac{1}{4}$ sec. 36, T. 100 N., R. 50 W.
Surface elevation: 1426.4 feet

0-11	clay, buff, sandy
11-55	clay, gray to buff, sandy
55-110	sand, medium to very coarse
110-145	clay, gray, silty and sandy
145-160	gravel, pea size
160-	hit a rock, could not penetrate

* * * * *

Test Hole R-3
Location: SW$\frac{1}{4}$ sec. 35, T. 100 N., R. 50 W.
Surface elevation: 1433.5 feet

0-35	clay, buff, sandy
35-80	clay, gray, sandy
80-115	sand and pea gravel with much iron staining
115-130	clay, buff, sandy, few pebbles
130-175	clay, gray, sandy
175-185	Carlile Shale

* * * * *

Test Hole R-4
Location: NE$\frac{1}{4}$ sec. 2, T. 99 N., R. 50 W.
Surface elevation: 1412.5 feet

0-15	clay, buff, sandy
15-30	clay, gray, sandy
30-40	clay, buff, sandy
40-41	clay, reddish-brown, sandy
41-55	clay, gray, sandy
55-105	sand, buff, and pea gravel at 90 feet
105-135	silt, gray, fine sand and clayey
135-150	clay, gray, and sand or silt
150-162	gravel, pea size
162-230	till, gray and very tough
230-255	Carlile Shale

* * * * *

Test Hole R-5
Location: NW$\frac{1}{4}$ sec. 1, T. 99 N., R. 50 W.
Surface elevation: 1416.3 feet

0-35	clay, buff, very sandy
35-125	sand, gray, medium grained, very clayey
125-140	silt
140-180	clay, gray, and pebbly till, abandoned hole

* * * * *

Test Hole R-6
Location: NW$\frac{1}{4}$ sec. 6, T. 99 N., R. 49 W.
Surface elevation: 1419.9 feet

0-15	clay, buff, sandy
15-35	clay, gray, buff sand
35-110	sand, fine, clayey
110-150	silt, gray, silty
150-160	gravel, pea size
160-235	clay, gray, sandy
235-270	Carlile Shale

* * * * *

Test Hole R-7
Location: NE$\frac{1}{4}$ sec. 6, T. 99 N., R. 49 W.
Surface elevation: 1395.9 feet

0-35	clay, buff, sandy, pebbly
35-140	clay, gray, pebbly

(continued on next page)

Test Hole R-7--continued

140-153	gravel
153-176	clay, gray, gravelly and sandy
176-200	sand, coarse, and pea gravel, abandoned hole

* * * * *

Test Hole R-8
Location: NW$\frac{1}{4}$ sec. 1, T. 99 N., R. 50 W.
Surface elevation: 1416.4 feet

0-19	sand, buff, very clayey
19-46	clay, buff, sandy
46-50	gravel, coarse, iron stained
50-95	clay, grayish-buff, very sandy and gravelly
95-145	silt, gray, clayey
145-160	gravel, pea size
160-185	Carlile Shale

* * * * *

Test Hole R-9
Location: NW$\frac{1}{4}$ sec. 11, T. 99 N., R. 50 W.
Surface elevation: 1405 feet

0-10	clay, buff, sandy
10-30	clay, gray, sandy
30-40	sand, fine-coarse
40-85	clay, gray, sandy and pebbly
85-110	sand, fine-coarse, gray
110-118	silt, clayey, gray
118-130	gravel, pea size
130-220	clay, gray, very tough
220-240	gravel, drilled very hard, few pebbles, abandoned hole

* * * * *

Test Hole R-10
Location: SE$\frac{1}{4}$ sec. 2, T. 99 N., R. 50 W.
Surface elevation: 1385.8 feet

0-4	topsoil
4-12	clay, buff, sandy
12-25	clay, gray, sandy
25-31	gravel, pea size
31-53	clay, gray, sandy

(continued on next page)

Test Hole R-10--continued

53-130	sand, medium, with a few stringers of clay and pea gravel
130-170	gravel, coarse
170-175	sand, medium, abandoned hole

* * * * *

Test Hole R-11
Location: SE$\frac{1}{4}$ sec. 1, T. 99 N., R. 50 W.
Surface elevation: 1388.7 feet

0-18	clay, buff, sandy
18-45	clay, gray, sandy
45-145	silt, gray, clayey, coal seams at 110 feet
145-167	gravel, pea size
167-185	Carlile Shale

* * * * *

Test Hole R-12
Location: SE$\frac{1}{4}$ sec. 6, T. 99 N., R. 49 W.
Surface elevation: 1377 feet

0-28	clay, buff, sandy
28-122	clay, gray, sandy
122-124	gravel, pea size
124-130	clay, gray, sandy
130-145	gravel, pea size and coarse, could not penetrate below 145 feet

* * * * *

Test Hole R-13
Location: SW$\frac{1}{4}$ sec. 7, T. 99 N., R. 49 W.
Surface elevation: 1399.5 feet

0-31	clay, buff, very sandy
31-55	clay, gray, very sandy
55-90	sand, medium-coarse
90-105	clay, gray, silty
105-120	silt, gray, clayey
120-165	gravel, pea size, abandoned hole

* * * * *

Test Hole R-14
Location: SW$\frac{1}{4}$ sec. 9, T. 99 N., R. 49 W.
Surface elevation: 1381.2 feet

0-20	clay, buff, sandy
20-35	clay, gray, sandy
35-40	sand, coarse
40-50	clay, gray, sandy
50-53	sand, coarse
53-85	clay, light grayish-pink, silty
85-109	Niobrara Chalk
109-140	Carlile Shale

* * * * *

APPENDIX B

Logs of Auger Test Holes in the Harrisburg Area

(for location see figure 2)

Test Hole A-1
Location: NW$\frac{1}{4}$ sec. 25, T. 100 N., R. 50 W.
Depth to water: 14 feet

0-4	topsoil
4-9	till, brown, small pebbles, moist at 8 feet
9-14	no cuttings
14-24	till, gray-brown, silty, pebbly, gray and brown striations
24-29	till, blue-gray, and saturated gray alluvium
29-49	till, blue-gray, moist
49-64	no cuttings, abandoned hole

* * * * *

Test Hole A-2
Location: SE$\frac{1}{4}$ sec. 24, T. 100 N., R. 50 W.
Depth to water: 44 feet

0-14	till, brown
14-44	till, gray
44-54	silt, gray, sandy, saturated
54-79	sand, gray, very silty, saturated, abandoned hole

* * * * *

Test Hole A-3
Location: SW$\frac{1}{4}$ sec. 20, T. 100 N., R. 49 W.
Depth to water: not measured

0-4	till, dark brown, pebbly
4-14	till, light brown, pebbly, and darkening the last 5 feet
14-64	till, dark gray, pebbly
64-74	till, gray, silty, moist, abandoned hole

* * * * *

Test Hole A-4
Location: SW$\frac{1}{4}$ sec. 20, T. 100 N., R. 49 W.
Depth to water: 24 feet

0-4	till, black
4-9	till, brown

(continued on next page)

Test Hole A-4--continued

9-24	till, gray
24-29	silt, gray, sandy, saturated
29-40	sand, silty, gray, saturated, abandoned hole

* * * * *

Test Hole A-5
Location: SW$\frac{1}{4}$ sec. 36, T. 100 N., R. 50 W.
Depth to water: 18 feet

0-4	topsoil and brown till
4-9	till, brown
9-14	till, brown, silty
14-19	till, brown, pebbly
19-24	till, changing from brown to gray, pebbly
24-39	till, blue-gray
39-49	silt, sandy, saturated, abandoned hole

* * * * *

Test Hole A-6
Location: NE$\frac{1}{4}$ sec. 2, T. 99 N., R. 50 W.
Depth to water: 50 feet

0-4	topsoil and yellow brown till
4-14	till, brown
14-34	till, dark brown
34-54	till, dark gray, moist
54-59	no cuttings
59-78	till, dark gray, saturated sandy silt also, abandoned hole

* * * * *

Test Hole A-7
Location: SE$\frac{1}{4}$ sec. 3, T. 99 N., R. 50 W.
Depth to water: 35 feet

0-4	till, black
4-9	till, brown
9-54	till, dark gray
54-69	sand, gray, fine-grained, saturated, abandoned hole

* * * * *

Test Hole A-8
Location: SE$\frac{1}{4}$ sec. 2, T. 99 N., R. 50 W.
Depth to water: 24 feet

0-4	till, brown, pebbly
4-19	till, gray, pebbly
19-24	till, gray, moist
24-29	till, gray, saturated
29-39	till, gray, silty
39-54	till, gray, silty, and some sand
54-59	no cuttings
59-64	till, gray, silty, saturated
64-79	till, gray, silty, some sand, saturated
79-94	sand, fine-grained, gray, clayey, saturated
94-109	sand, fine- to medium-grained, gray, silty, saturated, abandoned hole

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Test Hole A-9
Location: SW$\frac{1}{4}$ sec. 1, T. 99 N., R. 50 W.
Depth to water: not measured

0-4	topsoil and black, medium-grained, saturated sand
4-9	till, brown, pebbly, saturated
9-14	till, brown, pebbly, saturated
14-19	till, gray, pebbly, silty, saturated
19-24	till, gray, pebbly, silty, saturated
24-29	till, gray, pebbly, silty, saturated
29-34	till, gray, pebbly, silty, saturated
34-39	till, gray, pebbly, silty, saturated
39-44	till, gray, pebbly, silty, saturated
44-49	till, gray, pebbly, silty, saturated
49-54	no cuttings
54-59	no cuttings
59-64	no cuttings
64-69	till, gray, silty, saturated
69-74	sand, gray, clayey, and fine- to medium-grained
74-79	sand, gray, clayey, and fine- to medium-grained
79-84	sand, clayey, brownish and medium-grained
84-89	sand, clayey, brownish and medium-grained, abandoned hole

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Test Hole A-10
Location: SE$\frac{1}{4}$ sec. 1, T. 99 N., R. 50 W.
Depth to water: 29 feet

0-4	till, brown, pebbly

(continued on next page)

Test Hole A-10--continued

4-9	till, brown, pebbly, saturated
9-14	till, gray, pebbly
14-19	till, gray, pebbly
19-24	till, gray-brown, silty
24-29	till, gray, pebbly
29-44	silt, brown-gray, sandy, saturated
44-79	sand, fine, brown, silty, saturated
79-84	sand, fine, gray, saturated
84-104	sand, fine to medium, gray, saturated, abandoned hole

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Test Hole A-11
Location: NW$\frac{1}{4}$ sec. 7, T. 99 N., R. 49 W.
Depth to water: 54 feet

0-27	till, brown, pebbly
27-54	till, gray
54-59	sand, dark buff, some clay, saturated
59-99	sand, gray, very fine, clayey, abandoned hole

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Test Hole A-12
Location: NE$\frac{1}{4}$ sec. 12, T. 99 N., R. 50 W.
Depth to water: 35 feet

0-4	till, black, sandy, moist
4-9	till, brown, sandy, moist
9-14	till, dark gray, silty, saturated
14-34	till, dark gray, silty
34-39	till, gray, sandy, saturated
39-79	sand, medium-grained, gray, silty, saturated
79-98	sand, fine-grained, dark gray, silty, saturated, hole abandoned

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Test Hole A-13
Location: NE$\frac{1}{4}$ sec. 12, T. 99 N., R. 50 W.
Depth to water: 20 feet

0-4	till, black
4-9	till, brown, pebbly
9-14	till, brown and changing to a gray pebbly till

(continued on next page)

Test Hole A-13--continued

14-19	till, gray and pebbly and a brown, saturated silt
19-34	till, gray, and gray saturated silt
34-39	silt, gray, sandy, saturated
39-54	sand, very fine, grayish-tan, slightly silty, saturated
54-59	sand, medium-grained, brown, saturated
59-89	sand, fine- to medium-grained, gray, slightly clayey, saturated, hole abandoned

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Test Hole A-14
Location: NW$\frac{1}{4}$ sec. 7, T. 99 N., R. 49 W.
Depth to water: 40 feet

0-4	till, light brown
4-19	till, gray-brown
19-39	till, dark gray
39-59	sand, very fine-grained, saturated, buff
59-84	sand, fine- to medium-grained, tan, saturated
84-89	sand, fine- to medium-grained, gray, saturated, hole abandoned

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Test Hole A-15
Location: NE$\frac{1}{4}$ sec. 12, T. 99 N., R. 50 W.
Depth to water: 48 feet

0-4	till, dark brown, pebbly
4-39	till, brown
39-49	sand, fine-grained, moist
49-74	sand, fine-grained, brown, saturated
74-79	sand, light gray
79-84	sand, tan
84-89	sand, gray, hole abandoned

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APPENDIX C

Table 2.--Records of Wells

Well location: Letters stand for quarter section, first number for section, second for township north, third for range west
Type of well: D, drilled; B, bored
Water-bearing material: o, outwash; ss, sandstone; sl, sand lens; ch, chalk; Q, quartzite
Use of water: S, stock; D, domestic

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Water Bearing Material	Use of Water
SW- 2-99-49	John Juel	D	500	Sioux	Q	S,D
SE- 4-99-49	Richard Slack	D	80	Glacial	o	S
NE- 4-99-49	Diadem Corporation	D	75	Glacial	o	S
NW- 5-99-49	Martin Welter	D	142	Glacial	o	S
NW- 5-99-49	Leonard Welter	B	80	Glacial	o	S
SW- 6-99-49	Ed Sproul	D	160	Glacial	o	S
SE- 6-99-49	Frank Buswell	D	149	Glacial	o	S
NW- 6-99-49	C. J. Huffman	D	170	Glacial	sl	S
SW- 6-99-49	Henry Zabel	D	160	Glacial	o	S
SW- 8-99-49	Arden McGee	B	80	Glacial	sl	S,D
NW- 9-99-49	Burt Souvignier	D	65	Glacial	sl	S,D
SE-12-99-49	Vernon Slack	D	100	Glacial	o	S
NE-15-99-49	Harker Johnson	D	142	Glacial	sl	S
NW-16-99-49	Gilmore Gilbertson	D	465	Dakota	ss	S,D
NW-17-99-49	Don Javers	B	72	Glacial	sl	S
SW-17-99-49	Ole Iverson	D	100	Glacial	sl	S

Appendix C--Record of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Water Bearing Material	Use of Water
NW-17-99-49	Bill Norton	D	430	Glacial	ss	S,D
SE-19-99-49	Richard Timm	D	465	Sioux	Q	S,D
NE-19-99-49	K. O. Gedstad	B	60	Glacial	?	S
SW-21-99-49	Bill Nelson	D	100	Glacial	sl	S
SE-22-99-49	Warren Fossum	B	85	Glacial	?	S
NW-27-99-49	R. N. Kenison	D	80	Glacial	o	S
SW-29-99-49	Dick Van Den Toe	D	140	Glacial	sl	S
SW-30-99-49	Earl Helgeson	B	54	Glacial	sl	S
NW-30-99-49	Palmer Paulson	B	90	Glacial	?	S
NE- 1-99-50	Dwight Bumgard-ner	D	210	Niobrara	ch	S,D
NW- 1-99-50	Leslie Larson	D	200	Niobrara	ch	S,D
NW- 2-99-50	Joe Kielman	D	252	Dakota ?	ss	D
NE- 2-99-50	Elmer Hill	D	129	Glacial	o	S
NW- 2-99-50	James Oppold	D	101	Glacial	o	S,D
SW- 2-99-50	Frank Huizenga	D	90	Glacial	sl	S
NW- 3-99-50	H. W. Hoffman	D	128	Glacial	o	S,D
NE- 4-99-50	Lester Postma	D	128	Glacial	?	S
SW- 4-99-50	Odolph Johnson	D	130	Glacial	sl	S
NW- 4-99-50	Bernard Hoffman	B	35	Glacial	sl	S,D
NE- 5-99-50	C. E. Spielman	B	10	Glacial	sl	S,D
NW- 5-99-50	Henry Kling-hagen	D	170	Sioux ?	Q	S,D

Appendix C--Record of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Water Bearing Material	Use of Water
NE- 9-99-50	Clarence Schu-macher	D	280	Glacial	o	S
SE-10-99-50	Wilbur Wetering	D	465	Sioux ?	Q	S,D
NW-11-99-50	C. E. Sharp	D	151	Glacial	o	S
SW-12-99-50	C. A. Moen	B	100	Glacial	sl	S
NW-13-99-50	Henry Zakrvewski	D	100	Glacial	sl	S
SE-13-99-50	Harold French	D	460	Dakota ?	ss	S,D
NE-15-99-50	Leo Murphy	D	114	Glacial	sl	S
SW-15-99-50	Bert Tronson	D	92	Glacial	?	S
NE-17-99-50	Alferd Miles	D	150	Glacial	sl	S
SE-22-99-50	Dick Reiners	B	60	Glacial	?	S
NE-22-99-50	Dick Reiners	D	478	Sioux	Q	S,D
SW-24-99-50	Verlyn Ramstad	D	95	Glacial	sl	S
NE-27-99-50	Oscar Ramstad	D	90	Glacial	?	S
SW-16-100-49	Leonord Geraets	D	95	Glacial	?	S
SE-17-100-49	Clifford Osthus	D	170	Glacial	sl	S
NW-17-100-49	Lew Becker	B	105	Glacial	sl	S
NW-19-100-49	Clifford Osthus	D	140	Glacial	?	S
SW-20-100-49	LuVerne Poppinga	D	145	Glacial	sl	S
SW-21-100-49	Duiton Sneve	D	70	Glacial	?	S
SW-22-100-49	Dan Williams	D	60	Glacial	sl	S
NW-28-100-49	Roy Johnson	D	135	Glacial	sl?	S

Appendix C--Record of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Water Bearing Material	Use of Water
SE-28-100-49	John Cramer	D	112	Glacial	o	S,D
SW-29-100-49	Duane Harris	D	130	Glacial	sl	S
SW-31-100-49	Norman Enger	D	394	Sioux ?	Q	S
SE-31-100-49	Eugene Sproul	D	147	Glacial	sl	S
SW-32-100-49	Arthur Hart	D	73	Glacial	o	S
NE-32-100-49	George Rubley	D	154	Glacial	sl	S
SW-33-100-49	Ray Smeenk	D	138	Glacial	sl	S
SW-34-100-49	Walter Burgers	D	112	Glacial	?	S
SW-34-100-49	Edward G. Hanson	D	97	Glacial	o	S
SE-13-100-50	Orval Sievers	D	340	Sioux	Q	S,D
NW-14-100-50	Woodrow Devitt	D	50-60	Glacial	o	S
NW-15-100-50	H. H. Bement	D	240	Sioux	Q	S
NE-20-100-50	William F. Urban	D	180	Sioux ?	Q	S,D
SE-21-100-50	M. W. Stofferahn	D	200	Glacial	?	S
SW-22-100-50	Clem Oppold	D	175	Glacial	sl	S
SE-22-100-50	Lloyd Oppold	D	189	Glacial	sl	S
NW-23-100-50	Howard Knudsen	B	80	Glacial	?	S
NW-24-100-50	Belmont Nielsen	B	100	Glacial	sl	S,D
SW-24-100-50	August Tebben	D	170	Glacial	sl	S,D
NW-25-100-50	Richard Lommen	D	318	Sioux	Q	S
NW-27-100-50	Art Peters	D	115	Glacial	sl	S
NE-27-100-50	Ralph Allen	D	230	Niobrara	ch	S

Appendix C--Record of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Water Bearing Material	Use of Water
NE-27-100-50	Jake Fritz	D	238	Niobrara	ch	S
NE-28-100-50	Duane Alberts	D	259	Sioux ?	Q	S
SE-29-100-50	Art Bakker	D	246	Sioux	Q	S
NW-33-100-50	Bud Shatter	D	185	Glacial	o	S
SW-33-100-50	Henry Bakker	D	156	Glacial	sl	S,D
NE-35-100-50	Leslie Larsen	D	162	Glacial	sl	S
SE-36-100-50	Lawrence Johnson	D	200	Glacial	sl	S
NW-36-100-50	Lyle Johnson	D	170	Glacial	o	S
SW-36-100-50	Phil Devitt	D	120	Glacial	sl	S
Harrisburg	Mrs. Elmer Paschen	D	95	Glacial	sl	D