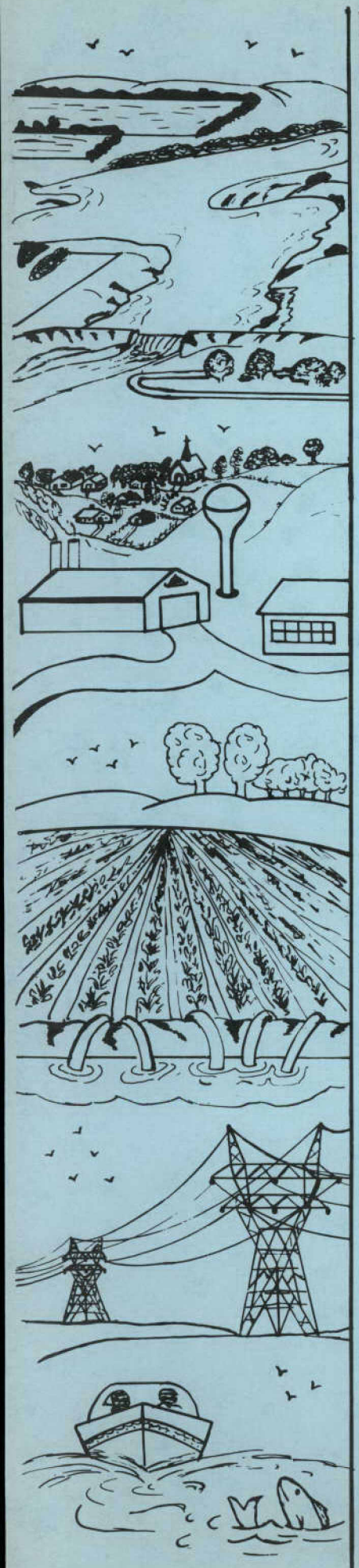

GLACIAL DRIFT AQUIFERS IN THE GACKLE AREA LOGAN AND STUTSMAN COUNTIES, NORTH DAKOTA

BY
D. G. ADOLPHSON
GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

NORTH DAKOTA GROUND WATER STUDIES

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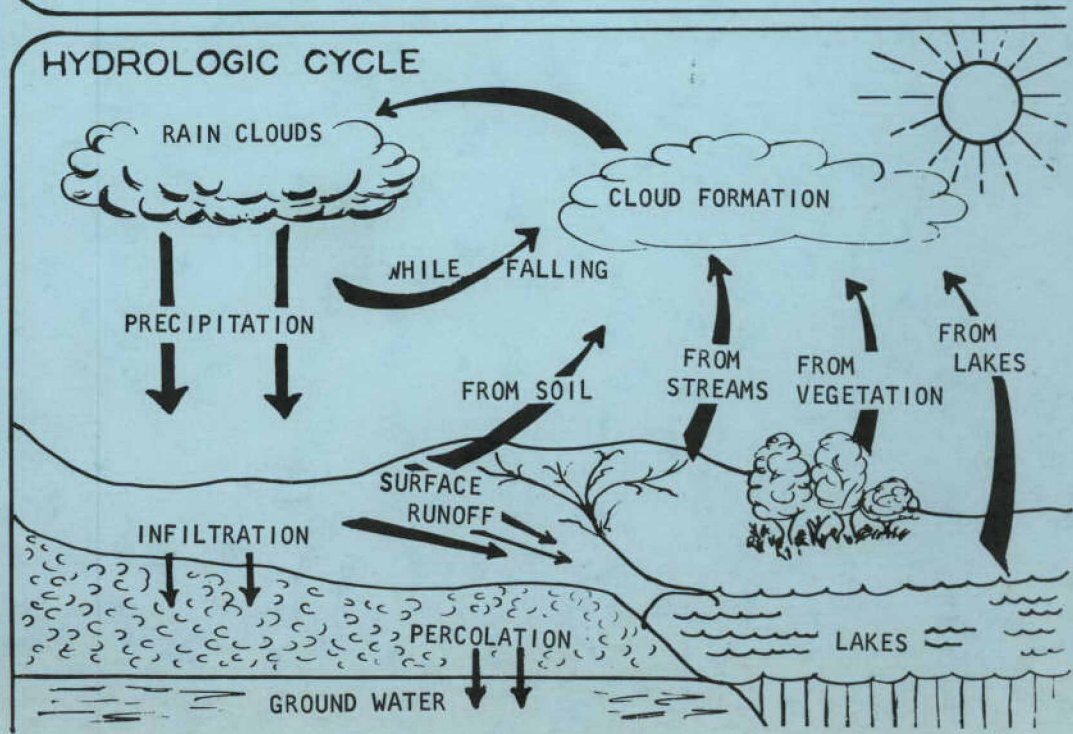
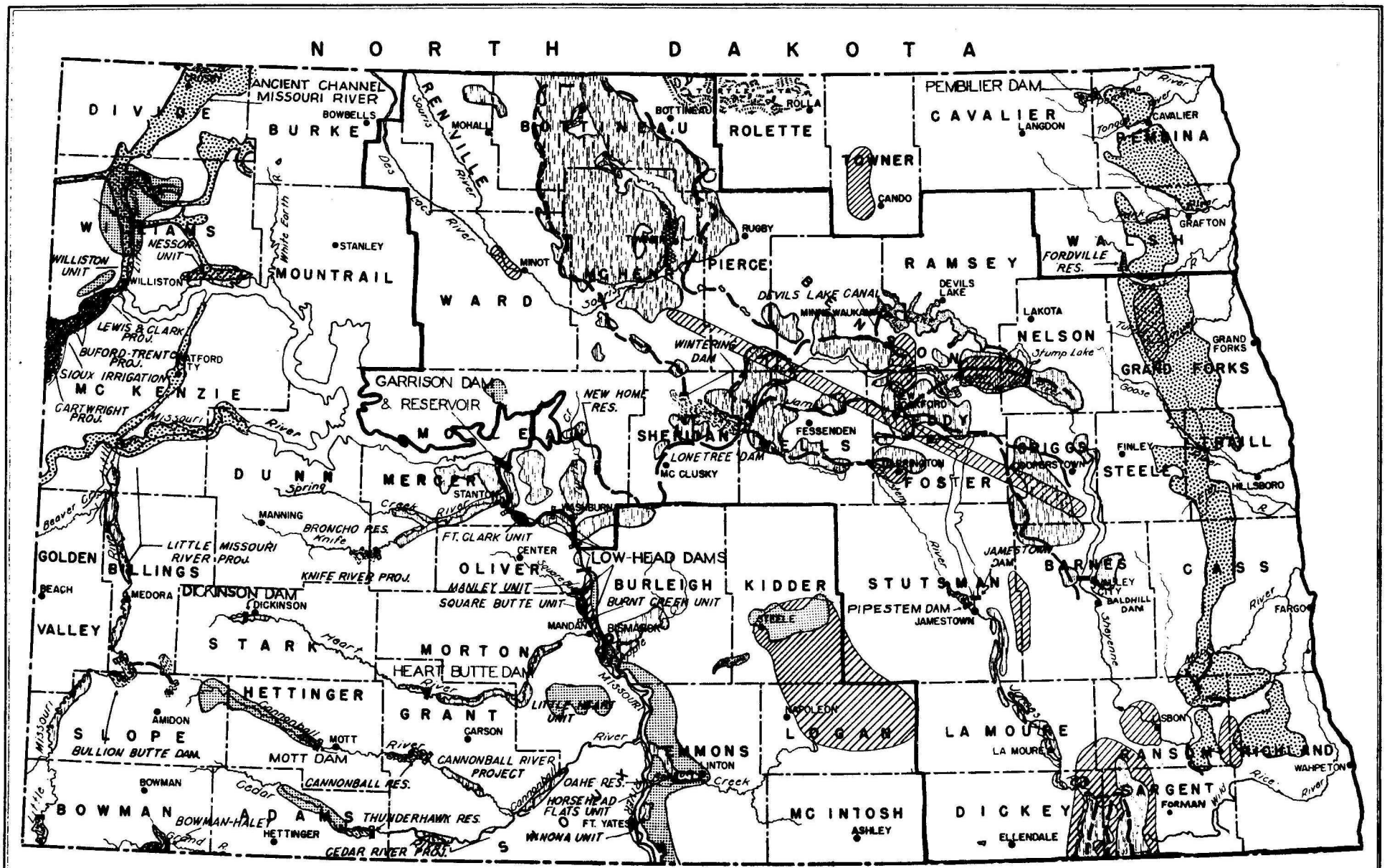
- 1961 -





NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

LANDS UNDER IRRIGATION

AREAS CONSIDERED IRRIGABLE

AREAS BEING INVESTIGATED

PROPOSED FOR INVESTIGATION

EXISTING

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GLACIAL DRIFT AQUIFERS IN THE GACKLE AREA

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GLACIAL DRIFT AQUIFERS IN THE GACKLE AREA

LOGAN AND STUTSMAN COUNTIES, NORTH DAKOTA

By
D. G. Adolphson

Introduction

A preliminary study of the ground-water situation of Gackle was made by the U. S. Geological Survey in January 1957. At that time the city obtained its water supply from shallow wells (nos. 1 and 2) producing water from the same aquifer, a fine to coarse sand lens in the glacial drift. The sand was 11 and 28 feet thick in the two wells. Comparison of measurements of the water level made in January 1957 with measurements made 2 years later show that the static water level in well 1 had lowered 17 feet and that in well 2 had lowered 10 feet, indicating that the ground water in storage was being depleted. (See table 1.)

Four test holes were drilled by the city between 1955 and 1959 in an attempt to obtain additional water. Two of these holes penetrated bedrock to a considerable depth but failed to find an adequate supply of potable water. The other test holes were drilled into the aquifer which supplies the two city wells. Because the yield of the test wells in this aquifer was only 15 gpm (gallons per minute) in each well, the city officials decided that a ground-water investigation of the area was needed to find a larger supply.

The city of Gackle sought aid from and made funds available to the North Dakota State Water Conservation Commission. In cooperation with the Water Commission, the U. S. Geological Survey began fieldwork in March 1959. An inventory of selected wells was made, measurements of well depths and water levels were made where possible. Fifteen test holes were drilled with a hydraulic-rotary drilling machine owned by the State Water Conservation Commission. Information on existing wells was gathered from a 100 square-mile

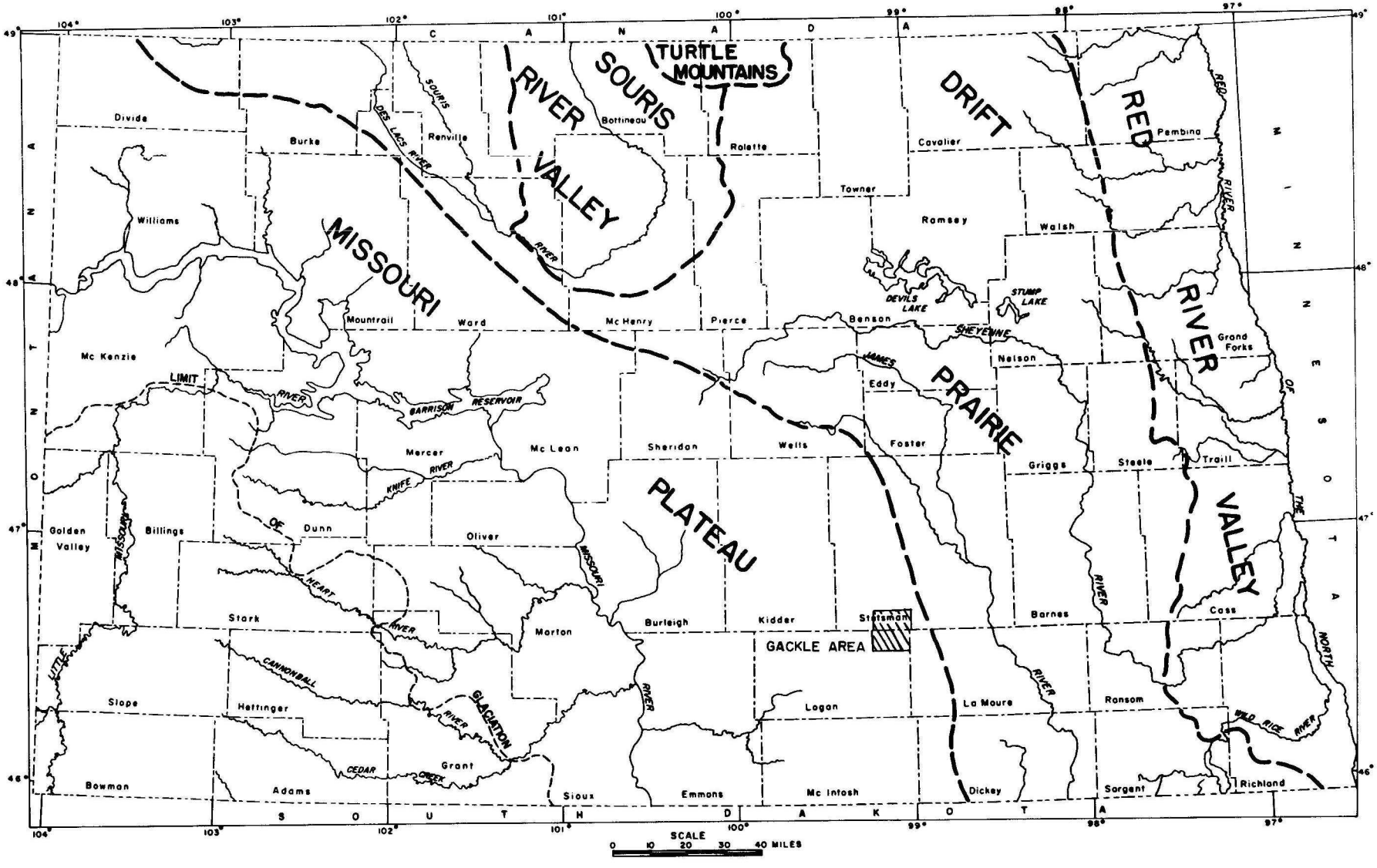

FIGURE 1--PHYSIOGRAPHIC PROVINCES IN NORTH DAKOTA AND LOCATION OF THE GACKLE AREA
(MODIFIED FROM SIMPSON, 1929)

area surrounding Gackle shown on figure 5, but test holes were drilled only in the southern half of the report area, in Logan County, which includes parts of T. 136 N., Rs. 67 and 68 W. The depth of the test holes ranged from 84 to 315 feet and averaged 176 feet; the total footage drilled was 2,643. Two water samples were collected from different aquifers and analyzed to determine their chemical quality, and a pumping test was made to determine the permeability of the water-bearing materials. This report contains the results of the fieldwork and a discussion of ground-water conditions in the area.

The geology and ground-water resources of Stutsman County are being studied by H. A. Winters and C. J. Huxel, Jr. The geology of Logan County has been studied by L. S. Clayton. A part of their geologic mapping has been used in this report.

Location and Extent of Area

The Gackle area, in southern Stutsman and northern Logan Counties, south-central North Dakota (fig. 1) includes parts of T. 137 N., Rs. 66, 67 and 68 W., and parts of T. 136 N., Rs. 67 and 68 W. The area is in the Missouri Plateau section of the Great Plains physiographic province of Fenneman (1931, p. 72). Gackle is surrounded by a "moraine plateau" type of topography characterized by rolling hills of both low and high relief and by depressions.

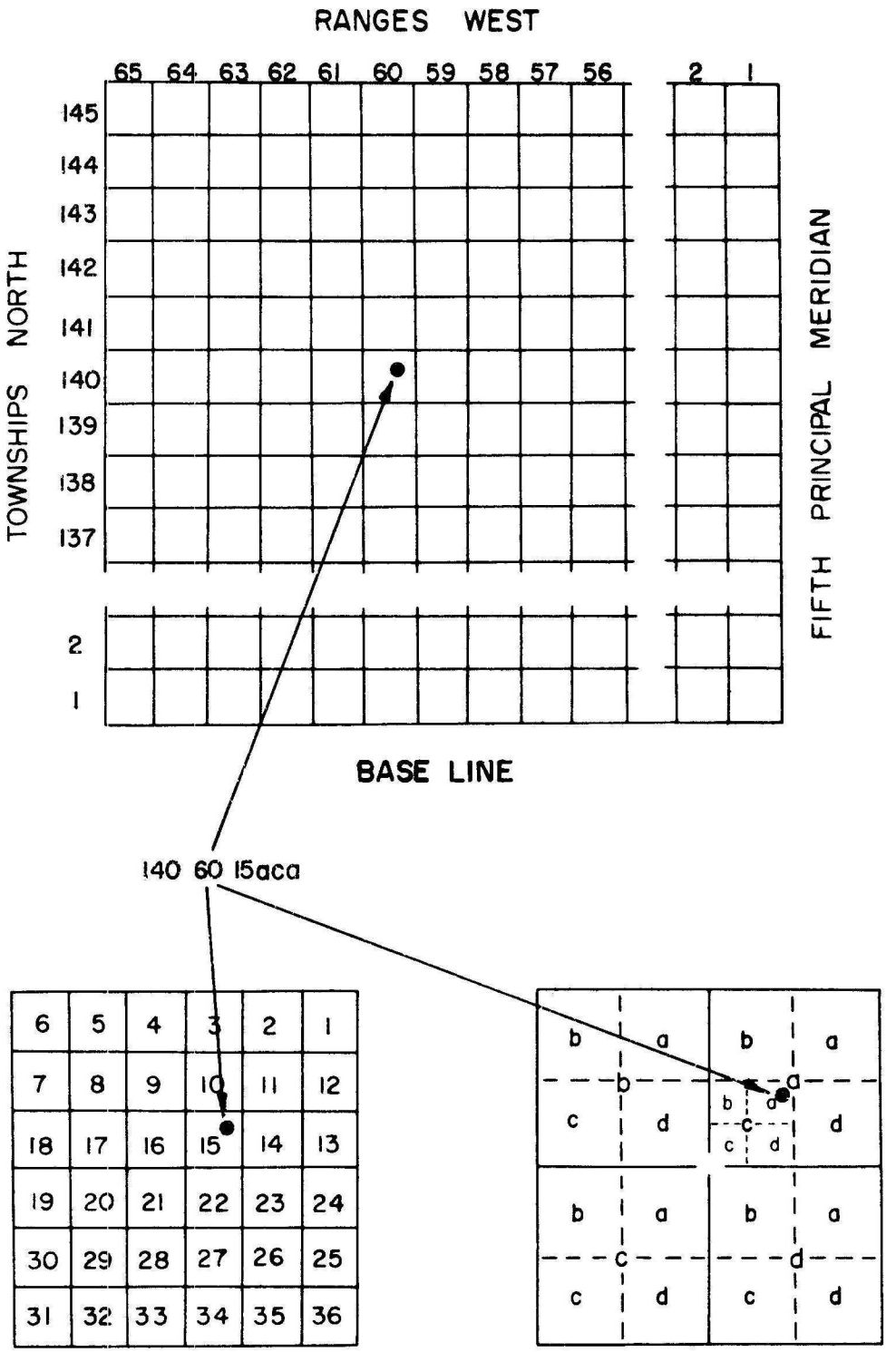

Figure 2 -- Sketch illustrating well-numbering system

Well-numbering System

The well-numbering system used in this report, illustrated in figure 2, is based upon the location of the well in the federal system of rectangular surveys of the public lands. The first numeral denotes the township north and the second numeral denotes the range west both referred to the Fifth principal meridian and base line; the third numeral denotes the section in which the well is located. The letters a,b,c and d designate respectively the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections (10-acre tracts) as shown on figure 2. Consecutive terminal numerals are added if more than one well is shown in a 10-acre tract. Thus, well 140-60-15aca is in the NE¼SW¼ NE¼ sec. 15, T. 140 N., R. 60 W. Consecutive terminal numerals are added if more than one well is recorded within a 10-acre tract.

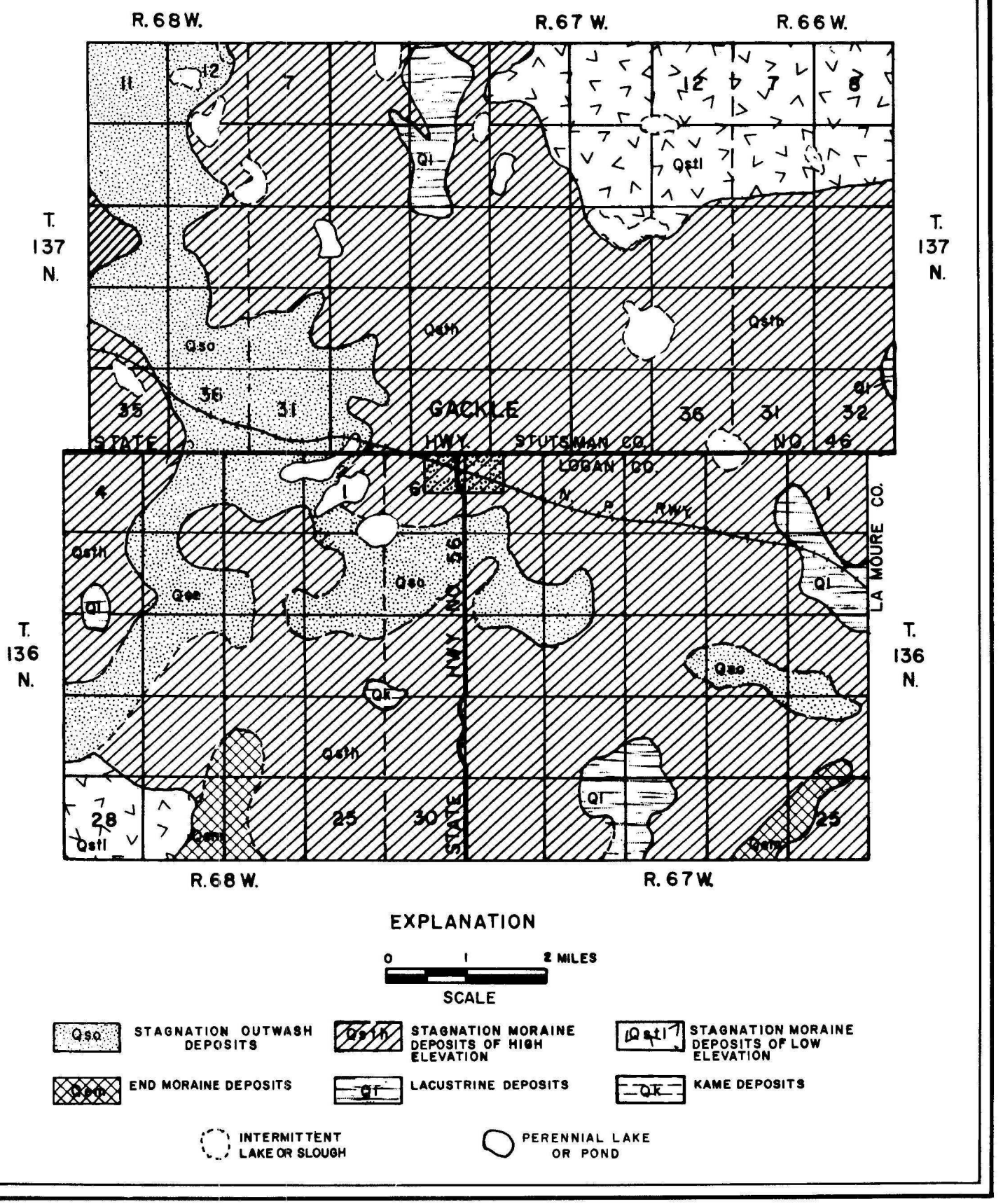

FIGURE 3--GENERALIZED GEOLOGIC MAP OF THE GACKLE AREA

FROM WINTERS AND HUXEL (IN PREPARATION) AND CLAYTON (IN PREPARATION)

Geology and Hydrology

The Gackle area is covered by glacial drift of Wisconsin age consisting of till, outwash, and lacustrine deposits. (See fig. 3.) The glacial drift has been subdivided in the following units: stagnation moraine of high elevation, stagnation moraine of low elevation, stagnation outwash and glacial-lake beds by Winters and Huxel (oral communication, 1960),[1/] and L. S. Clayton, (oral communication, 1960) [2/]

1/ Winters, H. A., and Huxel, C. J., Jr., report on geology and ground-water resources of Stutsman County in preparation for N. Dak. Geological Survey, N. Dak. State Water Conservation Commission and U. S. Geological Survey.
2/ Clayton, L. S., report on the geology of Logan County in preparation for N. Dak. Geological Survey.

Test drilling showed that the thickness of the till and associated sand and gravel deposits of the stagnation moraine of high elevation ranges from 243 feet at test hole 1452 (136-67-5bbb) to 310 feet at test hole 1453 (136-67-5bcc). (See fig. 4.) Isolated sand and gravel lenses within the till range in thickness from 4 feet in test hole 1454 (136-67-6aba) to 64 feet in test hole 1462 (136-67-17bcc). In test hole 1460 (136-67-17bcb), a quarter of a mile north of 1462, a sand and gravel lens 42 feet thick was found. These lenses consist of fine sand to coarse gravel containing shale pebbles and lignite fragments. The deposits at test holes 1460 and 1462 were the most favorable water-bearing material penetrated in test drilling. They are believed to by hydraulically connected and, therefore, constitute a single aquifer.

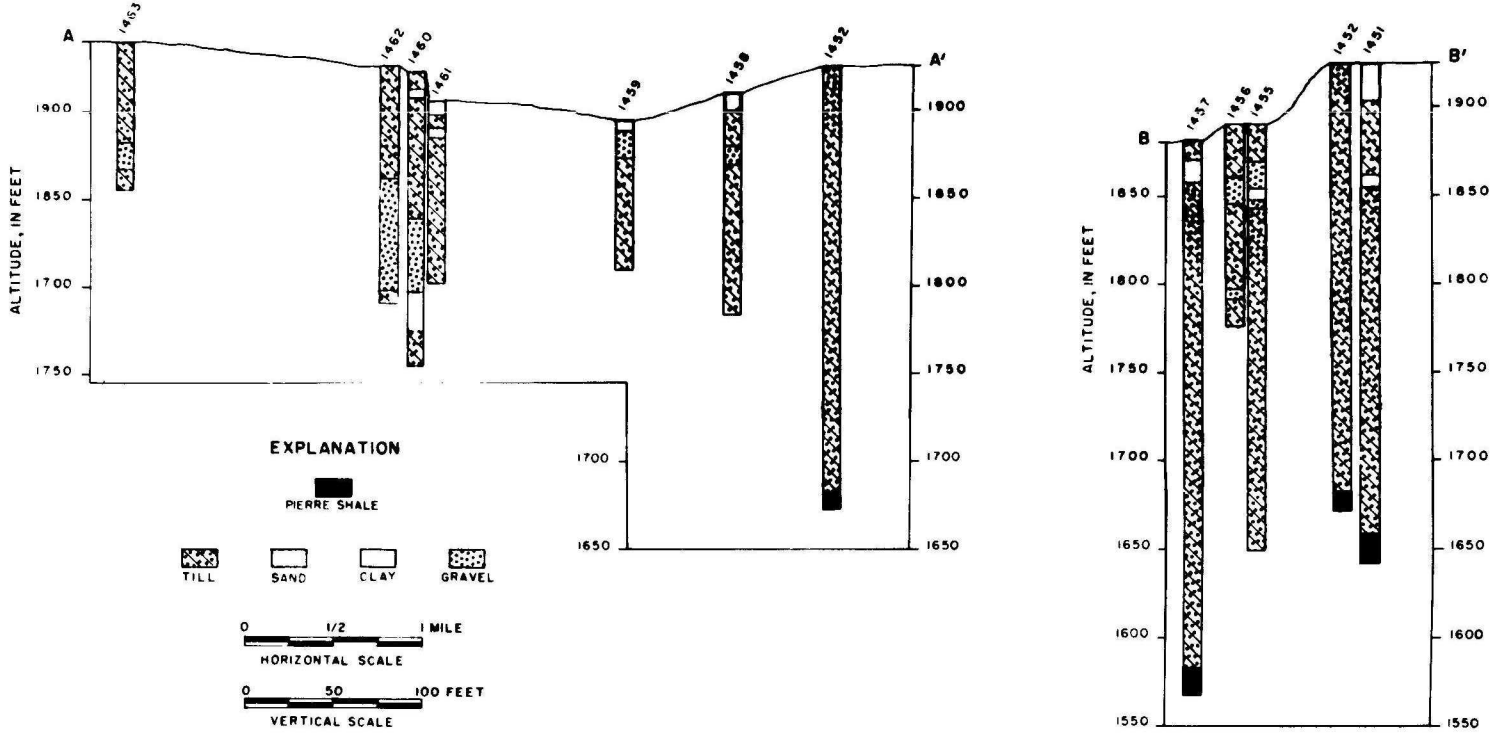

FIGURE 4-- GEOLOGIC SECTIONS THROUGH GACKLE

A pumping test was made of a new city well, which was constructed in August 1959 at the site of test hole 1462 (see fig. 5). The well was pumped at a rate of 55 gpm for 30 hours. The water level in the well was drawn down 26.4 feet during this period. After the pump was stopped the water level rose rapidly for a few hours, but the rate of recovery gradually decreased so that after 40 hours the water level was still 5.5 feet below the original static level. The slow rate of rise probably indicates that the piezometric surface was approaching a new static level because of removal of some water from storage. The coefficient of transmissibility was computed to be 4,000 gallons per day per foot by the Theis method (Theis,1935).

Transmissibility values computed from pumping tests are based on several assumptions. The key assumptions are that the water-bearing materials are homogeneous and isotropic. These assumed conditions are not found in most deposits, including those surrounding the new city well at Gackle. Furthermore, in tests of short duration and those in which the drawdown is measured in the pumped well, as in the above test, it is difficult or impossible to evaluate whether or not well entrance losses may have affected the results. Entrance losses can result in a computed transmissibility that would be lower than the true transmissibility of the formation and could account for the relatively low transmissibility mentioned above.

Test drilling in the stagnation outwash deposits showed that wells penetrate sufficient water-bearing material for ordinary domestic and farm supplies but not for municipal supplies.

The bedrock underlying the glacial drift in the area is the Pierre shale of Late Cretaceous age; it was penetrated in four test holes. The depth of the Pierre below the land surface ranges from 243 feet in test hole 1452 (136-67-5bbb) to 310 feet in test hole 1453 (136-67-5bcc). The shale yields little or no water to wells in the area.

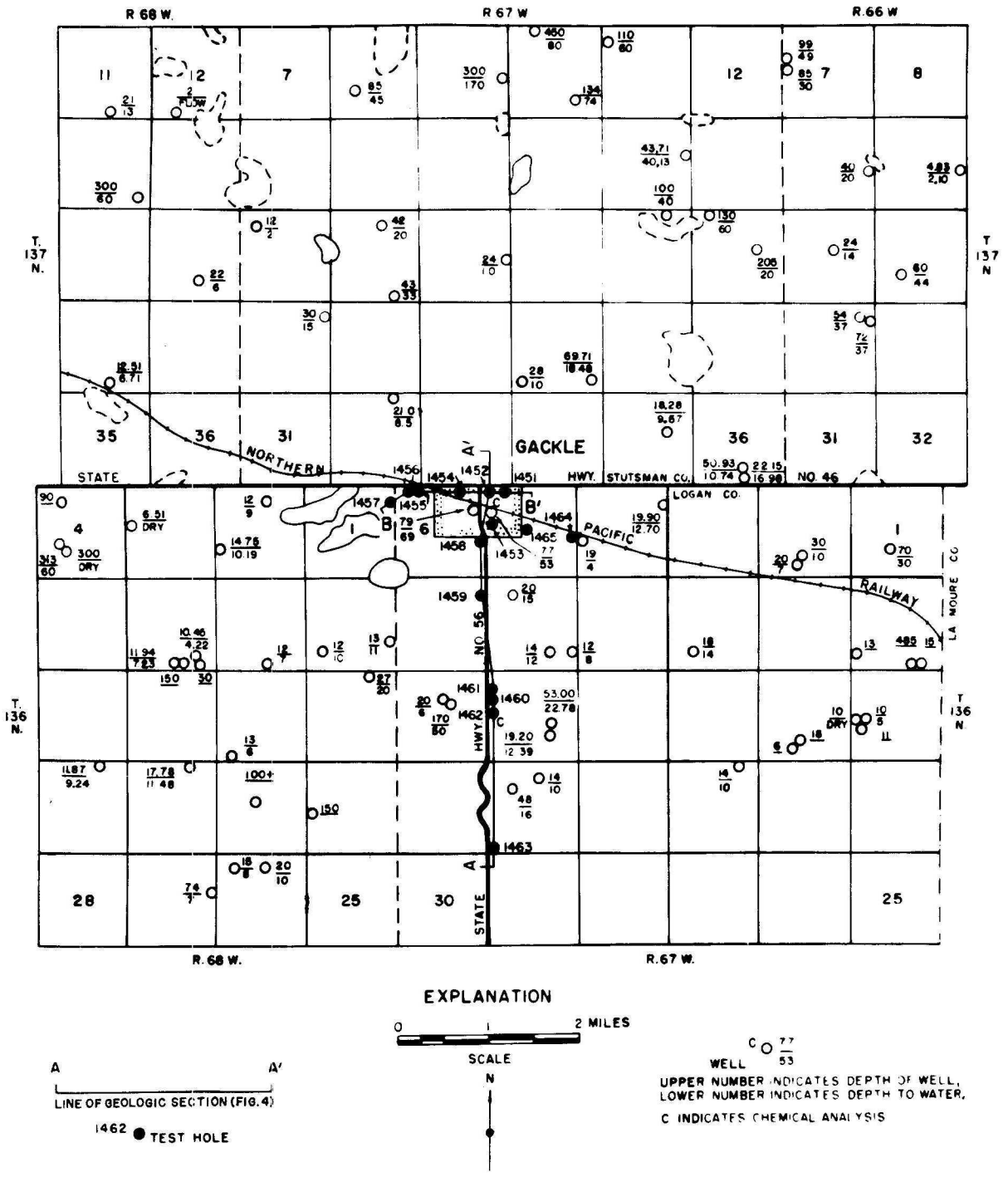

FIGURE 5--MAP OF THE GACKLE AREA SHOWING THE LOCATIONS OF WELLS AND TEST HOLES

Development of water supplies from bedrock formations underlying the Pierre is impractical because of their great depth. Furthermore they generally contain highly mineralized water.

Quality of Water

Analyses of the water from city well 1 and test hole 1462 (see table 2) showed that the mineral content and chemical type are very similar. The dissolved-solids content was 1,120 ppm (parts per million) in the city well and 838 ppm in test hole 1462, and the water in both samples contained large amounts of calcium, sodium, bicarbonate, and sulfate. The hardness of water from the city well 1 was 488 ppm and that from test hole 1462 was 428 ppm. Water having a hardness this high is considered very hard and would require softening to be satisfactory for most uses.

Conclusion

An aquifer south of Gackle can supply ground water in sufficient quantity to meet current municipal demands and perhaps for little expansion to meet slightly larger demands. The supply is found in an isolated sand and gravel lens of the glacial drift. Results of a pumping test at test hole 1462 and other geologic data based on test holes and surface features indicate that natural replenishment to the ground-water supply may not be sufficient to support substantial additional pumping. Continuing periodic measurements should be made of the water level in the new city well (1959) or a nearby well If the water level remains relatively fixed over a long period of time, it will indicate that the ground-water supply is not being depleted and that the well may continue indefinitely as a productive source of supply. If, on the other hand, the water level declines over a long period, it will indicate that recharge is not supplying as much water to the aquifer as is being withdrawn by pumping.

Large additional water supplies are difficult to locate in the area because the only water-bearing materials in the till are small isolated aquifers. However, most of these are adequate for individual farm and domestic supplies.

Depth: Measured depths are given in feet and tenths; reported depths are given in feet.
Type of well: Dr, drilled; Du, dug.

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Date completed
136-67					
1cad	Alvin Dewitt	70	30 x 30	Du	1935
2cda1	Kaupila	20	...	Du	1939
2cda2	Do.	30	30 x 30	Du	1935
4aad	Ezra Hehn	.19.90	3	Dr	1955
4cbb1	Art Schlecht	...	12 x 12	Du	....
4cbb2	Do	19	24 x 24	Du	1920
5bba	Test hole 1451	283	5	Dr	3-12-59
5bbb	Test hole 1452	252	5	Dr	3-13-59
5bcb	City well	77	...	Dr	....
5bcc	Test hole 1453	315	5	Dr	3-14-59
5bdd	Test hole 1465	157	5	Dr	3-24-59
5daa	Test hole 1464	105	5	Dr	3-24-59
6aba	Test hole 1454	157	5	Dr	3-16-59
6ada	City well	79	10	Dr	1946
6bab	Test hole 1455	241	5	Dr	3-17-59
6bba	Test hole 1456	115	5	Dr	3-17-59
6daa	Test hole 1458	126	5	Dr	3-19-59
7aad	Test hole 1459	84	5	Dr	3-19-59
8bac	Paul Schlenker	20	2	Dr	1945
8dca	Mrs. Ina Wirkkune	14	2½	Dr	1948
8dda	Chris Brosz	12	30 x 30	Du	1940
10cdb	Carl Holstrom	18	40 x 40	Du	1945
12ccb1	Emil Klundt		36 x 36	Du	....
12ccb2	Do	13		Du	....
12dcd1	Schott	15	36 x 36	Du	....
12dcd2	Do	485	2½	Dr	1930
13cbb1	J. Klundt	10	24 x 24	Du	1957
13cbb2	Do	10	24 x 24	Du	1957
13cbb3	Do	11	30 x 30	Du	1934
14cda1	Edwin Klundt	6		Du	....
14cda2	Do	18	4	Dr	1930
17bbc	Test hole 1461	105	5	Dr	3-20-59
17bcb	Test hole 1460	168	5	Dr	3-19-59
17bcc	Test hole 1462	136	5	Dr	3-21-59
17dba	Herbert Presler	53	3	Dr	1949
17dbd	Herbert Kinzler	19.20	36 x 36	Du	1948
18acb1	Rudolph LaBren	20	24 x 24	Du	1956
18acb2	Do	170	5	Dr	....
20abc	Arnold Santanen	14	. ...	Du	1897
20bdb	Jacob Moos	48	24 x 24	Dr	1955
20ccc	Test hole 1463	84	5	Dr	3-23-59
22aab	Edwin Holstrom	14	48 x 48	Du	1932

Use of water: D, domestic; N, none PS, public supply, S, stock; T, test hole.

Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Remarks
30	3-17-59	D,S	.....	Supply reported adequate
7	3-17-59	D	Gravel, sand	
10	3-17-59	S	.....	Do.
12.75	3-17-59	D,S	Sand	Do.
.....	3-17-59	D	.....	Do.
4	3-17-59	S	.....	Do.
.....	.....	T	.....	See log.
.....	.....	T	.....	Do.
43	1- -57	PS	do	
.....	.....	T	.....	Do.
.....	.....	T	.....	Do.
.....	.....	T	.....	Do.
.....	.....	T	.....	Do.
52	1- -57	PS	Sand	See log, chemical analysis.
.....	.....	T	.....	See log.
.....	.....	T	.....	Do.
.....	.....	T	.....	Do.
.....	.....	T	.....	Do.
15	3-17-59	D,S	Gravel	Supply reported adequate.
12	3-16-59	D,S	Sand	
18	3-18-59	D	.....	Do.
14	3-16-59	D,S	Gravel	
.....	3-17-59	D,S	.....	Do.
.....	3-17-59	D	.....	
.....	3-17-59	D	.....	Do.
.....	3-17-59	S	.....	Do.
5	3-17-59	D,S	.....	Do.
Dry	3-17-59	N	.....	Do.
.....	3-17-59	N	Gravel	Do.
.....	3-17-59	D,S	do	Do.
.....	3-17-59	D	.....	
.....	.....	T	.....	See log.
.....	.....	T	.....	Do.
.....	.....	T	.....	Do.
22.78	3-16-59	S	.....	Supply reported inadequate, unfit for drinking.
12.39	3-16-59	D	Sand	Do.
6	3-18-59	D,S	Gravel,sand	Do.
50	3-18-59	S	.....	Do.
10	3-16-59	D,S	Sand	Supply reported adequate.
16	3-16-59	D	.....	Do.
.....	.....	T	.....	Do.
10	3-17-59	S	Gravel	Supply reported inadequate, unfit for drinking.

TABLE 1.--RECORDS OF WELLS AND TEST HOLES

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Date completed
136-68					
1aad	Test hole 1457	315	5	Dr	3-18-59
2abc	Melun Zenker	12	36 x 36	Du	....
2cbc	Jack Zenker	14.75	24 x 24	Du	1945
3bcc	Do	6.51	48 x 48	Du	....
4bac	A. H. Schult	90	3	Dr	....
4cac1	Elbo Schmedt	313	3	Dr	1953
4cac2	do	300	3	Dr	1953
10dcc1	Peter Miller, Jr.	150	3	Dr	....
10dcc2	do	11.94	36 x 36	Du	....
10ddc1	John Kammerr	30	48 x 48	Du	....
10ddc2	do	10.45	36 x 36	Du	1947
11dcc	Paul Gienger	12	48 x 48	Du	....
12cca	Ted Schlemkle	12	36 x 36	Du	....
12dad	R. R. Ruff	13	48 x 48	Du	....
13aba	Gott Schlenker	27	5	Dr	1919
14ccd	Paul Mayer	13	....	Du	....
21aba	G. Muller	11.87	36 x 36	Du	1934
22aba	Gus Mayer	17.78	36 x 36	Du	1952
23bdd	Bill Slinger	100+	4	Dr	....
24cbb	do	150	4	Dr	....
26abc	Deserted	20	36 x 36	Du	....
26bbd	do	15	36 x 36	Du	....
27add	Olaf Sarkinen	74	24	Dr	1936
137-66					
7bcc1	Gust Schmierer	99	.3	Dr	1915
7bcc2	do	85	.3	Dr	....
17daa	A. F. Lehr	4.83	48	Du	....
18daa	Joe Kiruida	40	24	Dr	....
19acc	Loyd Flaig	24	36	Dr	1930
20cac	Aaron Reich	60	24	Dr	1933
30aad1	G. E. Summerfield	54	...	..	1934
30aad2	do	72	3	Dr	1918
137-67					
8cac	August Flang	85	36	Dr	1911
9daa	Lorenz Schroeder	300+	3	Dr	....
10bab	Christ Jerke	450	2	Dr	....
10dca	Art Reimbolt	134	3	Dr	1936
11bbc	John Heinrich	110	4	Dr	1957
14add	Unknown	43.71	24	Dr	....
19bbd	Jacob Koeing	12	...	Du	....
20abc	Arnold Diede	42	24	Dr	....
20dcd	Fred Schmierer	43	48	Du	1958
21daa	Richard Burkle	24	36	Dr	....
23aba	Emanual Heller	100	3	Dr	....
24acd	Hurod Zimmerman	205	2½	Dr	1925
24bba	W. C. Heinrich	130	6	Dr	....
27cc	Ernest Hehn	28	6	Dr	1938
27dd	Ed. G. Humboldt	69.71	24	Dr	....
30aad	Reubin Ruth	30	36	Du	....
32aba	Elroi Fischer	21.0	...	Du	....

GACKLE AREA, STUTSMAN COUNTY

Depth to water below land surface (feet)	Date of measurement	Use	Aquifer	Remarks
.....	.....	T	.....	See log.
9	3-17-59	D,S	Sand	
10.19	3-17-59	D,S	Clay	
Dry	3-17-59	N	do	Supply reported inadequate.
.....	3-17-59	D,S	Sand	
60	3-17-59	S	Shale	Supply reported diminishing.
Dry	3-17-59	D	do	Supply reported inadequate.
.....	3-17-59	D	Sand	
7.23	3-17-59	D,S	do	
.....	3-17-59	D	do	Reportedly can be pumped dry.
4.22	3-17-59	S	Gravel,sand	
7	3-16-59	D,S	Gravel	Supply reported adequate.
10	3-16-59	D,S	....	Supply reported inadequate.
11	3-16-59	D,S	Gravel	Do.
20	3-16-59	D,S	Sand	Supply reported adequate.
6	3-17-59	D,S	Gravel	
9.24	3-17-59	S	do	Supply reported inadequate.
11.48	3-17-59	D,S	do	Do.
.....	3-17-59	D,S	Gravel, sand	Supply reported adequate, heavily pumped.
.....	3-17-59	D,S	Clay	Supply reported inadequate.
10	3-17-59	N	....	
8	3-17-59	N	....	
7	3-17-59	D,S	....	Supply reported adequate.
49	.....	D,S	Gravel	Supply reported adequate.
30	.....	S	do	Do.
2.10	8- 5-58	S	do	Supply reported inadequate; unfit for drinking
20	.....	D,S	Sand,clay	Supply reported adequate.
14	.....	D,S	Sand	Do.
44	.....	D,S	do	Do.
37	.....	D,S	Gravel	Do.
37	.....	D,S	Gravel, sand	Do.
45	.....	D,S	Gravel	Do.
170	.....	D,S	Sand	Do.
80	.....	D,S	Gravel	Do.
74	.....	D,S	do	Do.
60	.....	D,S	do	Do.
40.13	8- 1-58	S	....	
2	.....	D,S	Gravel	Supply reported adequate.
20	.....	D,S	do	Do.
33	.....	D,S	Sand	Supply reported inadequate.
10	.....	D,S	Gravel	Supply reported adequate.
40	.....	D,S	....	Do.
20	.....	D,S	Sand	Do.
60	.....	D,S	....	Do.
10	.....	D,S	do	Do.
18.48	8- 1-58	D,S	Gravel	Do.
15	.....	D,S	do	Do.
8.5	.....	D,S	do	Do.

TABLE 1.--RECORDS OF WELLS AND TEST HOLES

Location No.	Owner or name	Depth (feet)	Diameter or size (inches)	Type	Date completed
137-67 - Continued					
35acd	Albert Kinzler	18.28	24	Dr	....
36dcc1	Emil Schweigert	50.93	24	Dr	....
36dcc2	do	22.15	24	Dr	....
137-68					
11dcc	Alex Schlenker	21	40	Du	1957
12cdc	Art Kienzle	2	36	Du	....
14dd	John Grenz	300	3	Dr	....
24dcb	Edward Schlenker	22	48	Du	....
26dcc	Alvin Grenz	12.51	48	Du	....

GACKLE AREA, STUTSMAN COUNTY

Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Remarks
9.57	8- 1-58	D,S	Sand and gravel	Do.
10.74	8- 6-58	D,S	Sand	Supply reported adequate.
16.98	8- 6-58	S	Gravel	Do.
13	.....	D,S	do	Do.
Flow	.....	D,S	do	Do.
60	.....	D,S	.....	Do., saline
6	.....	D,S	Gravel	Supply reported adequate
6.71	8- 2-58	D,S	Sand and gravel	Do.

TABLE 2.--CHEMICAL ANALYSES

Results in parts per million except as indicated

Location No.	Owner or name	Aquifer	Depth of well (feet)	Date of collection	Depth to water (feet below land surface)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
136-67										
6ada	City well 1	Drift	79	1-22-59	69	0.6	120	46	162	18
17bcc	Test hole 1462	Drift	136	8-17-59	4.40	.4	116	34	92	11

a/Includes bicarbonate (HCO_3) as carbonate (CO_3)

OF GROUND WATER

Analyses by State Laboratories, Bismarck, North Dakota

Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$	Dissolved solids	Sum of determined - constituents	Percent sodium
371	0	439	28	0.2	1.1	0.3	488	1,120	998a/	40
319	0	300	26	.3	.6	.7	428	838	738a/	30

TABLE 3.--LOGS OF WELLS AND TEST HOLES

136-67-5bba
Test hole 1451

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black.....	2	2
	Clay, sandy, buff to light-gray, oxidized.....	19	21
	Till, clayey, light-gray, fine gravel; lignite fragments; and shale pebbles.....	10	31
	Till, clayey, gray; fine to medium gravel; lignite fragments; and shale pebbles.....	32	63
	Clay, silty, light-gray, conchoidal fracture..	7	70
	Till, clayey, light-gray; fine gravel; lignite fragments; and shale pebbles.....	12	82
	Till, clayey, gray; fine gravel; lignite fragments; and shale pebbles.....	184	266
Pierre shale:			
	Shale, blue-gray, dense.....	17	283

136-67-5bbb
Test hole 1452

Glacial drift:			
	Topsoil, black.....	2	2
	Till, clayey, mottled yellow to gray, oxidized; fine to medium gravel.....	18	20
	Till, clayey, light-gray; fine gravel and cobbles; lignite fragments; and shale pebbles.....	223	243
Pierre shale:			
	Shale, blue to gray	9	252

136-67-5bcc
Test hole 1453

Glacial drift:			
	Topsoil, black.....	3	3
	Till, clayey, mottled buff to yellow, oxidized; fine gravel; lignite fragments; and shale pebbles.....	18	21
	Gravel, coarse, and coarse sand; large fraction of carbonate and shale pebbles.....	18	39
	Till, clayey, light-gray to gray; medium gravel; lignite fragments; and shale pebbles	34	73
	Till, clayey, gray; coarse sand and fine to medium gravel; lignite fragments; and shale pebbles.....	217	290
	Gravel, fine; large fraction of shale pebbles.	3	293
	Till, clay, gray; fine to medium gravel; lignite fragments; and shale pebbles.....	17	310
Pierre shale:			
	Shale, gray-blue.....	5	315

TABLE 3.--LOGS OF WELLS AND TEST HOLES -- Continued

136-67-5bdd
Test hole 1465

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black, weathers to gray when exposed to air	2	2
	Clay, light-gray to chalky white, highly oxidized	4	6
	Clay, smooth, yellow	6	12
	Clay, smooth, gray-blue; trace of tabular gypsum	31	43
	Till, clayey, gray; fine to medium gravel; shale pebbles; and selenite crystals	37	80
	Clay, smooth, gray-blue	49	129
	Till, gray; fine to coarse gravel; shale pebbles	28	157

136-67-5daa
Test hole 1464

Glacial drift:			
	Topsoil,sandy	2	2
	Till, clayey, sandy, yellowish-gray to buff, highly oxidized; fine gravel; shale pebbles	4	6
	Till clayey, gray; fine gravel; lignite fragments	40	46
	Gravel, fine to medium; and fine to coarse sand, clean; lignite fragments;and shale pebbles	17	63
	Till, clayey, gray; fine to medium gravel; lignite fragments; and shale pebbles	42	105

136-67-6aba
Test hole 1454

Glacial drift:			
	Topsoil, dark-brown	2	2
	Till, clayey, yellow, mottled, oxidized, sandy.	14	16
	Till, clay, gray; fine gravel and cobbles; and shale pebbles	27	43
	Gravel, fine to medium, silty; and large shale pebbles	4	47
	Till, clayey, gray; fine to medium gravel; lignite fragments	110	157

136-67-6ada
Gackle city well 1
(Log furnished by Independent
Drilling Co., Inc., Aberdeen, S. Dak.)

Glacial drift:			
	Clay, yellow, and gravel	3	3
	Gravel, clay, yellow	9	12
	Clay, yellow, sandy	10	22
	Clay, yellow	13	35
	Sand, fine	5	40
	Clay, blue	18	58
	Clay, blue, sandy	2	60
	Sand, coarse	2	62
	Clay, blue	6	68
	Sand, coarse	11	79
	Clay, blue	22	101

TABLE 3.--LOGS OF WELLS AND TEST HOLES -- Continued

136-67-6bab
Test hole 1455

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, dark-brown to black.....	2	2
	Till, clay, yellow-buff, mottled; fine gravel, oxidized.....	19	21
	Gravel, fine to coarse; fine to coarse sand, clean.....	15	36
	Clay, light-gray.....	7	43
	Gravel, fine to medium, very clean, rounded; shale pebbles.....	5	48
	Till, clayey, gray; fine to medium gravel; lignite fragments; and shale pebbles.....	193	241

136-67-6bba
Test hole 1456

Glacial drift:			
	Topsoil, dark-brown, black.....	2	2
	Till clayey, yellow-buff, mottled, oxidized; fine gravel.....	13	15
	Till, clayey, gray; shale pebbles.....	15	30
	Gravel, fine to coarse; fine to coarse sand; lignite fragments and shale pebbles.....	15	45
	Till, clayey, gray; fine to coarse gravel and cobbles; lignite fragments; and shale pebbles	49	94
	Gravel, fine to medium; coarse sand; abundant shale pebbles.....	6	100
	Till,clayey, fine to coarse gravel; abundant shale pebbles.....	15	115

136-67-6daa
Test hole 1458

Glacial drift:			
	Topsoil, black.....	5	5
	Clay, sandy to silty.....	5	10
	Till, clayey, yellow, buff, mottled, oxidized; fine to coarse gravel; lignite fragments; and shale pebbles.....	20	30
	Gravel, fine to coarse, and some cobbles, clean; fine to coarse sand; lignite fragments; and shale pebbles.....	11	41
	Till, clayey, light-gray to gray; fine to coarse gravel; lignite fragments; and shale pebbles.....	85	126

TABLE 3.--LOGS OF WELLS AND TEST HOLES -- Continued

136-67-7aad
Test hole 1459

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	2	2
	Clay, yellow, buff to light-gray, mottled, oxidized; fine to medium gravel; and shale pebbles	4	6
	Gravel, fine to medium; lignite fragments; shale pebbles; and fine to coarse sand	15	21
	Till, clayey, gray; fine to medium gravel; lignite fragments; and abundant shale pebbles	63	84

136-67-17bbc
Test hole 1461

Glacial drift:			
	Topsoil, black	3	3
	Clay, white to light-gray, chalky to highly oxidized	5	8
	Till, clayey, gray; fine to medium gravel, oxidized	7	15
	Sand, fine to coarse; fine gravel; lignite fragments; and abundant shale pebbles	6	21
	Till, clayey, gray; fine gravel; lignite fragments; and shale pebbles	84	105

136-67-17bcb
Test hole 1460

Glacial drift:			
	Topsoil, black	2	2
	Till, clayey, sandy, light-olive-gray, well-oxidized; fine gravel	8	10
	Clay, light-yellow, oxidized	5	15
	Till, clayey, olive-gray, slightly oxidized; medium gravel; lignite fragments; and shale pebbles	27	42
	Till, clayey, dark-olive-gray; fine to medium gravel; lignite fragments; and shale pebbles	42	84
	Gravel, fine to medium; medium to coarse sand, clean, rounded; and large shale pebbles	31	115
	Gravel, very fine, well-rounded and sorted; almost entirely shale	11	126
	Clay, silty, gray cohesive	22	148
	Till, clayey, gray; medium to coarse gravel; large shale pebbles	20	168

Lower till (148-168) appears to be different from upper till.

TABLE 3.--LOGS OF WELLS AND TEST HOLES -- Continued

136-67-17bcc
Test hole 1462

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	3	3
	Till, clay, buff to yellow, mottled; fine gravel; and shale pebbles	16	19
	Till, clayey, gray; fine to coarse gravel; and shale pebbles	45	64
	Gravel, fine to coarse, clean; fine to coarse sand; lignite fragments; and abundant shale pebbles	64	128
	Till, clay, gray; fine to coarse gravel; and shale pebbles	8	136

136-67-20ccc
Test hole 1463

Glacial drift:			
	Topsoil, dark-brown to brown; very fine,silty, sand	1	1
	Till, clayey, light-brown to buff to yellow; abundant selenite crystals; oxidized gravel	11	12
	Till, clayey, gray; fine to medium gravel and cobbles; shale pebbles; a calcic lattice has formed thru section of till immediately above gravel	45	57
	Gravel, fine to medium; fine to coarse sand; lignite fragments; and abundant shale pebbles	15	72
	Till, clayey, gray; fine to medium gravel	12	84

136-68-1aad
Test hole 1457

Glacial drift:			
	Topsoil, black	2	2
	Till, clayey, yellow-buff, mottled, oxidized; fine to medium gravel; lignite fragments; and shale pebbles	14	16
	Sand, fine to coarse; fine to coarse gravel; lignite fragments; and shale pebbles	8	24
	Till, clayey, gray; fine to medium gravel; lignite fragments; and abundant shale pebbles	275	299
Pierre shale:			
	Shale, gray-blue	16	315

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