STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

SPECIAL REPORT 15

WATER SUPPLY FOR THE CITY OF LAKE PRESTON, SOUTH DAKOTA

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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota Geological Survey during the summer of 1961, for the city of Lake Preston, Kingsbury County, South Dakota (fig. 1) for the purpose of locating additional water supplies. The city now receives its water from three artesian wells in the Dakota Group. The three wells are 1178, 1157, and 1160 feet deep and collectively can pump about 160 gallons per minute, which is inadequate during the latter part of the summer when water consumption is at a maximum. The water obtained from these wells is high in mineral content. Consequently, the State Geological Survey was asked to help the city locate additional water supplies.

A survey of the ground water possibilities was conducted in and around Lake Preston during parts of June, July and September of 1961. This survey consisted of mapping the areal geology, drilling 34 shallow test holes and 4 deep test holes, running 4 electric logs, making a well inventory, and collecting and analyzing 13 water samples.

The 35 shallow test holes were drilled with the State Geological Survey's jeep-mounted auger drill and the 4 deep test holes were drilled with the Survey's truck-mounted Bucyrus-Erie 10-R rotary drill.

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, and with the assistance of Mike Clancy and Steve Pottratz. Robert Schoon, staff driller and geologist, was in charge of the rotary drilling operations. Thanks are due to the residents of Lake Preston and the surrounding area for their cooperation while conducting the survey. Special acknowledgement is made to Mayor Gordon Maxam and City Engineer E. L. Shanks for their cooperation. Ervin Johnson, a private well contractor, provided invaluable assistance by making his records available to the Survey. Stanley Rausch was supplied by the city to assist in running elevations.

The writer also wishes to thank the State Chemical Laboratory in Vermillion for reconditioning the water analysis equipment used in this survey and for furnishing a portable pH meter, and the U. S. Geological Survey for furnishing a specific conductance meter.

Location and Extent of Area

The city of Lake Preston is located in east-central South Dakota in Kingsbury County, on the west flank of the Coteau des Prairies section of the Central Lowland physiographic province (fig. 1).

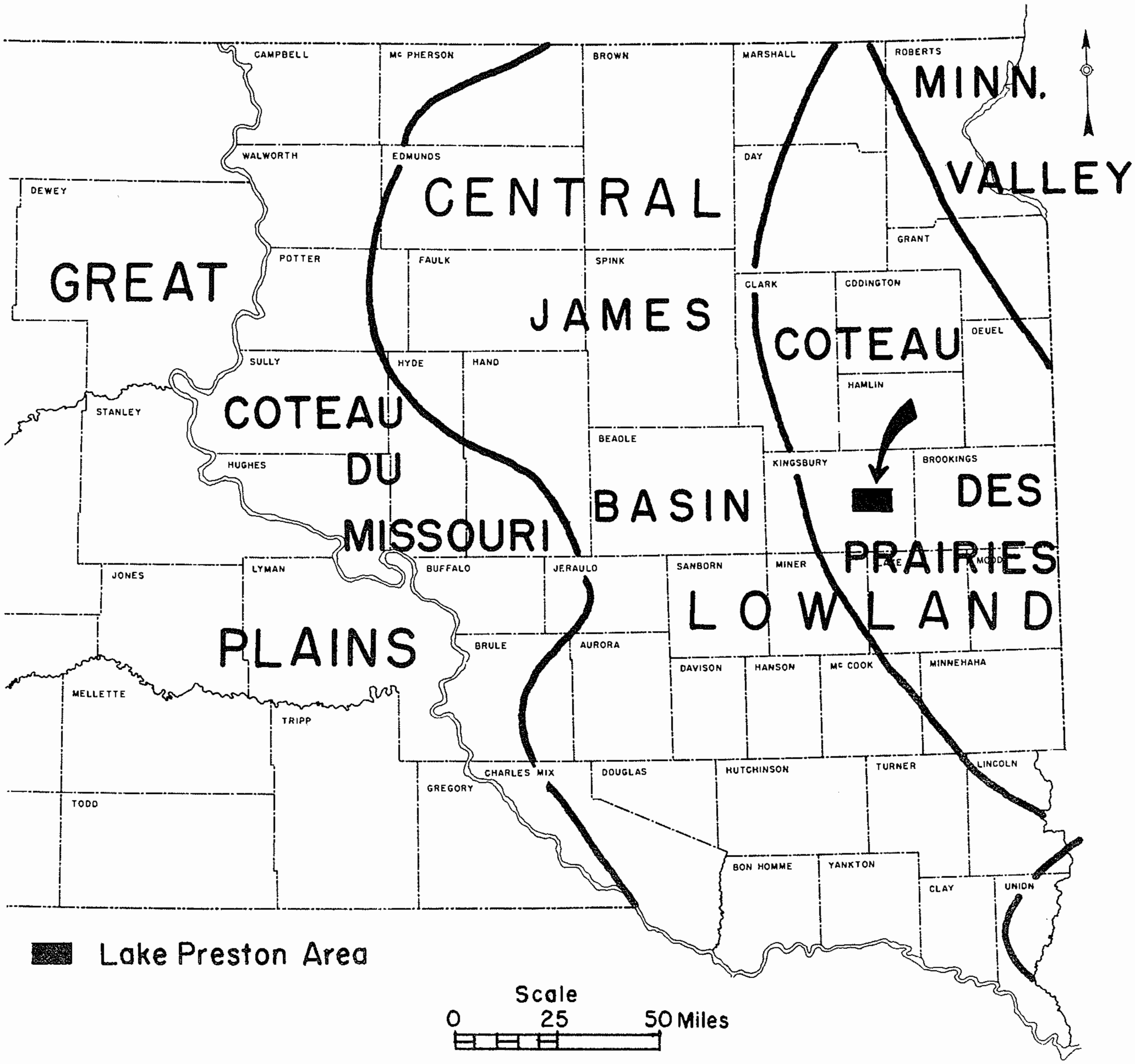


Figure I. Major Physiographic Divisions in Eastern South Dakota.

Climate

The climate is continental temperate, with large daily fluctuations in temperature. The average yearly temperature is 45°F., and the average annual precipitation is 18.49 inches, at the U. S. Weather Bureau Station in Brookings, 40 miles to the east.

Topography and Drainage

The topography of the area is youthful glacial moraine--gently undulating, poorly drained, and containing numerous knobs and kettles. The kettles (depressions) generally contain ponds or marshes during wet periods. Conspicuous in the area are elongate depressions as much as seven miles long which now contain lakes (Lake Preston and Lake Whitewood, fig. 2). Similar chain-like depressions on the Coteau des Prairies are presumed to be related to pre-glacial drainage channels (Flint, 1955, p. 67).

Total relief in the area is about 140 feet, ranging from 1640 feet in the bed of Lake Henry to about 1781 feet three miles northwest of Lake Preston.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits consist chiefly of Wisconsin glacial drift of Pleistocene age. The drift in this area can be subdivided into till, outwash, and ice-contact stratified deposits. Of these, till is by far the most abundant (fig. 2).

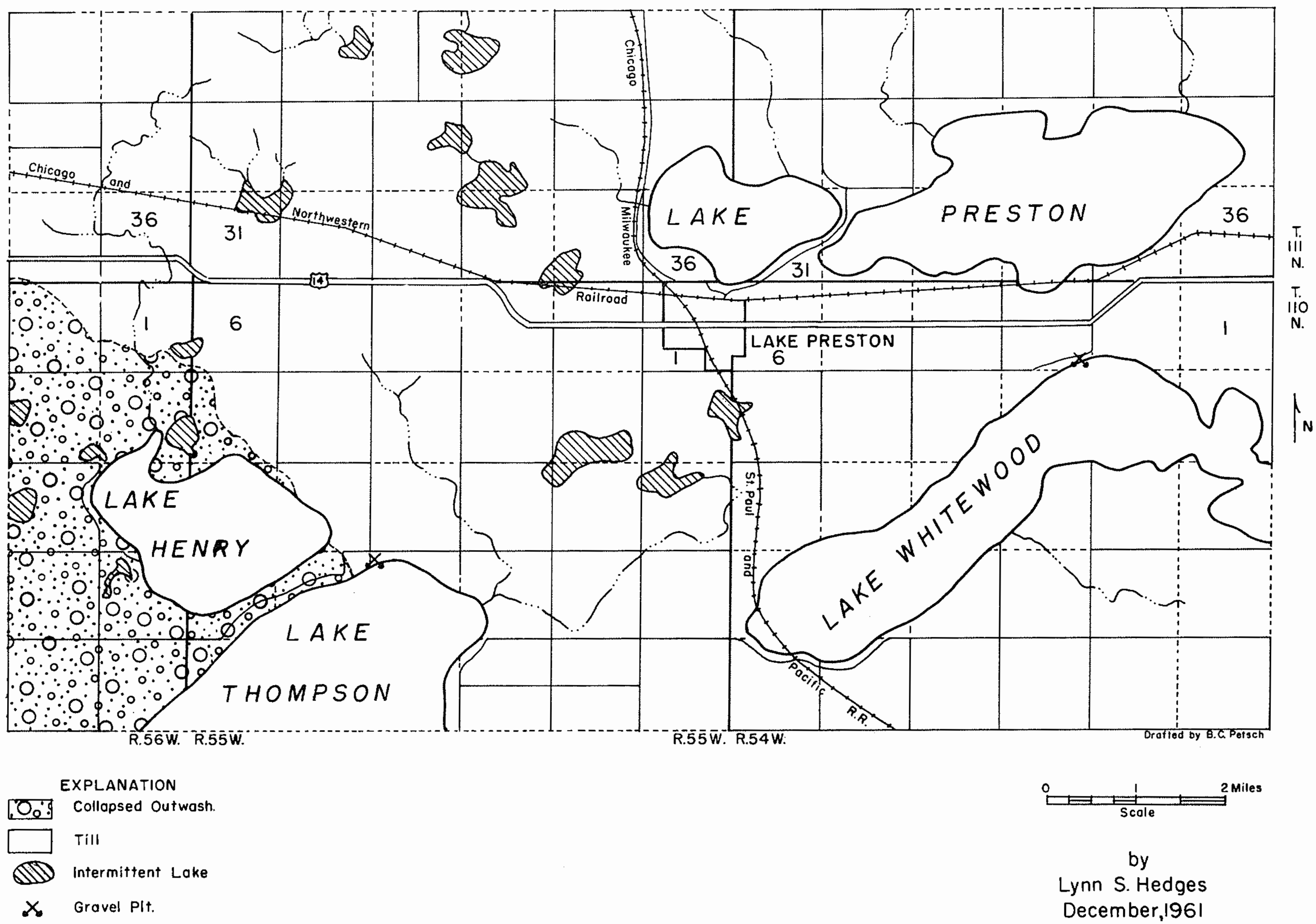
Till consists of clay and silt randomly mixed with boulders, pebbles, and sand, which were carried and deposited by the ice itself. Because of its unsorted nature, till does not readily yield water.

Outwash consists of gravel, sand, and silt deposited by meltwater flowing away from the ice. Outwash yields water more readily than till because it is better sorted.

Ice-contact stratified drift accumulated upon or against melting ice. As the ice melted, the sediments "collapsed" leaving knolls and closed depressions. In this area the ice-contact deposits consist mostly of gravel and sand that is called "collapsed outwash". In Figure 2 all surface gravel and sand is mapped as collapsed outwash; this probably includes some that is not collapsed.

Underlying the collapsed outwash in the Lake Henry area is a homogeneous deposit of fine sand. At the present time not enough information is available to determine the exact origin and extent of this deposit.

Figure 2. Generalized Geologic Map of Lake Preston Area.



Incorporated with and directly underlying the till in this area are deposits of gravel and sand of glacial origin, which vary from thin "lenses" of small areal extent to deposits that apparently extend throughout the area mapped. One of these buried sand and gravel deposits, which is as much as 15 feet thick and occurs at a depth of 160 to 180 feet, if present to the north, east, and southwest of Lake Preston, but it probably thins or pinches out laterally. A second deposit of buried sand and gravel is as much as 37 feet thick and occurs at a depth of about 300 feet. This deposit lies on the eroded surface of the bedrock throughout most of the area studied and is herein termed the basal gravel and sand.

Other surficial deposits in the area include swamp muck, reworked till, and lake deposits. Swamp muck and reworked till are present in the undrained or partially drained depressions, and consist mostly of silt and clay. Lake deposits are more diverse consisting of gravel, sand, silt, and clay derived mainly from reworked till and possibly also from outwash.

Subsurface Bedrock

Stratified sedimentary rocks of Cretaceous age are present beneath the unconsolidated glacial deposits in the Lake Preston area. These deposits in descending order are the Pierre, Niobrara, Carlile, Greenhorn, and Graneros Formations, and the Dakota Group.

The Pierre Formation consists of light- to dark-gray clayey bentonitic shale and sandy shale with ironstone concretions, and is approximately 150 feet thick.

The Niobrara Formation consists of a light- to medium-gray shale or marl, which contains numerous microscopic white calcareous specks and is approximately 180 feet thick.

The Carlile Formation consists of gray to dark-gray bentonitic shale with pyrite concretions, and thin sandstone layers; it is approximately 190 feet thick.

The Greenhorn Formation consists of a layer of hard cream to white limestone containing numerous fossil fragments. This limestone layer is overlain (and possibly underlain) by a layer of dark-gray shale containing numerous small white calcareous specks. The thickness of the limestone portion of this formation is approximately 50 feet.

The Graneros Formation is gray to dark-gray clayey bentonitic shale, with some thin beds of sandstone. The thickness of this formation is approximately 170 feet.

With the possible exception of the thin sandstone layers in the Carlile Formation, none of the above formations will yield water readily in this area.

The Dakota Group consists of a series of alternating sandstones and shales from which the three present city wells obtain their water. The water is under artesian pressure, but does not flow in this area.

The sediments of the Dakota Group are underlain by older sedimentary and Precambrian rocks.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Despite the common belief that ground water occurs in "veins" which criss-cross the country in a disconnected maze, it can be shown that water occurs almost everywhere in the ground, at depths below the surface which vary from a few feet to several tens of feet. The top of this zone of water saturation is known as the water table, and in the Lake Preston area it ranges from 3 to 60 feet below the surface.

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 (water-bearing material), 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.

The volume of water capable of being stored in a saturated material is equal to the volume of voids or pore space in the material. A measurement of the capability of a material to store water is called porosity. Therefore porosity is the ratio of the volume of voids in the material 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 no effect. Therefore a container filled with sand and a similar one filled with gravel, if they have the same shape and packing, could hold the same quantity of water. Sands and gravels usually have porosities that range from 20 to 40 percent. Sandstones normally have porosities of 15-25 percent; the lower porosity is due to closer packing and the degree of cementation.

The rate at which water will drain or pass through a material is a function of its permeability. Water will pass through a material with interconnected pores, but will not pass through a 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 little 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.

Thus the type of deposit that contains the water governs the amount which can be withdrawn and, in part, how rapidly it can be recharged. For this reason, the object in trying to locate a good water supply is not to find a "vein" but rather, because water occurs almost everywhere, to find a sand or gravel deposit beneath the water table.

Ground Water in Glacial Deposits

It was stated earlier that glacial deposits are divided into till, outwash, and ice-contact stratified deposits, and that outwash and ice-contact stratified deposits yield water more readily than till because of their better sorted nature. In the vicinity of Lake Preston there are four glacial deposits capable of high water yields: (1) the basal sand and gravel which rests on the bedrock and underlies the entire mapped area; (2) the buried gravel and sand at a depth of 160-180 feet; (3) the collapsed outwash at the surface in the Lake Henry area; and (4) a sand deposit in the Lake Henry area immediately below the collapsed outwash.

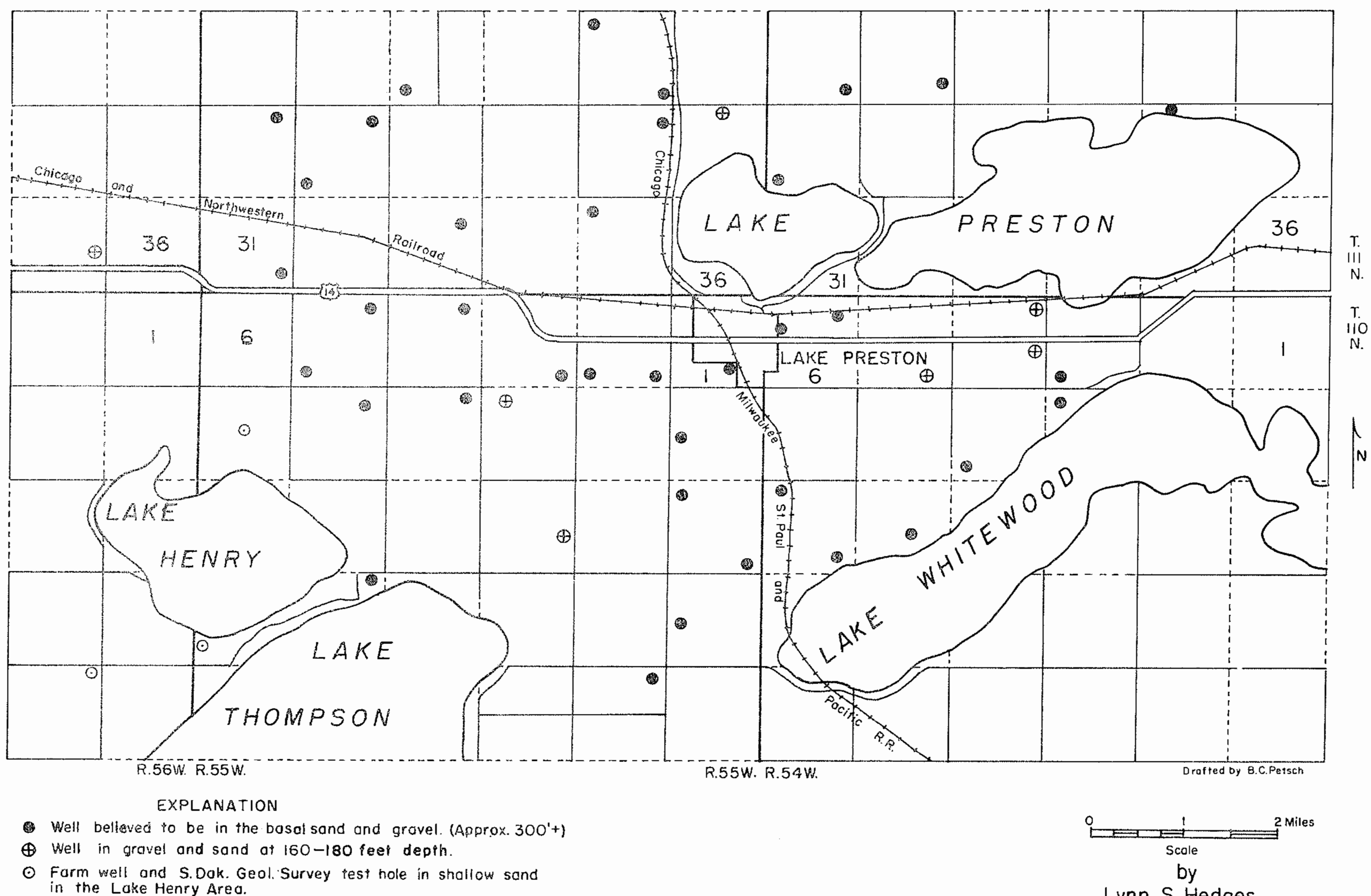
1. The basal gravel and sand covers an extensive area (fig. 3) and is at least 37 feet thick (Drill Hole B, Appendix B) and the entire thickness of this deposit is water-saturated. The water is under artesian pressure, with the impervious till above acting as the confining stratum. This basal gravel and sand could probably supply enough water for a municipal well but this should be confirmed by further test-drilling and pump-tests.

2. The gravel and sand at 160-180 feet (fig. 3) is as much as 15 feet thick, but probably thins or pinches out laterally. This deposit furnishes an adequate supply for farm wells but could probably not supply the quantity of water required for a municipal supply.

3. The collapsed outwash in the Lake Henry area is a silty sandy gravel covering approximately nine square miles as far as it was mapped. In most places it is thin, not exceeding nine feet (Test Holes 21 and 25, Appendix A), and contains no water. About four miles north of this area, around De Smet, the outwash thickens to as much as 42 feet and yields an adequate supply of water for the city of De Smet.

4. The sand deposit in the Lake Henry area is as much as 35 feet thick and is almost completely water-saturated (Test Holes 25 and 26, Appendix A). This sand lies directly beneath a thin layer of collapsed outwash. On the north side of Lake Henry a similar deposit could be a continuation of this same sand as shown by the Aughenbaugh farm well (Appendix C), in the middle of Sec. 7, T. 110 N., R. 55 W. where the sand is at least 15 feet thick. The areal extent of the sand is not known, because it at least partly underlies the collapsed outwash and may be partly covered by the waters of Lake Henry. If further test drilling shows that its areal extent is adequate, this aquifer could probably provide a municipal water supply.

Figure 3. Map Showing Locations of Wells and Test Holes Believed to be in Extensive Sand and Gravel Aquifers in the Lake Preston Area.



by
Lynn S. Hedges
December, 1961

Ground Water in Bedrock

The extensive sandstones of the Dakota Group and the thin sandstone layers in the Carlile Formation are the only known bedrock aquifers in the Lake Preston area from which water is produced at present. The thin sandstones of the Carlile Formation occur at a depth of approximately 700 feet, and the water is under artesian pressure but is not known to flow. There are several farm wells in this aquifer but it is doubtful if it could produce enough water to supply a city.

The Dakota Group from which the present city wells obtain their water consists predominantly of quartz sand with moderate permeability and porosity. No wells in the area producing from the Dakota are known to flow. In fact, the pumping level for the Lake Preston City Wells is presently at about 360 feet below the surface and is slowly dropping, according to City Engineer E. L. Shanks.

The main source of recharge for these Dakota Sandstones in South Dakota is thought to be in the Black Hills region where they are exposed at a much higher elevation than in the Lake Preston area; this higher elevation is thought to be the source of the pressure head that forces the water toward the surface in a well.

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 as the water vapor condenses and falls, (2) from soil and underlying deposits as the water percolates downward to the water table, and (3) from sediments below the water table, in which the water is circulating.

In general, the more minerals a water contains, the poorer its quality. The water in the Dakota Sandstones is poorer in quality than the water in the surficial glacial deposits.

In Table 1 Sample O (City Well S-2) shows that the water from the Dakota Group exceeds the Public Health Drinking Water Standards in sulfate, fluoride, and total solids.

Samples G and H from the Larsen and Able wells are characteristic of the water in the basal gravel and sand at about 300-350 feet depth, and exceeds the Public Health Drinking Water Standards in sulfate, iron, manganese, and total solids. It should be noted that the total solids and the sulfate content are approximately one-half that of water from the Dakota Group. It should also be noted that Samples G and H contain very little sodium, chloride, and fluoride in comparison with the Dakota water. However, particular attention should be called to the high iron and manganese content of Samples G and H. Excessive amounts of these minerals can be detrimental to plumbing and fixtures.

Table 1 shows that Samples G and H are very hard waters (500-700 ppm) when compared to the Dakota waters (38 ppm). However, hardness

Table I.--Chemical Analyses of Water Samples from the Lake Preston Area (for locations see Fig. 4)

Sample	Source	Parts Per Million (ppm)										Hardness	Total Solids
		Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate	Fluoride	pH		
A		--	--	--	250	500*	0.3	0.05	10	0.9-1.7**	--	--	1000*
B	UPPER SAND	67		28	6	78	0.2				7.7	280	477
C	UPPER SAND	58		39	10	49	0.0				7.8	300	462
D	BURIED OUTWASH	365		106	16	1264	0.2					1340	
D1	BURIED OUTWASH	390	182	85	14	1600	5.6	1.9	1.0	0.4		1324	2706
E	BURIED OUTWASH	330		99	20	1069	0.1				7.5	1220	1942
F	BURIED OUTWASH	330		151	20	1069	0.6				7.5	1430	2070
G	BASAL SAND AND GRAVEL	197		8	36	583	0.3					525	
G1	BASAL SAND AND GRAVEL	223	108	36	38	700	2.0	2.7	0.3	0.4		703	1430
H	BASAL SAND AND GRAVEL	352			28	573	0.2					550	
H1	BASAL SAND AND GRAVEL	156	100	45	23	483	0.4	1.9	Trace	0.4		576	1094
I	BASAL SAND AND GRAVEL	282		44	36	583	2.0				7.6	880	1349
J	BASAL SAND AND GRAVEL	150		51	68	486	0.0				7.8	580	1192
K	BASAL SAND AND GRAVEL	169		39	32	437	0.2					580	
L	BASAL SAND AND GRAVEL	240		250	36	1166	0.5					1600	
M	BASAL SAND AND GRAVEL	275		263	48	1312	0.7					1740	
N	BASAL SAND AND GRAVEL	150		61	48	297	0.0				7.8	620	1042
O	DAKOTA	11	796	2	180	1124	0.1	0.0	2.5	6.8	7.8	38	2321

A. U. S. Dept. of Public Health Drinking Water Standards (1961)
B. Pollock, NE¼NE¼ sec. 26, T. 110 N., R. 56 W.
C. Pollock, SW¼SE¼ sec. 19, T. 110 N., R. 55 W.
D. Odden, NE¼SE¼ sec. 15, T. 110 N., R. 55 W.
E. Tolzin, SE¼ sec. 4, T. 110 N., R. 54 W.
F. SW¼ sec. 5, T. 110 N., R. 54 W.
G. Larsen, SW¼NW¼ sec. 6, T. 110 N., R. 54 W.
H. Able, NW¼ sec. 18, T. 110 N., R. 54 W.
I. Brekke, SE¼ sec. 18, T. 110 N., R. 54 W.
J. Casper, SW¼ sec. 12, T. 110 N., R. 55 W.
K. Neilson, SW¼ sec. 14, T. 111 N., R. 54 W. (not on data map)
L. NE¼ sec. 23, T. 111 N., R. 55 W.
M. SE¼ sec. 23, T. 111 N., R 55 W.
N. SE¼ sec. 13, T. 110 N., R. 55 W.
O. City Well No. S-2

Samples D_1, G_1, and H_1 analyzed by State Chemical Laboratory in Vermillion; sample O analyzed by State Department of Health in Pierre; other samples analyzed by State Geological Survey field testing kit.

* modified for South Dakota by the State Dept. of Health (written communication, Feb. 5, 1962)

** optimum

is not as important an element of water as the other minerals mentioned above, as can be seen by the fact that the U. S. Public Health Service sets no limits on hardness. Also, with modern-day detergents and softening processes, hardness has become less of a problem than in the past.

Samples B and C from the Pollock farm (table 1) are characteristic of the water from the sand deposit beneath the collapsed outwash in the Lake Henry area. Neither sample exceeds the Public Health Drinking Water Standards (by field kit analyses).

Samples D, E, and F are characteristic of water from thin lenses of gravel or sand at the 160-180 foot level. These samples exceed the Public Health Drinking Water Standards in sulfate, iron (except E), and manganese, and contain almost as many total solids as water from the Dakota Group.

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the city of Lake Preston make tests for additional water supplies in the basal gravel and sand just north of town, in the southern half of Sec. 36, T. 111 N., R. 55 W. A Geological Survey test hole in this area shows as much as 37 feet of sand and gravel (Test Hole B, Appendix B). The entire thickness of the gravel and sand was not penetrated because of binding of the drill. The areal extent of this aquifer is widespread, as seen by the four Geological Survey Test Holes (Appendix B) and by farm wells (fig. 3). The quality of water in this aquifer is shown by Samples G through N in Table 1.

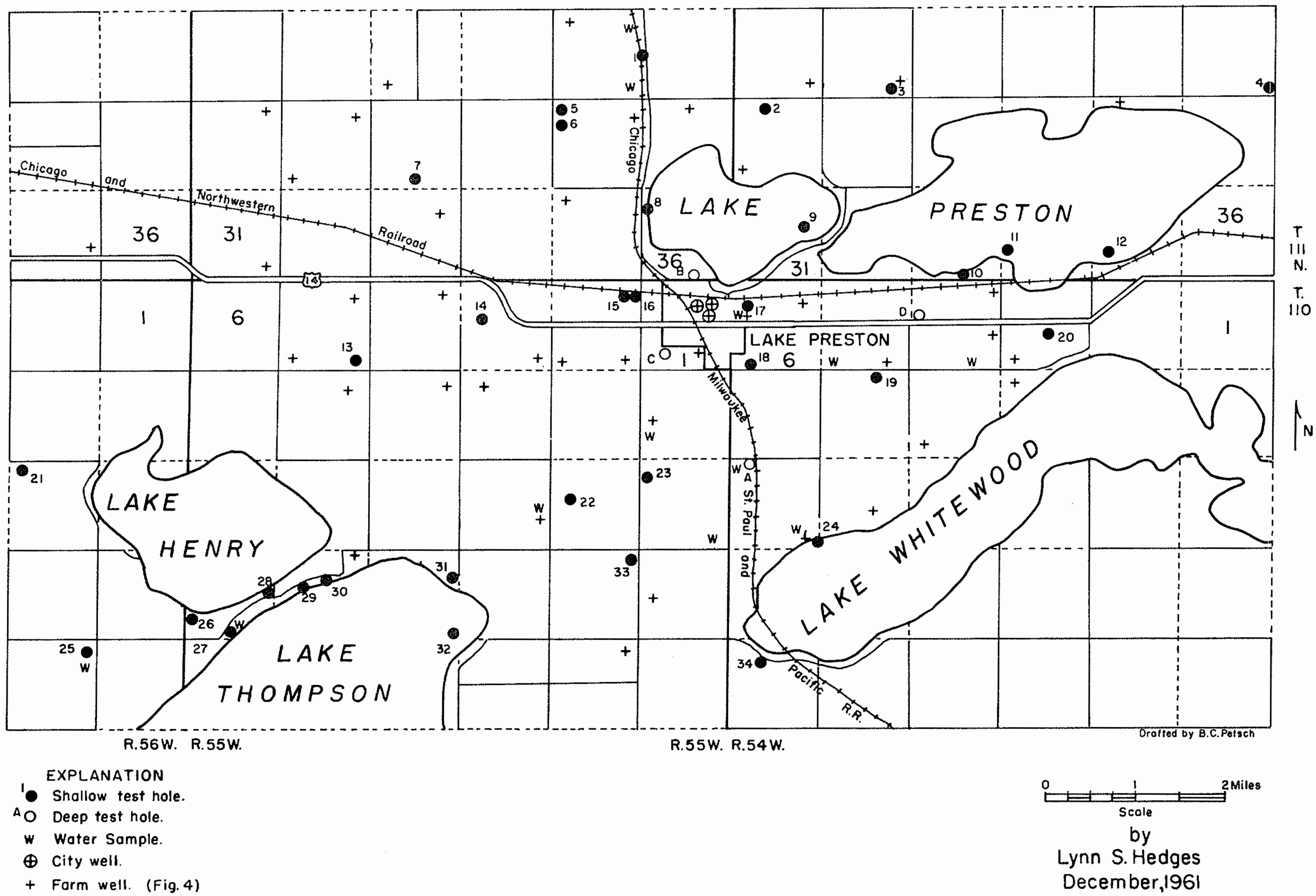
The city should also test the shallow deposit below the collapsed outwash in the Lake Henry area. At least one test hole should be drilled in the southern half of Sec. 7, T. 110 N., R. 55 W., as close to the lake as possible. The thickness of the sand in that area is not known, but if at least 25 feet of a well-sorted saturated sand is present, additional test-drilling in the area should be done. Test Holes 25 and 26 (fig. 4) showed 35 feet of saturated sand (Appendix A) beneath the collapsed outwash. Further test-drilling in either of these two locations is also recommended.

The only other possibility of additional ground water supplies in the Lake Preston area is further development of the city's present source, the Dakota Group.

After a well site is chosen for test drilling in either of the above areas, 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.

It is suggested that the city contract with 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.

Figure 4. Data Map of the Lake Preston Area.



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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.

APPENDIX A

Logs of Shallow Test Holes in the Lake Preston Area

(for locations see figure 3)

Test Hole No. 1
Depth to water: 42 feet

0- 4	topsoil, brown clay, sandy
4-19	clay, brown, sandy
19-29	clay, dark brown, pebbly
29-49	clay, dark brown
49-59	same, blue clay

* * * * * *

Test Hole No. 2
Depth to water: 10 feet

0- 4	topsoil
4-19	clay, light-colored
19-44	clay, brown

* * * * * *

Test Hole No. 3
Depth to water: 10 feet

0- 4	topsoil, light-brown clay
4- 9	clay, light brown
9-29	clay, dark brown
29-44	clay, blue

* * * * * *

Test Hole No. 4
Depth to water: none

0- 4	topsoil, light-brown clay
4- 9	clay, light brown, trace of sand
9-24	clay, grayish brown, pebbly
24-28	clay, dark brown
28-39	clay, blue

* * * * * *

Test Hole No. 5
Depth to water: 11 feet

0- 4	topsoil, brown clay, sandy
4- 9	clay, brown, sandy
9-19	clay, yellowish
19-35	clay, blue, (power take-off drive chain broke at 35 feet)

* * * * * *

Test Hole No. 6
Depth to water: 20 feet

0- 4	topsoil, clay, brown, sandy
4- 9	clay, yellow
9-14	clay, brown
14-84	clay, blue, trace of sand on auger at about 60 feet

* * * * * *

Test Hole No. 7
Depth to water: 17 feet

0- 4	topsoil
4- 9	clay, brown
9-19	clay, blue
19-29	clay, brown and blue
29-64	clay, blue

* * * * * *

Test Hole No. 8
Depth to water: 10 feet

0- 4	topsoil, clay, dark and sandy
4-14	clay, dark and sandy
14-19	clay, light-colored
19-24	clay, brown
24-59	clay, blue

* * * * * *

Test Hole No. 9
Depth to water: 4 feet

0- 4	sand, coarse
4-14	sand, medium, clayey
14-19	clay
19-24	clay, pebbly
24-39	clay, some sand
39-64	clay, blue

* * * * * *

Test Hole No. 10
Depth to water: 8 feet

0- 4	clay, dark, and coarse sand
4- 9	same
9-19	clay, brown, sandy
19-39	clay, brown
39-44	clay, gray
44-69	clay, blue

* * * * * *

Test Hole No. 11
Depth to water: 7 feet

0- 4	topsoil, gravelly
4- 9	gravel
9-14	gravel, clayey, lost bit

* * * * * *

Test Hole No. 12
Depth to water: 10 feet

0-14	clay, blue, sandy
14-39	clay, brown
39-69	clay, blue

* * * * * *

Test Hole No. 13
Depth to water: 55 feet

0- 4	topsoil, brown clay
4-19	clay, brown
19-29	clay, brown, pebbly
29-44	clay, brown
44-59	clay, gray
59-69	clay, blue

* * * * * *

Test Hole No. 14
Depth to water: 13 feet

0- 4	clay, brown
4- 9	sand, coarse and red
9-14	clay, light brown
14-24	clay, brown, pebbly
24-54	clay, brown

* * * * * *

Test Hole No. 15
Depth to water: 33 feet

0- 4	topsoil, sandy, brown clay
4- 9	clay, reddish, pebbly
9-29	clay, brown
29-49	clay, brown

* * * * * *

Test Hole No. 16
Depth to water: 14 feet

0- 4	topsoil and brown clay
4- 9	clay, brown
9-14	same, pebbly
14-24	same, sandy
	hit boulder and had to stop

* * * * * *

Test Hole No. 17
Depth to water: none

0- 4	topsoil and brown clay
4-29	clay, brown

* * * * * *

Test Hole No. 18
Depth to water: none

0- 4	topsoil, brown clay
4-49	clay, brown, drilling hard, had to quit

* * * * * *

Test Hole No. 19
Depth to water: 23 feet

0- 4	topsoil, clay
4-19	clay, brown
19-29	clay, brown and blue
29-69	clay, blue

* * * * * *

Test Hole No. 20
Depth to water: 12 feet

0- 4	topsoil and brown clay
4-39	clay, brown
39-59	clay, gray
59-69	clay, blue

* * * * * *

Test Hole No. 21
Depth to water: none

0- 4	topsoil and sand
4- 9	gravel, layers of clay
9-14	clay, brown

* * * * * *

Test Hole No. 22
Depth to water: none

0- 4	topsoil, and gray clay
4-29	clay, brown, rollers binding and clutch burned out, had to stop

* * * * * *

Test Hole No. 23
Depth to water: 7 feet

0- 4	topsoil
4-30	clay, light tan, broke auger at 30 feet

* * * * * *

Test Hole No. 24
Depth to water: none

0- 4	clay, brown, pebbly
4- 9	clay, brown
9-14	clay, gray
14-44	clay, blue

* * * * * *

Test Hole No. 25
Depth to water: 3 feet

0- 9	clay, gravelly
9-37	sand, fine
37-44	sand, clayey

* * * * * *

Test Hole No. 26
Depth to water: 7 feet

0- 4	topsoil, sandy
4- 9	sand, coarse
9-14	sand, with clay layers
14-44	sand, medium
44-49	clay

* * * * * *

Test Hole No. 27
Depth to water: 11 feet

0- 4	topsoil, sandy
4- 9	sand
9-29	clay, blue

* * * * * *

Test Hole No. 28
Depth to water: 6 feet

0- 4	gravel
4- 9	sand, with thin clay layer
9-19	clay, sandy

* * * * * *

Test Hole No. 29
Depth to water: 8 feet

0- 4	gravel and sand
4- 9	sand, coarse
9-14	clay, sandy

* * * * * *

Test Hole No. 30
Depth to water: 13 feet

0-14	sand, coarse
14-34	clay, with some sand
34-39	clay

* * * * * *

Test Hole No. 31
Depth to water: 45 feet

0- 3	topsoil
3- 7	clay, light-colored
7-15	same, pebbly
15-35	clay, dark-colored
35-55	clay, gray

* * * * * *

Test Hole No. 32
Depth to water: 7 feet

0- 9	sand and clay
9-19	clay, brown, sandy
19-24	clay, brown

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Test Hole No. 33
Depth to water: none

0- 3	topsoil
3- 8	clay, thin lens of gravel
8-33	clay, brown
33-48	clay, blue

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Test Hole No. 34
Depth to water: 7 feet

0- 7	sand, coarse
7-19	clay, brown, sandy
19-29	clay, light-colored

APPENDIX B

Logs of Deep Test Holes in the Lake Preston Area

Test Hole A
Location: NE$\frac{1}{4}$NW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 18, T. 110 N., R. 54 W.

0-120	clay, with some sand, had trouble keeping circulation
120-238	clay, very sandy, pebbly, few thin (6-in.) gravel lenses
238-250	sand, coarse, and fine gravel
250-290	clay, very sandy
290-317	sand, coarse, fine gravel, 1-2 foot clay stringers
317-340	Pierre Shale

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Test Hole B
Location: SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 36, T. 111 N., R. 55 W.

0-120	no cuttings, lost circulation, drilled as if clay
120-335	clay, gray, very sandy and pebbly
335-372	gravel, coarse, binding on drill so had to stop drilling

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Test Hole C
Location: NE$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 6, T. 110 N., R. 55 W.

0-100	no cuttings, losing mud, drills like clay
100-336	clay, very sandy and pebbly with 6-in. gravel stringers
336-340	sand, coarse
340-348	clay, or fine sand
340-358	gravel, coarse

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Test Hole D
Location: SW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 4, T. 110 N., R. 54 W.

0- 20	sand, coarse
20- 75	clay, gray, sandy
75-255	clay, gray, fine sand, few thin gravel stringers
255-265	gravel, coarse
265-275	clay, gray, sandy
275-307	gravel, coarse, some sand
307-310	Pierre Shale

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APPENDIX C

Table 2.--Well Records in the Lake Preston Area

Location: letters stand for quarter section; first number for section, second number for township north, and third number for range west.
Use: S-Stock; D-Domestic

Name	Location	Depth of Well in feet	Geologic Source	Use
Johnson, W.	SE$\frac{1}{4}$35-111-56	12	Lake Sediments	S
Johnson, W.	SE$\frac{1}{4}$35-111-56	110	Glacial	S, D
Bergan, E.	SE$\frac{1}{4}$11-111-55	360	Glacial	S
Smith, H.	SE$\frac{1}{4}$12-111-55	335±	Glacial	S
Bergan, E.	SW$\frac{1}{4}$14-111-55	170	Glacial	S
Blachford, R.	SW$\frac{1}{4}$21-111-55	320	Glacial	S
Hauck, R.	SW$\frac{1}{4}$22-111-55	750	Carlile (?)	S, D
Jibben, F.	SE$\frac{1}{4}$23-111-55	310	Glacial	S
Gartineau, C.	NW$\frac{1}{4}$23-111-55	360	Glacial	S
Leighton, G.	NE$\frac{1}{4}$26-111-55	287	Glacial	S
Johnson, A.	NE$\frac{1}{4}$29-111-55	320±	Glacial	S, D
Isaacson, E.	SW$\frac{1}{4}$29-111-55	355	Glacial	S
Parkhorst, A.	NE$\frac{1}{4}$30-111-55	320	Glacial	S, D
Isaacson, E.	NE$\frac{1}{4}$31-111-55	200	Glacial	S
Isaacson, E.	SE$\frac{1}{4}$31-111-55	290	Glacial	S
Williams, L.	NE$\frac{1}{4}$33-111-55	340	Glacial	S
Sass, H.	NW$\frac{1}{4}$25-111-55	155	Glacial	S
Wienk, R.	SW$\frac{1}{4}$7-111-54	354	Glacial	S
Danielson, A.	SE$\frac{1}{4}$8-111-54	365	Glacial	S,D
Wastum, T.	SW$\frac{1}{4}$10-111-54	90	Glacial	S

Appendix C--Table 2 - continued

Name	Location	Depth of Well in feet	Geologic Source	Use
Weiss, A.	SE$\frac{1}{4}$11-111-54	365	Glacial	S, D
Neilson, M.	SW$\frac{1}{4}$14-111-54	322	Glacial	S, D
Thompson, M.	NE$\frac{1}{4}$18-111-54	320	Glacial	S
Sjolie, G.	SE$\frac{1}{4}$19-111-54	400	Glacial	D
Johnson, A.	NW$\frac{1}{4}$26-111-54	327	Glacial	S,D
Kopperud	SW$\frac{1}{4}$30-111-54	360	Glacial	S, D
Thompson	NE$\frac{1}{4}$30-111-54	270	Glacial	S
Miller, K.	SE$\frac{1}{4}$34-111-54	16	Glacial	S
Karbon, A. M.	1-110-55	380	Glacial	S
Field, J.	SW$\frac{1}{4}$2-110-55	285	Glacial	S
Casper, A. E.	SE$\frac{1}{4}$2-110-55	300+	Glacial	S
Larsen, P.	SE$\frac{1}{4}$3-110-55	250+	Glacial	S
Kerr, D.	NE$\frac{1}{4}$5-110-55	300	Glacial	S
Kerr, D.	SW$\frac{1}{4}$5-110-55	300	Glacial	S
Aughenbaugh, H.	middle7-110-55	15	Glacial	S, D
Smith, J.	NW$\frac{1}{4}$7-110-55	200±	Glacial	S
Lee, M.	SW$\frac{1}{4}$7-110-55	223	Glacial	S
Olson, E.	NE$\frac{1}{4}$9-110-55	375	Glacial	S
Casper, W.	SW$\frac{1}{4}$12-110-55	320±	Glacial	S
Brekke, H.	SE$\frac{1}{4}$13-110-55	340	Glacial	S
Odden, M.	SE$\frac{1}{4}$14-110-55	145	Glacial	S
Pollock, C.	19-110-55	12	Glacial or Lake	D
Steenson, L.	NE$\frac{1}{4}$20-110-55	340	Glacial	S

Appendix C--Table 2 - continued

Name	Location	Depth of Well in feet	Geologic Source	Use
Larson, F.	NE$\frac{1}{4}$24-110-55	710	Carlile (?)	S
Berdahl, H.	SW$\frac{1}{4}$3-110-54	315	Glacial	S
Tolzin, E.	SE$\frac{1}{4}$4-110-54	140+	Glacial	S
Melstad, C.	NE$\frac{1}{4}$4-110-54	160	Glacial	S
Olson, M.	SE$\frac{1}{4}$5-110-54	175	Glacial	
Larsen, P.	NE$\frac{1}{4}$6-110-54	325	Glacial	S
Seeman, V.	SW$\frac{1}{4}$9-110-54	280	Glacial	S
Ellingson, M.	NW$\frac{1}{4}$10-110-54	414	Glacial	S
Brekke, H.	SE$\frac{1}{4}$18-110-54	340	Glacial	S
Abel, C.	NW$\frac{1}{4}$18-110-54	329	Glacial	S
Casper, A.	NW$\frac{1}{4}$2-109-55	320	Glacial	S