STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

SPECIAL REPORT 16

WATER SUPPLY FOR THE CITY OF MENNO, SOUTH DAKOTA

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CONTENTS

ILLUSTRATIONS

Page

Figure

TABLES

APPENDIXES

INTRODUCTION

Present Investigation

This report is the result of a special investigation by the South Dakota State Geological Survey during the summer of 1961 in and around the city of Menno, Hutchinson County, South Dakota (fig. 1). In the spring of 1961 the Menno City Council had requested that a complete survey be made of the ground water conditions in and around the city.

Presently the city's water is supplied by two wells, one of which produces from a depth of 357 feet, and the second from a depth of 530 feet. In addition to these two deep wells, one shallow well (210 feet deep) exists but is not in operation. These wells supply an adequate quantity of water but the extremely poor quality of the water has become an increasing problem for the city.

On July 25, 1961, an investigation of the ground water conditions in an area of about 80 square miles around the city was started. This investigation consisted of the geologic mapping of the area, the drilling of 21 shallow test holes with a State Survey jeep-mounted auger drill, the drilling of 18 deeper test holes with the State Survey's rotary drill, the inventory of all farm wells in the area, and the collecting and analyzing of 5 water samples.

The field work and preparation of this report were performed under the supervision of Merlin J. Tipton, geologist in charge of ground water studies for the State Geological Survey. Geologic assistance was given by Robert Schoon, geologist-driller for the State Geological Survey and Jim McMeen, Keith Munneke, Richard Brown, and Loren Rukstad. The writer wishes to thank the residents of the Menno area for their cooperation, especially Mayor R. G. Schumacher, and Elmer Hertz and Vern Liebl of the Menno Drilling Company.

Special thanks are due to the South Dakota State Chemical Laboratory in Vermillion for reconditioning the field analysis kit and for providing a portable pH meter, and to the U. S. Geological Survey for providing the specific conductance meter. These instruments made it possible to obtain quick field chemical analyses of water.

Location and Extent of Area

The city of Menno is located in Hutchinson County in southeastern South Dakota, and has a population of 837 (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 mean annual temperature is 48.3°F., and the average annual precipitation is 22.86 inches, at the U. S. Weather Bureau Station in Menno.

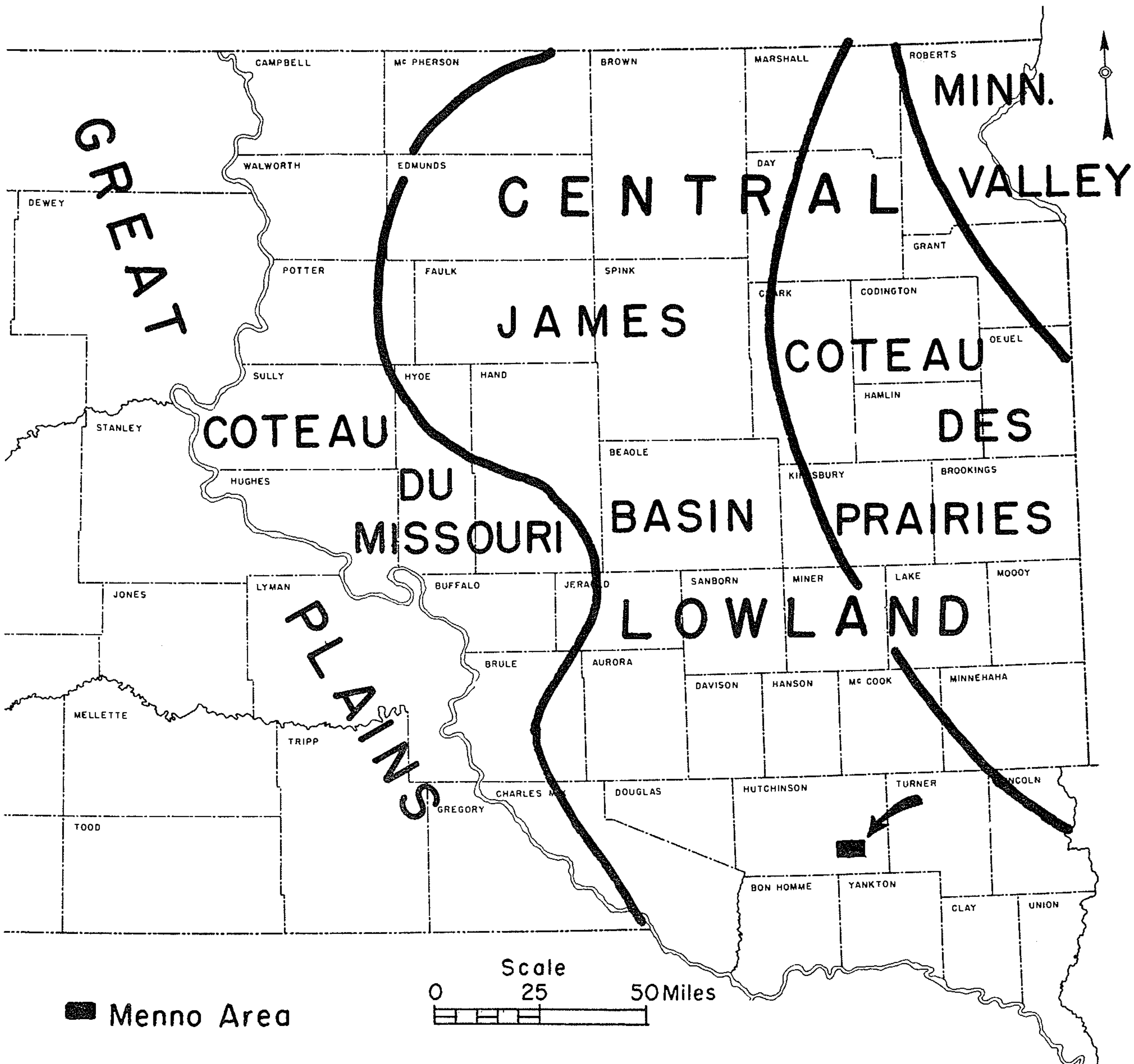

Figure I. Major Physiographic Divisions of Eastern South Dakota.

Topography and Drainage

The topography of the area is youthful glacial moraine--rolling hills and valleys with knobs and kettles.

All streams in the mapped area drain in a westerly direction to the James River which flows in a southerly direction, eventually emptying into the Missouri River about 35 miles southeast of Menno. The largest of the westward flowing streams in the mapped area is Furlong Creek which has been dammed to form Lake Menno (fig. 2) and a recreation area.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Menno area are mostly the result of glaciation during the Pleistocene Epoch. These glacial deposits are collectively called drift and can be divided into till and outwash sediments.

Till consists of clay- and silt-size particles mixed randomly with sand, pebbles, and boulders and was deposited by the glacial ice itself. The major surficial deposit in the Menno area is till (fig. 2).

Outwash sediments consist chiefly of sand and pebbles with minor amounts of silt and clay and were deposited by meltwater streams. No mappable surface outwash deposits occur in the area studied; however, a buried outwash covered by as much as 200 feet of till is present in the west-central part of 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 as much as 40 feet thick occurs along the James River and as thinner deposits along some minor tributary valleys (fig. 2).

Subsurface Bedrock

Stratified sedimentary rocks of Cretaceous age lie beneath the surficial deposits in the Menno area. These sediments in descending order are the Pierre, Niobrara, and Carlile Formations, and the Dakota Group.

Figure 3 is a contour map showing the configuration of the surface of the bedrock as it would appear if all glacial deposits were removed. This bedrock surface consists of the Niobrara Formation, except for a small area in the SE$\frac{1}{4}$ sec. 7, T. 97 N., R. 56 W., which has a thin veneer of Pierre Shale. A bedrock high or ridge is present about three miles east of Menno. The crest of the ridge trends northwest-southeast and the sides slope steeply to the southwest, toward Menno, and move gently to the northeast.

The Pierre Shale was present in only one drill hole in the Menno area. Drill Hole R (fig. 4 and Appendix B) showed 15 feet of dark-gray shale.

The Niobrara Formation, in the subsurface, consists of bluish-gray clay marl with a high percentage of organic calcium carbonate, and is sometimes highly fractured. This formation crops out north of the mapped area, along the James River, where it is a yellowish-brown argillaceous limestone (called "chalk rock" by local residents).

The Carlile consists of medium- to dark-gray bentonitic shale.

The Greenhorn Limestone and Graneros Shale may be present in the southern part of the mapped area. They are white limestone and dark siliceous shale, respectively.

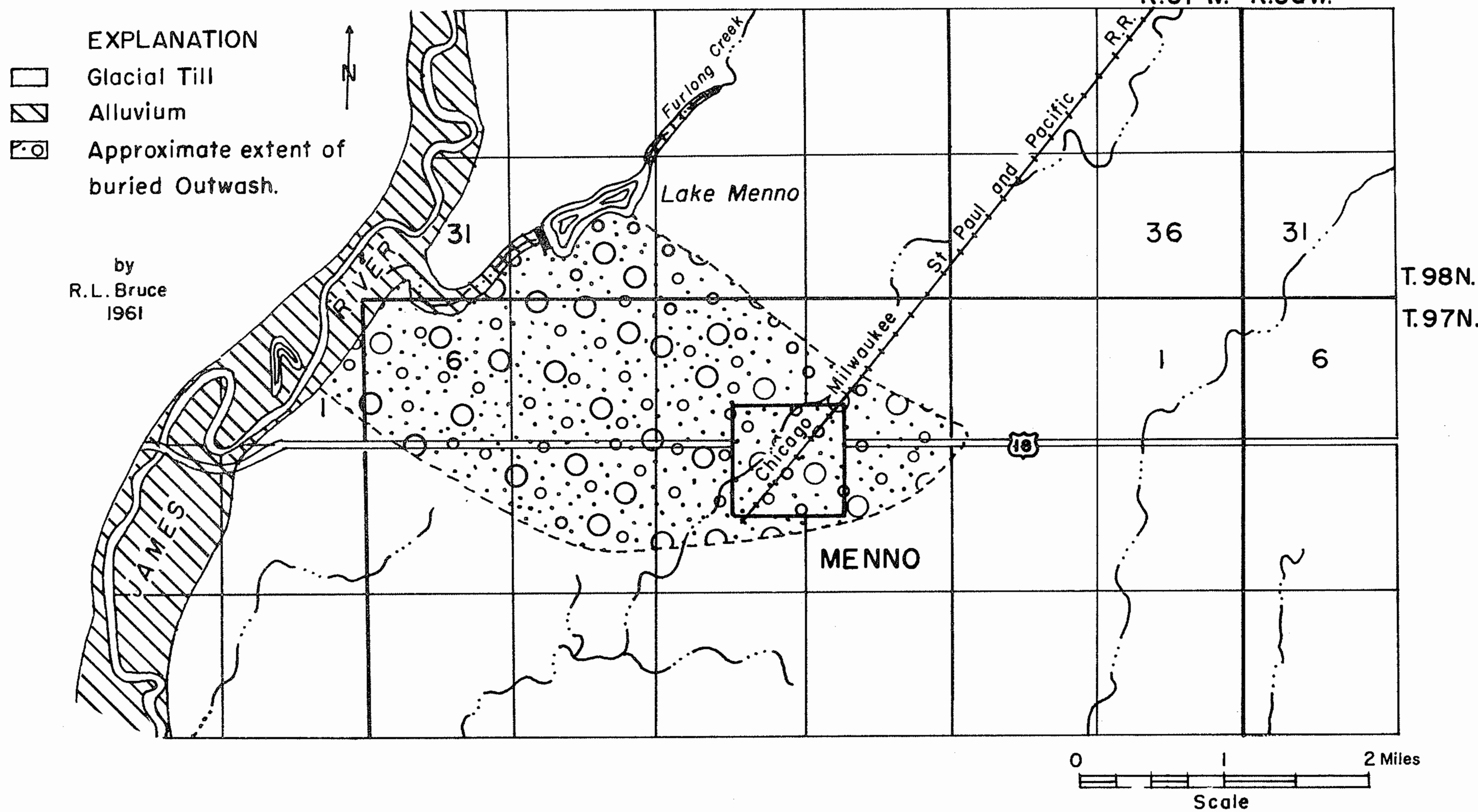

Figure 2. Generalized Geologic Map of the Menno Area.

Drafted by Bruno Petsch

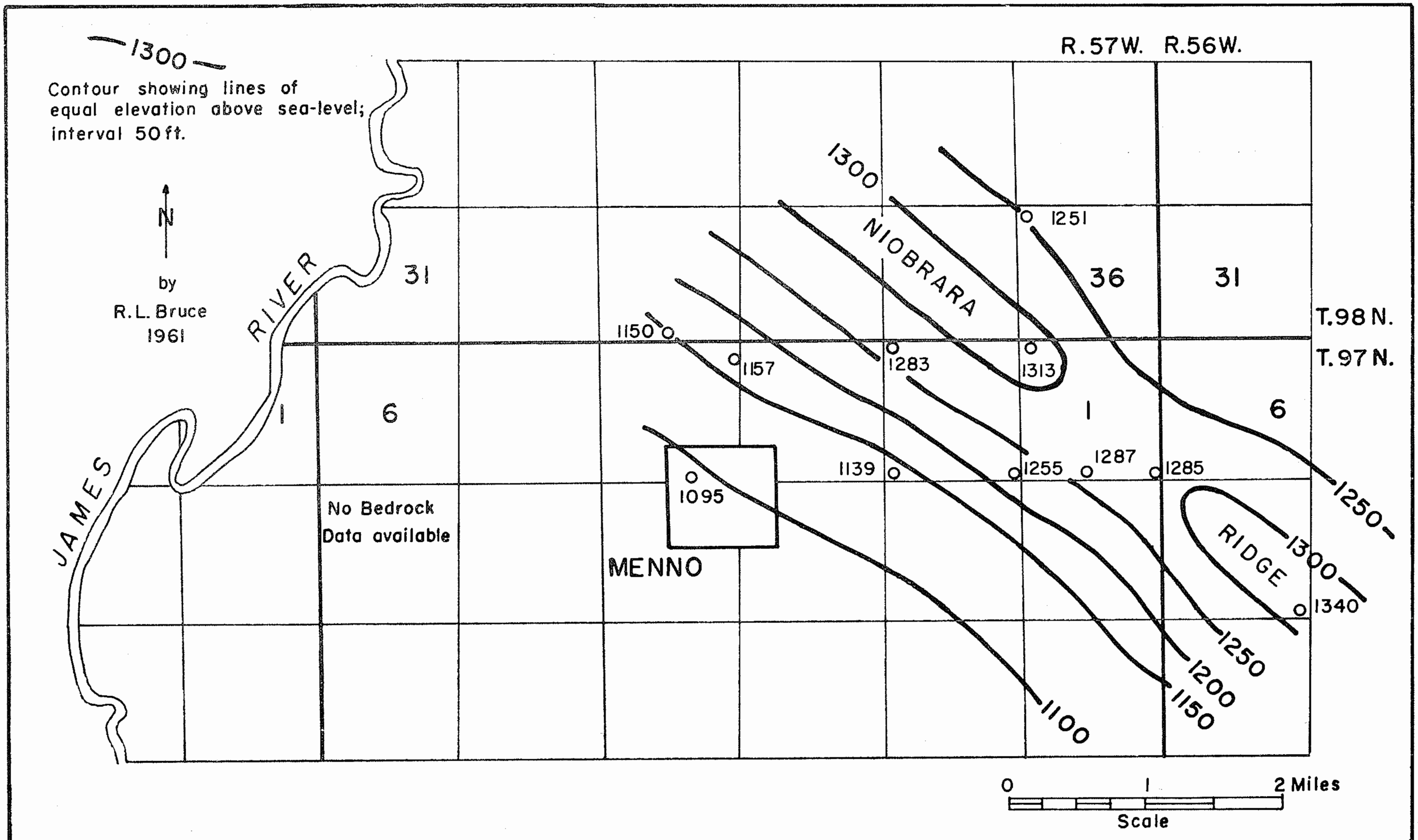

Figure 3. Contour Map of the Buried Bedrock Surface.

Drafted by Bruno Petsch

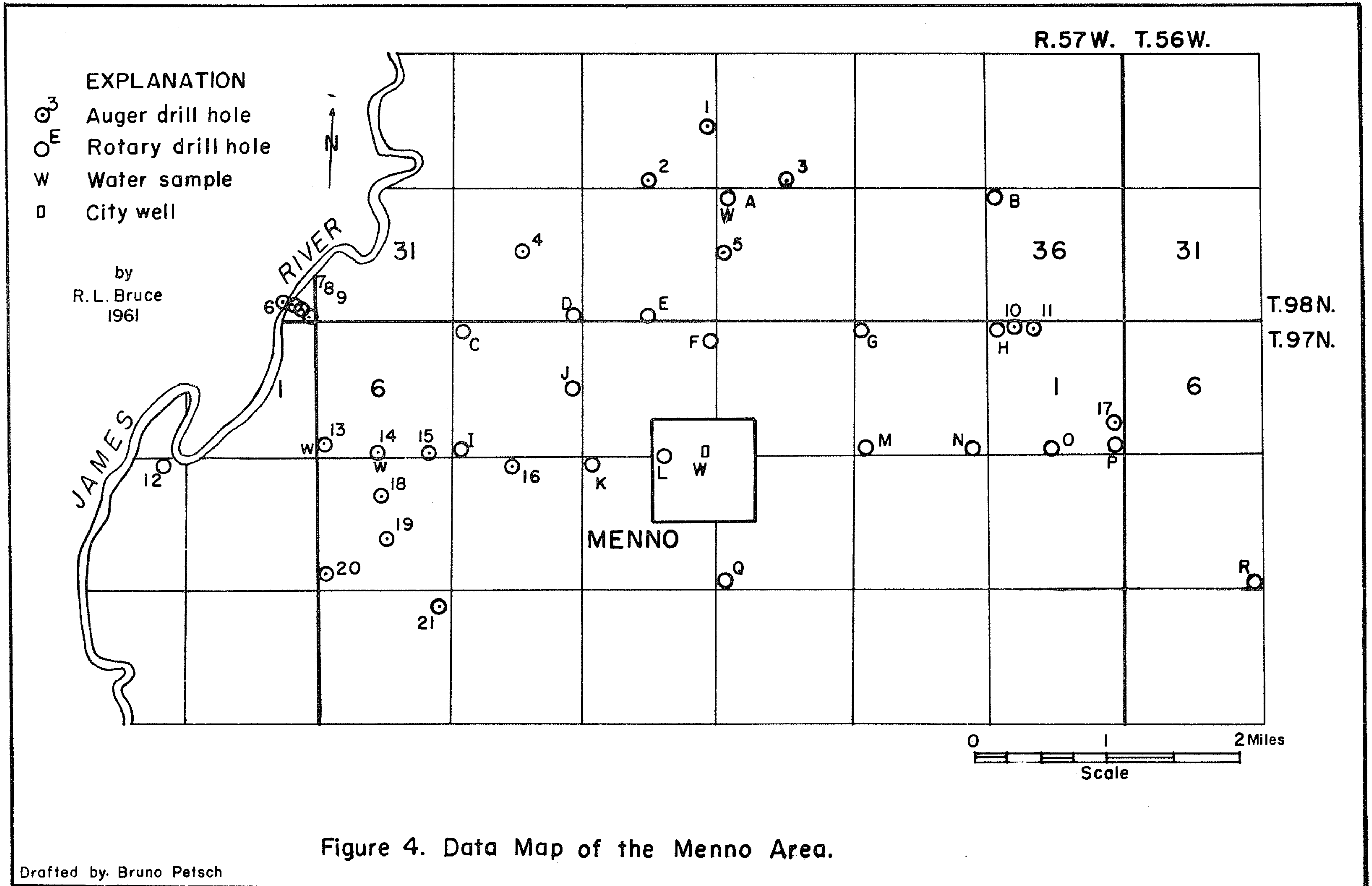

Figure 4. Data Map of the Menno Area.

The Dakota Group is found in approximately the southern one-fourth of the mapped area, and consists chiefly of fine to coarse light-colored sandstones interbedded with gray shales.

The Cretaceous sediments are underlain by the Sioux Quartzite of Precambrian age. This is a very hard gray-pink orthoquartzite. The rock is generally dense but sometimes exhibits permeability and is fractured in the Menno area to some degree. The formation is present a little more than 350 feet below the city of Menno, but its surface falls off rapidly to the south. The surface of this formation is covered, in some areas, by a "wash" which is a weathered part of the formation.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Ground water may be defined as water contained in the voids or openings of rock or sediments below the water table. Therefore, the water table marks the upper surface of the saturated zone of the water-bearing formation. The common belief that water occurs in "veins" which criss-cross the area in a disconnected maze is not true, as water occurs nearly everywhere below the surface. The existence of a water supply is controlled by the water table; this is not a static level, but fluctuates, and in a general way reflects the surface topography. The water table ranges from a few feet to many tens of feet below the surface; in the Menno area it is 5-30 feet below the surface.

The amount of water that is contained in the reservoir rock or aquifer is controlled by the porosity and permeability of the rock. Porosity is a measure of the number of voids in a rock and is expressed in the ratio of pore space to the total volume of rock.

Porosity is dependent on (1) the shape and arrangement of individual particles, (2) the degree of sorting of the particles, (3) the degree of cementation and compaction of the particles, and (4) the amount of material that has been removed by percolating ground water. Sands and gravels usually have porosities that range from 20 to 40 percent depending on the above conditions, whereas sandstones have porosities of 15-25 percent. Sandstones have lower porosities owing to their higher degree of compaction and cementation.

Permeability is a measure of the rate at which a fluid will pass through a material. A material that has a high percentage of interconnected pores likewise has a high permeability, whereas a material that is high in porosity but in which the pores are not connected will have low permeability. Therefore, it can be seen that porosity and permeability are not synonymous but are nevertheless related.

Nearly 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. In general, ground water moves laterally down the hydraulic gradient, and is said to be in transient storage.

Recharge is the addition of water to an aquifer, and is accomplished in three ways: (1) by downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, and (3) by lateral underflow of water in transient storage.

Discharge, or the removal of ground water from an aquifer, is accomplished in four main ways: (1) by evaporation and transpiration by plants, (2) by seepage upward or laterally into surface bodies of water as by springs, (3) by lateral underflow of water in transient storage, and (4) by pumping of wells.

Ground Water in Glacial Deposits

Till does not yield water readily because of its highly unsorted nature and low porosity and permeability; on the other hand outwash is usually a favorable source for ground water. No surface outwash deposits of any extent occur in the Menno area.

The logs of the test holes (Appendix B) show that many shallow sand and gravel layers occur in the glacial drift in the Menno area. A geologic cross-section (fig. 5) shows that these layers are not continuous but appear to interfinger or to be isolated outwash pockets. Owing to their discontinuous nature and to their highly variable thickness these lenses probably would not produce enough water for a city supply. However, some of the larger lenses produce enough water for most farm needs.

One buried outwash deposit appears to be continuous and thick enough to be considered for future exploration as a city water supply. Geological Survey rotary Test Holes C, D, E, I, J, K, L, and M (Appendix B) penetrated a coarse sand and fine gravel deposit, which has an average thickness of 34 feet where tested.

Figure 5 shows an east-west cross-section extending approximately two miles west and three miles east of Menno. This figure shows the buried Niobrara ridge east of town. The buried outwash probably thickens toward the west but this is not certain as Drill Holes C and J failed to penetrate the total thickness of the outwash. This buried outwash pinches out to the east between Test Holes M and O.

The buried outwash is overlain by as much as 200 feet of glacial drift west of Menno. East of Menno, where it laps against the Niobrara ridge, it is overlain by about 150 feet of drift. This buried outwash is generally present at greater depth, and increases in thickness toward the northwest. The buried outwash is underlain by the Niobrara Formation east of Menno and by glacial till west of Menno (fig. 5).

The exact extent of this buried outwash is not known; however, the area where it was penetrated in drill holes is shown on the geologic map (fig. 2). The limits shown are undoubtedly smaller than the actual extent of the buried outwash.

Ground Water in Alluvium

The alluvium below the water table in the James River and its tributaries holds a large quantity of water but yields this water slowly because of its low permeability. Geological Survey Test Holes 6, 7, 8, and 9 (Appendix A) show that the alluvium is composed of clays and fine silts. This deposit is unsuitable for a water supply except for small domestic needs.

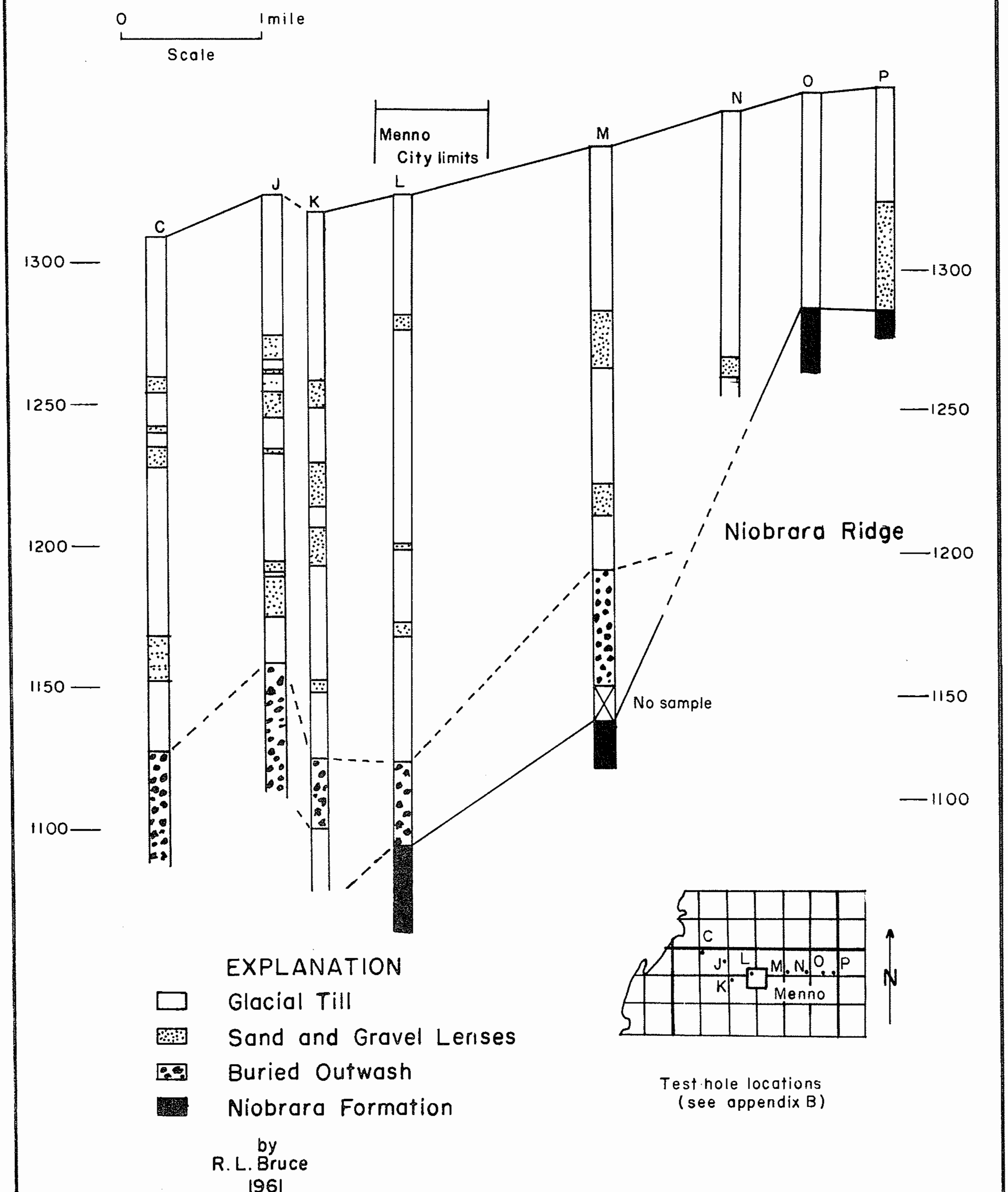

Figure 5. Geologic Cross-Section, Menno Area.

Drafted by Bruno Petsch

Ground Water in Bedrock

The Niobrara Formation is a known water-producer in some areas of the State. In the Menno area it supplies farm needs in the area of the bedrock high shown in Figure 3. These wells in the "chalk rock" range in depth from 59 to 190 feet below the surface.

This water is contained in joints and solution cavities along bedding planes in the formation. It has been reported that wells producing from the "chalk rock" in this area are under artesian pressure and that some of the wells flow.

The Niobrara Formation will continue to supply water to domestic wells in the area described. It is doubtful, however, that this formation could supply enough water for the city of Menno.

Sandstones in the Dakota Group constitute a potential aquifer in the area a few miles south of Menno, where it rests on top of the quartzite. This aquifer contains poor-quality water under artesian pressure. The Dakota is not a potential source of water for the city because of this poor quality and because it does not occur near the city.

The city is now supplied by two wells bottomed in the Sioux Quartzite. One well produces from the "wash" on top of the formation and the other produces from fractures in the quartzite. The water from these wells is of poor quality.

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, the more minerals a water contains, the poorer its quality.

Table 1 shows the chemical properties of various waters in the Menno area, as compared with the present city water and with the standards for drinking water established by the U. S. Department of Public Health. The two producing city wells (Samples C and D) are of very poor quality. They tested very high in magnesium, sulfate, iron, fluoride, hardness, and total solids. In addition, Sample C tested high in manganese. The very high iron and manganese content results in the formation of undesirable deposits in the pipes and pumps of the city water system. A small amount of fluoride in water is desirable (table 1); however, an over abundance as is found in the present city supply may result in mottling of teeth. Total solids is a measure of the total amount of minerals dissolved in the water.

The shallowest city well (Sample B, table 1), which is probably producing from the buried outwash, has water which is high in sulfate, iron, manganese, and total solids.

Water Samples E, F, G, and I (table 1) are from farm wells that are also believed to be pumping from the buried outwash aquifer. Sample E is of very good quality while F, G, and I are of fair quality. If further testing corroborates the high content of manganese found in Sample F it should be removed by treatment before use.

Water Sample H is from the Niobrara Chalk, and it tested high in sulfate and total solids.

Table 1.--Chemical Analysis of Water Samples
from the Menno Area

(for locations see fig. 4)

Sample	Parts Per Million											
	Calcium	Sodium	Mag-nesium	Chloride	Sulfate	Iron	Man-ganese	Nitrate	Fluoride	pH	Hard-ness $CaCO_3$	Total Solids
A	--	--	50	250	500*	0.3	0.05	10*	0.9-1.7**	--	--	1000*
B	163		44	43	911	1.9	1.4	1.5	0.9	7.3	593	1614
C	410		88	126	1319	1.8	0.5	0.5	2.8	7.2	1387	2443
D	395	133	82	127	1230	8.2	0.0	0.6	2.8	7.3	1337	2411
E	282			8	170	0.2					300	664
F	193	69	28	8	583	0.2	3.1	0.2	0.2		596	1246
G	253			20	875	0.2					880	1765
H	241	176	1	22	861	0.5	none	0.7	0.4		606	1826
I	282			46	826	0.2					650	1655

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

** Optimum

A. U. S. Dept. of Public Health Drinking Water Standards (1961)
B. Menno City Well, 210 foot depth
C. Menno City Well, 357 foot depth
D. Menno City Well, 530 foot depth
E. Giddeon Bender farm, NE$\frac{1}{4}$ sec. 7, T. 97 N., R. 57 W.
F. Orin Bender farm, N$\frac{1}{2}$ sec. 7, T. 97 N., R. 57 W.
G. Ross Howen farm, NE$\frac{1}{4}$ sec. 13, T. 97 N., R. 57 W.
H. William Korn farm, NE$\frac{1}{4}$ sec. 34, T. 98 N., R. 57 W.
I. Laverne Mensch farm, NE$\frac{1}{4}$ sec. 10, T. 97 N., R. 57 W.

Samples B, C, D analyzed by the S. Dak. Dept. of Public Health, Pierre
Samples F, H analyzed by the State Chemical Laboratory, Vermillion
Samples E, G, I analyzed by the field kit

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the city of Menno test for future water supplies in the buried outwash deposit (fig. 2). Test holes drilled by the State Geological Survey in this area show more than 40 feet of water-saturated sand and gravel. Farm wells producing from this aquifer show qualities significantly better than the quality of the present city supply.

It is recommended that the city drill several test holes in the western half of Sec. 4, T. 97 N., R. 57 W., and in Sec. 5, T. 97 N., R. 57 W., to determine the extent and thickness of the aquifer. On the basis of these test holes a location may be picked and a test well put in and test-pumped. This test-pumping should be conducted by licensed engineers for a minimum of 72 hours. These tests are extremely important to determine if the aquifer is continuous, and also to determine what capacity and type of permanent well should be constructed.

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

REFERENCES CITED

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

APPENDIX A

Logs of State Geological Survey Auger Test Holes in the Menno Area

(for locations, see figure 4)

Test Hole No. 1
Surface Elevation: 1344 feet
Depth to Water: not measured

0- 9	till, brown, sandy
9-49	till, blue, dense, little sand
	very hard drilling at 49 feet

* * * * * *

Test Hole No. 2
Surface Elevation: 1335 feet
Depth to Water: not measured

0- 2	till, light brown, dry
2-27	till, dark brown, dry
27-45	till, blue, dry
	very hard drilling at 45 feet

* * * * * *

Test Hole No. 3
Surface Elevation: 1351 feet
Depth to Water: not measured

0-19	till, dark brown, some sand, little water
19-34	till, blue, dense
34-61	till, blue, some fine silt

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Test Hole No. 4
Surface Elevation: 1270 feet
Depth to Water: not measured

0- 2	topsoil, black
2-14	till, brown, silty, dry
14-20	till, brown, silty, wet
20-41	till, blue, silty

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Test Hole No. 5
Surface Elevation: 1346 feet
Depth to Water: not measured

0-14	till, brown, silty, little water
14-59	till, blue, gravelly, some sand

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Test Hole No. 6
Surface Elevation: 1190 feet
Depth to Water: 13 feet

0- 4	topsoil, black
4-14	clay, brown, trace of sand, dry
14-24	clay as above, saturated
24-59	clay, blue, 10 percent sand, water, sticky

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Test Hole No. 7
Surface Elevation: 1190 feet
Depth to Water: 6 feet

0- 9	clay, brown, silty, dry
9-29	clay, brown, sandy, wet
29-78	clay, blue, sandy, silty

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Test Hole No. 8
Surface Elevation: 1190 feet
Depth to Water: $5\frac{1}{2}$ feet

0-39	clay, brown, sandy, wet
39-74	clay, blue, sandy

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Test Hole No. 9
Surface Elevation: 1190 feet
Depth to Water: not measured

0- 4	clay, brown, silty, dry
4-39	clay, brown, silty, wet
39-69	clay, blue

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Test Hole No. 10
Surface Elevation: 1365 feet
Depth to Water: not measured

0-33	till, brown, some sand
	hit possible coal boulder at 33 feet; moved 100 yards east to Test Hole No. 11

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Test Hole No. 11
Surface Elevation: 1365 feet
Depth to Water: not measured

0-19	till, brown, damp
19-29	till, gray, silty
29-34	till, olive green
34-69	till, blue, very hard drilling

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Test Hole No. 12
Surface Elevation: 1190 feet
Depth to Water: not measured

0-44	clay, black, silty
44-49	clay, blue

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Test Hole No. 13
Surface Elevation: 1302 feet
Depth to Water: not measured

0-21	till, brown
21-36	gravel and sand
36-49	no cuttings, very hard drilling

* * * * * *

Test Hole No. 14
Surface Elevation: 1304 feet
Depth to Water: $6\frac{1}{2}$ feet

0-19	till, brown, sandy
19-64	till, blue

* * * * * *

Test Hole No. 15
Surface Elevation: 1314 feet
Depth to Water: none

0-3	?
	Made three attempts to drill holes. Could not get below three feet.

* * * * * *

Test Hole No. 16
Surface Elevation: 1320 feet
Depth to Water: not measured

0-24	till, brown
24-30	till, olive green

* * * * * *

Test Hole No. 17
Surface Elevation: 1371 feet
Depth to Water: 15½ feet

0-24	till, brown, sandy
24-34	till, olive green
34-74	till, blue
74-75	till, yellow-green, very dense, no sand or silt

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Test Hole No. 18
Surface Elevation: 1300 feet
Depth to Water: not measured

0-19	till, brown, sand

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Test Hole No. 19
Surface Elevation: 1300 feet
Depth to Water: 25½ feet

0-19	till, brown
19-34	till, blue

* * * * * *

Test Hole No. 20
Surface Elevation: 1290 feet
Depth to Water: not measured

0-12	till, brown, gravelly
12-28	till, blue

* * * * * *

Test Hole No. 21
Surface Elevation: 1311 feet
Depth to Water: not measured

0-22	till, brown, dry
22-60	till, brown, wet

* * * * * *

APPENDIX B

Logs of State Geological Survey Rotary Test Holes in the Menno Area

(for locations, see Figure 4)

Test Hole A
Surface Elevation: 1342 feet

0-34	till, sandy, silty
34-58	sand and gravel
58-60	till ?
	Bit plugged at 60 feet, hole abandoned

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Test Hole B
Surface Elevation: 1365 feet

0-43	till, sandy
43-54	sand, coarse, pea gravel
54-60	till
60-70	sand, coarse
70-114	sand and gravel
114-120	Niobrara Formation

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Test Hole C
Surface Elevation: 1310 feet

0- 48	till, sandy
48- 54	sand, coarse
54- 65	till, sandy, gravelly
65- 67	gravel, pea-size
67- 73	till, very sandy
73- 80	gravel, pea-size
80-137	till, sandy
137-155	gravel with interbedded clay
155-179	till, sandy
179-220	sand, medium to coarse

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Test Hole D
Surface Elevation: 1327 feet

0- 30	till, sandy
30- 33	gravel, pea-size, dry
33- 53	till, sandy

(continued on next page)

Test Hole D--continued

53- 56	gravel, pea- to nut-size
56- 61	till, sandy
61- 65	gravel, pea-size
65- 75	till, sandy
75- 77	gravel, pea-size
77- 83	till, sandy
83- 90	sand, boulder at 90 feet
90-103	gravel, nut-size
103-107	till, sandy
107-111	gravel, nut-size
111-113	till, sandy
113-140	sand, coarse, some gravel
140-160	no sample

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Test Hole E
Surface Elevation: 1335 feet

0- 38	till, sandy
38- 40	sand, medium to coarse
40- 60	till, sandy
60- 68	sand and fine gravel
68-120	till, gravel stringers, boulders
120-126	gravel, pea- to nut-size
126-140	till
140-148	gravel with clay stringers
148-165	till, sandy
165-185	sand, coarse, well sorted
185-197	Niobrara Formation

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Test Hole F
Surface Elevation: 1341 feet

0- 52	till, sandy, silty
52- 54	sand, coarse
54- 56	till, sandy
56- 58	sand, coarse
58- 64	till, sandy
64- 74	gravel, interbedded clay
74-150	till, sand stringers
150-160	sand
160-170	till, gravelly
170-180	sand, fine to medium
180-184	till, sandy, boulders

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Test Hole G
Surface Elevation: 1348 feet

0- 50	till, sandy
50- 65	sand and fine gravel with interbedded clay
65-120	Niobrara Formation

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Test Hole H
Surface Elevation: 1365 feet

0- 47	till, sandy
47- 52	sand and fine gravel
52- 80	Niobrara Formation

* * * * * *

Test Hole I
Surface Elevation: 1315 feet

0- 48	till, sandy
48- 53	sand, very fine
53- 66	till, sandy
66- 75	sand and coarse gravel
75-102	till, sandy
102-104	gravel
104-192	till, gravel, sandy, boulders
192-210	sand, coarse with interbedded clay
210-220	till, very sandy
220-260	sand, coarse, very clean

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Test Hole J
Surface Elevation: 1326 feet

0- 50	till, sandy
50- 58	sand, coarse, clay
58- 70	till
70- 78	sand and gravel
78- 88	till, sandy
88- 92	sand and gravel
92-128	till, sandy
128-134	sand, coarse
134-148	sand, coarse, with some gravel
148-165	till, sandy
165-182	gravel, coarse, sandy
182-190	sand and gravel with clay stringers
190-210	gravel and sand, coarse

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Test Hole K
Surface Elevation: 1320 feet

0- 60	till, very sandy
60- 68	sand and gravel
68- 88	till, sandy, gravelly
88-105	gravel with interbedded clay
105-112	till, sandy
112-124	gravel, pea-size
124-165	till, gravelly
165-168	gravel, pea-size
168-192	till, sandy
192-217	sand
217-240	till, sandy

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Test Hole L
Surface Elevation: 1325 feet

0- 42	till, sandy
42- 47	sand, medium
47-105	till with thin gravel layers
105-123	till, sandy
123-125	gravel, pea-size
125-150	till, sandy
150-155	sand and pea-size gravel
155-200	till
200-230	sand, fine to medium
230-260	Niobrara Formation

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Test Hole M
Surface Elevation: 1343 feet

0- 58	till, sandy
58- 70	sand, coarse
70- 78	gravel, pea-size
78-119	till
119-131	gravel, pea-size
131-148	till, sandy
148-155	gravel, pea-size
155-192	sand and pea gravel
192-204	no sample
204-220	Niobrara Formation

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Test Hole N
Surface Elevation: 1355 feet

0- 25	till, silty
25- 87	silt, clay, and sand
87- 94	gravel
94-100	till, boulders

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Test Hole O
Surface Elevation: 1362 feet

0- 18	till, sandy
18- 75	till, sandy, silty
75-100	Niobrara Formation

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Test Hole P
Surface Elevation: 1363 feet

0-16	till
16-40	silt
40-67	sand, medium to coarse
67-78	gravel, pea-size
78	Niobrara Formation

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Test Hole Q
Surface Elevation: 1326 feet

0- 53	till, sandy
53- 65	till with interbedded gravel layers
65- 72	gravel, pea-size
72-107	till, sandy
107-112	gravel, pea-size
112-135	till, sandy
135-143	sand, coarse, some gravel
143-157	till, sandy
157-163	gravel, pea-size
163-170	till, sandy
170-173	gravel, pea-size
173-176	till, sandy
176-177	gravel, pea-size
177-178	till, sandy
178-182	gravel, pea-size
182-188	clay and interbedded gravel

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Test Hole R
Surface Elevation: 1375 feet

0-35	till
35-50	Pierre Shale
50-60	Niobrara Formation

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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.

Well Location	Owner or Tenant	Depth of Well Below Land Surface (feet)	Diameter of Well (inches)	Geologic Source	Depth to Water (feet)
SE14-98-57	Leo Mettler	30-40	24	Glacial	12
SE14-98-57	Egor Styrele	40-50		Glacial	5
NW15-98-57	Calven Mettler	50	24	Glacial	20
SW15-98-57	Gerald Mettler	45	18	Glacial	15
SW16-98-57	Herbert Mettler	130	4	Chalk	flows
N20-98-57	A. R. Wellman	50	24	Glacial	30
NE21-98-57	Greg Mettler	120		Chalk	10
SE21-98-57	Leroy Mettler	120	3	Chalk	flows
SE21-98-57	Leroy Mettler	80		Glacial	?
SE21-98-57	Delmer Mettler	30	24	Glacial	0
SW25-98-57	John Mehlhaf	100	3	Glacial?	12
SE26-98-57	Harvey Mettler	98	3	Glacial?	5
NW26-98-57	Gideon C. Mettler	45	24	Glacial	18
NE30-98-57	Milton Handel	276	3	Quartzite ?	flows
SE31-98-57	Leonard Heer	365	3	Quartzite	flows
NE32-98-57	Robert Auch	190	3	Chalk ?	?
NE33-98-57	Wilman Mehlhaf	50		Glacial	?
NW33-98-57	Elmer Neuharth	197	4	Chalk ?	60
NE34-98-57	William Korn	100	$2\frac{1}{2}$	Chalk	90 ?

Well Location	Owner or Tenant	Depth of Well Below Land Surface (feet)	Diameter of Well (inches)	Geologic Source	Depth to Water (feet)
34-98-57	Helmuth Mehlhaf	55	30	Glacial	1
34-98-57	Helmuth Mehlhaf	100	3	Chalk	4
NW35-98-57	Aaron Schnabel	25	24	Glacial	7
SE36-98-57	Glenn Heckenlaible	202	3	Chalk ?	16
NE1-97-58	Lindy Corth	365	2	Quartzite	flows
SW1-97-57	Arnold Goehring	95	3	Chalk	flows
NE1-97-57	Edmond Heckenlaible	59	3	Chalk	flows
SW3-97-57	Gideon Mettler	75	24	Glacial	?
NE3-97-57	Ben and Fred Schoppert	90	24	Chalk	?
NE5-97-57	Richard Auch	60	30	Glacial	30
NW6-97-57	William Rames	367	2	Quartzite	flows
NE7-97-57	Gideon Bender	169 (?)	3	Buried Outwash	?
SW8-97-57	Ed Lehr	154	3	Glacial	142 ?
NE10-97-57	Laverne Mensch	209	3	Buried Outwash	?
SE10-97-57	Jake Bezug	93	24	Glacial	56
SW10-97-57	Eugene Redman	65	24	Glacial	35
11-97-57	Richard Bender	198	3	Glacial	32
SE11-97-57	Henry Heckenlaible	500	3	Quartzite	?
SE11-97-57	Henry Heckenlaible	75	24	Glacial	?
NW12-97-57	Theodore Bender	120	3	Chalk	flows
NE13-97-57	Ross Howen	155	3	Buried Outwash	flows
NE13-97-57	Ross Howen	75		Glacial	0

Well Location	Owner or Tenant	Depth of Well Below Land Surface (feet)	Diameter of Well (inches)	Geologic Source	Depth to Water (feet)
SW13-97-57	Albert Herboldt	65	24	Glacial	10-15
NW13-97-57	Clifford Preszler	508	2	Quartzite	80
SE14-97-57	Frank Quast	90	3	Glacial	30
SE14-97-57	Frank Quast	65	24	Glacial	20
SE15-97-57	Art Lehr	83	24	Glacial	15
NW15-97-57	Oscar Guthmiller	40	24	Glacial	15
SW17-97-57	Theodore Guthmiller	40	24	Glacial	15
NW17-97-57	Arnold Winter	20	8	Glacial	5
SE19-97-57	Fred Woehl	60	24	Glacial	45
NE20-97-57	Harold Zeeb	200 ?	3	Glacial	?
SE21-97-57	Ruben Zeeb	30	24	Glacial	15
NW21-97-57	Art Mettler	610	3	Quartzite	flows
NW22-97-57	Richard Sayler	50	24	Glacial	25
22-97-57	John Sayler	60	2	Glacial	45
SE23-97-57	William Nusz	300	3	Dakota ?	?
SW24-97-57	Alton Nusz	60	24	Glacial	30
NW25-97-57	Jack Mehlhaf	500	3	Quartzite	20
NW27-97-57	Wilmar Zieb	55	16	Glacial	15
NW28-97-57	Bertram Hagge	145	3	Glacial	115
SW5-97-56	Clifford Handel	110	3	Chalk ?	30
NW6-97-56	A. Streyle	93	$2\frac{1}{2}$	Chalk ?	13
SE6-97-56	Aduel Handel	90	3	Chalk ?	?
SE7-97-56	Donald Handel	60	30	Glacial	10
NW7-97-56	Erwin Handel	92	4	Chalk	18