STATE OF SOUTH DAKOTA
Richard Kneip, Governor

SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 53

GROUND-WATER INVESTIGATION FOR THE CITY OF HAZEL, SOUTH DAKOTA

by

Assad Barari

Science Center
University of South Dakota
Vermillion, South Dakota
1972

CONTENTS

Page

Introduction 1

Present investigation 1

Location and extent of the area 1

Topography and drainage 1

General geology 1

Surficial deposits 1

Subsurface bedrock 1

Occurrence of ground water 4

Principles of occurrence 4

Ground water in glacial deposits 5

Ground water in bedrock 5

Quality of ground water 5

Discussion and recommendations 5

References cited 12

ILLUSTRATIONS

Page

Figure 1. Map of eastern South Dakota showing the major physiographic divisions and location of the Hazel area 2

2. Generalized geologic map of the Hazel area 3

3. Map showing location of rotary and auger test holes in the Hazel area 6

4. Map showing location of water samples collected from the Hazel area 9

TABLES

Table 1. Chemical analyses of water samples from the Hazel area 7

2. Significance of some chemical and physical properties of drinking water 10

APPENDICES

Appendix A. Logs of test holes in the Hazel area 13

B. Well records in the Hazel area 20

INTRODUCTION

Present Investigation

This report contains the results of a special ground-water investigation by the South Dakota Geological Survey conducted in part of June and August, 1970, in and around the city of Hazel, Hamlin County, South Dakota. Purpose of the investigation was to assist the city in locating a municipal water supply for a future central water supply.

Included in the survey of the Hazel area was: (1) a review of the geology as mapped by Tipton (1958), and additional mapping of a total of 16 square miles, (2) the drilling of 22 auger and 6 rotary test holes, (3) a collection and analyses of 14 water samples, and (4) a well inventory.

Results of the investigation reveal that there are three possible sources of ground water for the city in the Hazel study area. However, water from these sources have high dissolved chemicals; consequently, it has been recommended that the city of Hazel consult an engineering firm to determine the cost of treatment for these waters. In addition, it is advised that Hazel consider building a community water system to pipe water in from a distant source and serve the farms as well.

Cooperation of the residents of Hazel, especially Town Board member, Donald Roe, is greatly appreciated. The project was financed by the South Dakota Geological Survey, East Dakota Conservancy Sub-District, and the city of Hazel.

Location and Extent of the Area

The city of Hazel is located in east-central South Dakota in Hamlin County. The area is in the Coteau des Prairies division of the Central Lowland physiographic province (fig. 1). The Hazel study area as used in this report includes a region that measures 4 miles north-south and 4 miles east-west.

Topography and Drainage

Hazel area is characterized by swell and swale topography with some undrained depressions. A small stream drains the north part of the area.

GENERAL GEOLOGY

Surficial Deposits

Surficial deposits of the Hazel area are the result of glaciation late in the Pleistocene Epoch of geologic time. Glacial deposits are collectively called drift, and can be divided into till and outwash deposits. Till consists of unsorted material that ranges in size from boulders to clay and was deposited directly by the ice. Outwash material was deposited by meltwater streams issuing from the ice; such material is more sorted, consisting mostly of gravel and sand with minor amounts of silt. Figure 2 shows the geologic map of the Hazel area. The entire study area is covered with glacial till.

Subsurface Bedrock

No bedrock is exposed in the study area; but data obtained from well logs in this area reveal that cretaceous stratified sedimentary rocks underlie the glacial drift. These deposits in descending order are Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone, Granerous Shale, and Dakota Formation.

Pierre underlies approximately 520 feet of glacial drift. It consists of approximately 240 feet

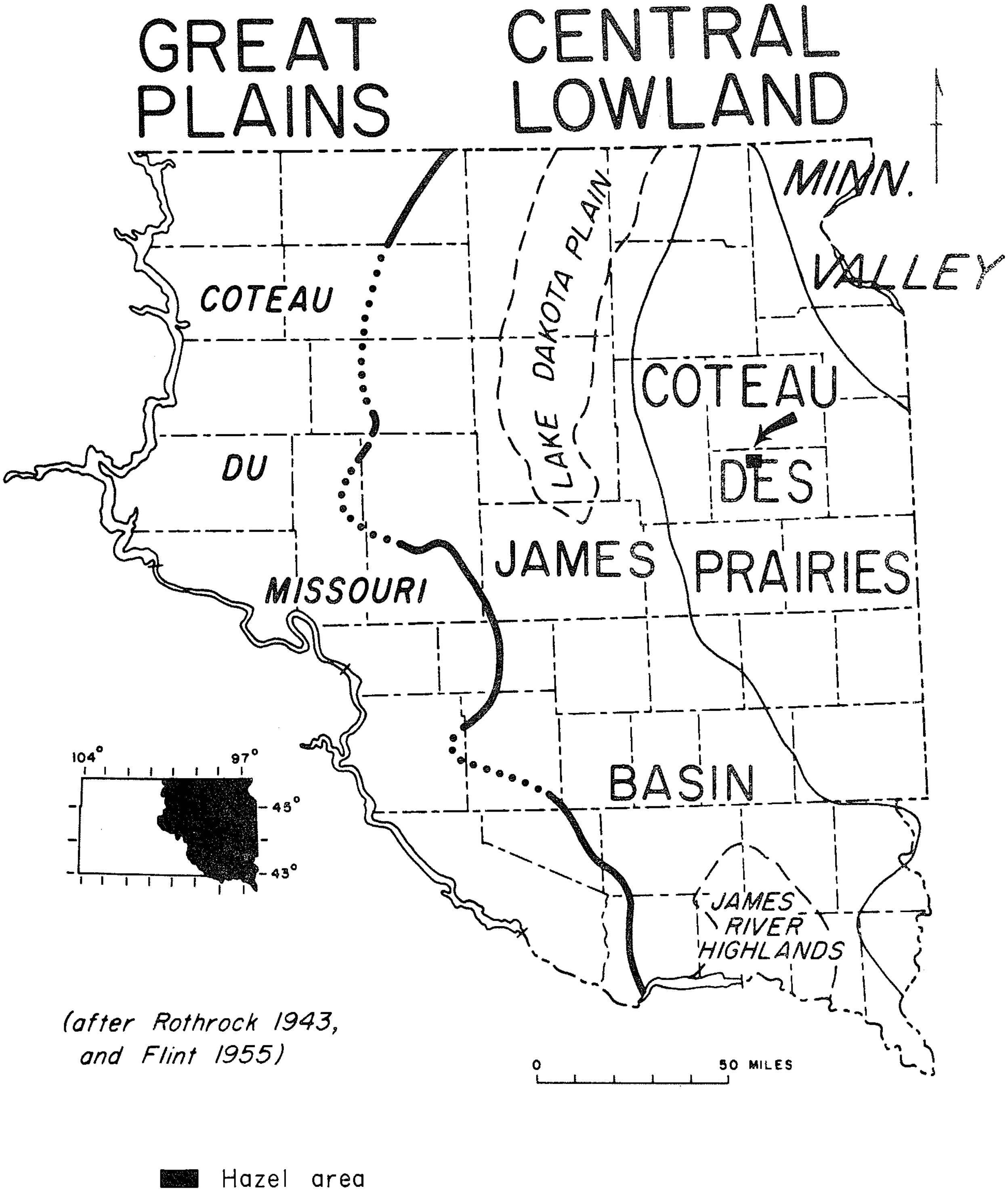
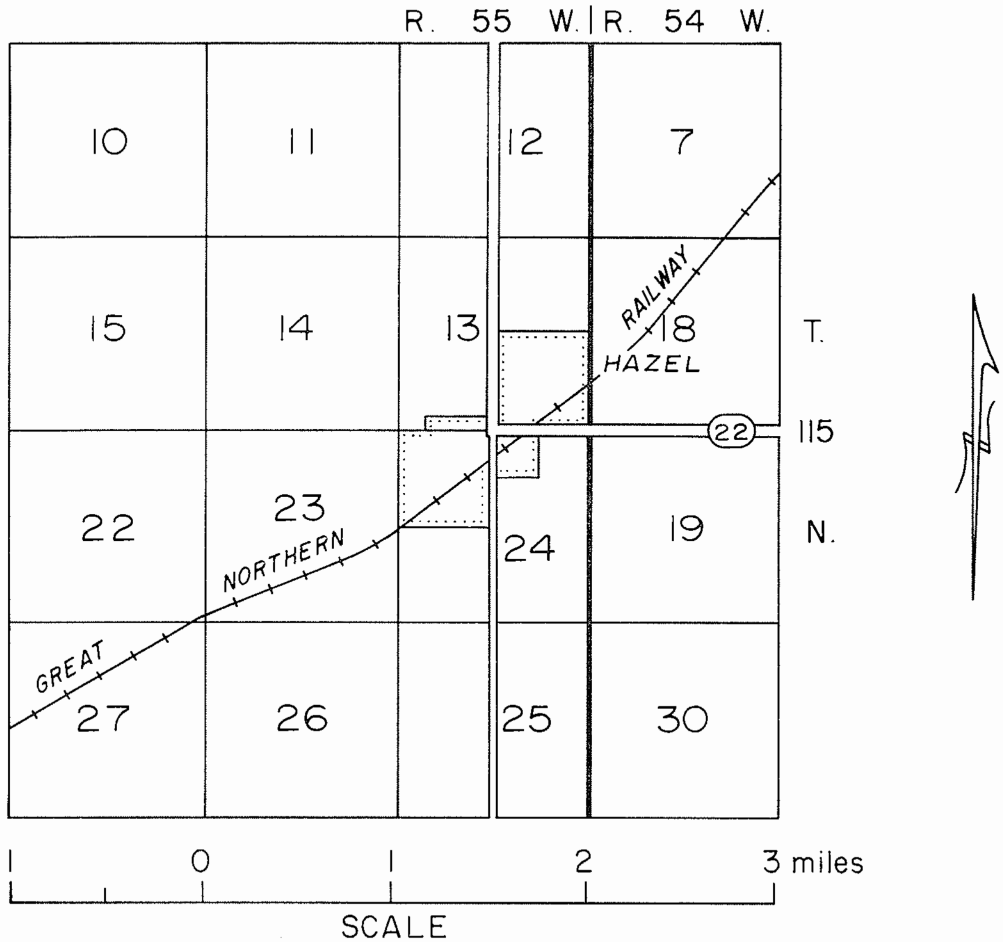


Figure 1. Map of eastern South Dakota showing the major physiographic divisions and location of the Hazel area.



EXPLANATION

Entire study area is glacial till

by Assad Barari, 1970

drafted by D. W. Johnson

Figure 2. Generalized geologic map of the Hazel area. *(Modified from M. J. Tipton, 1958)*

of light-to dark-gray shale.

Niobrara Marl, approximately 120 feet thick, consists of light-to medium-gray chalk with shaly layers and numerous microscopic white specks.

The Carlile consists of approximately 180 feet of light-gray to black shale with thin silt and sand layers.

The Greenhorn is composed of about 25 feet of hard, gray limestone.

The Granerous is gray to dark-gray shale, often containing thin layers of cemented sandstone. Average thickness of these sediments is approximately 150 feet.

A sequence of alternating sand, sandstone, and shale beds approximately 100 feet thick makes up the Dakota Formation. Beneath the Dakota Formation are rocks of Precambrian age, usually quartzite and granite.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Ground water is defined as water contained in the voids or openings within rocks or sediments below the water table. Practically all open spaces in the rocks that lie below the water table are filled with water; this zone is called the zone of saturation. The water table is the upper surface of the zone of saturation and is under atmospheric pressure. Rocks (including the soil) that lie above the water table are in the zone of aeration because only some of the open spaces in this zone are filled with water; the remaining portion contains air. Water in this zone is either held by molecular attraction, or is moving downward toward the zone of saturation. Water within the ground above the saturated zone moves downward under the influence of gravity, whereas in the saturated zone, it moves in a direction determined by the hydraulic head.

Contrary to popular belief, ground water does not occur in "veins" that crisscross the land at random; instead, it can be shown that water is found nearly everywhere beneath the suface, but at varying depths.

Nearly all ground water is derived from precipitation in the form of rain, melting snow, or ice. This water either evaporates, 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 into the rocks.

Recharge is the addition of water to an aquifer (a formation having structures that permit appreciable water to move through it under ordinary field conditions), and is accomplished in four main ways: (1) by downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, (3) by lateral underflow of water in transient storage into the area, and (4) by artificial recharge, which takes place from excess irrigation, seepage from canals, and water purposely applied to augment ground-water supplies.

Discharge 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, (3) by lateral movement of water in transient storage out of the area, and (4) by pumping from wells, which constitutes the major artificial discharge of ground water.

Porosity of a rock or soil is a measure of the contained open pore spaces, and it is expressed as the percentage of void spaces to the total volume of the rock. Porosity of a sedimentary deposit depends chiefly on (1) the shape and arrangement of its constituent particles, (2) the degree of sorting of its particles, (3) the cementation and compaction to which it has been subjected since its deposition, (4) the removal of mineral matter through solution by percolating waters, and (5) the fracturing of the rock, resulting in joints and other openings. Thus, the size of the material has little or no effect on porosity if all other factors are equal.

Permeability of a rock is its capacity for transmitting a fluid. Water will pass through a material with interconnected pores, but will not pass through material with unconnected pores, even if the latter material has a higher porosity. Therefore, permeability and porosity are not synonymous terms.

Ground Water in Glacial Deposits

It is stated earlier that glacial deposits are divided into till and outwash. Till does not yield water readily because of its highly unsorted (different sized and shaped particles) nature resulting in permeability. Locally there are some lenses of sand within the till which provide an adequate supply of water for farm wells.

Outwash, a highly permeable deposit, may make an aquifer. There are two different outwash deposits in the Hazel area: shallow buried outwash and deep buried outwash.

A shallow buried outwash deposit is located approximately 1 to 1½ miles north and northeast of the town and was penetrated by test holes, 3, 10, and 11 at a depth of approximately 70 feet below the land surface. For location of and logs of these test holes, see figure 3 and appendix A.

A deep buried outwash about 20 feet thick underlies the town and was penetrated by test holes 14, 21, and 25 at a depth of approximately 500 feet below the surface.

Ground Water in Bedrock

The Dakota Formation is the only aquifer other than glacial outwash that could supply significant quantities to the town of Hazel. The water in the Dakota Formation is under pressure in most parts of the State. Artesian wells which have higher hydraulic head than the ground surface yield water to flowing wells.

Quality of Ground Water

Ground water always contains dissolved chemical substances in various amounts. Contained chemicals are derived (1) from the atmosphere as water vapor condenses and falls, (2) from soil and underlying deposits as the water moves downward to the water table, and (3) from rocks below the water table where the water is moving. In general, the more chemical substances that a water contains, the poorer its quality.

Table 1 shows the chemical quality of water samples collected in the Hazel area (for location of water samples, fig. 4). All water samples, except for samples W-7 and W-13, have higher sulfate and total solids than the limits set by the South Dakota Department of Health.

Samples W-1, W-2, W-4, W-5, W-7, W-8, W-10, and W-13 were collected from wells yielding water from shallow sand and gravel lenses or shallow outwash deposits. Samples W-4, W-5, W-10 have more nitrate; samples W-2, W-7, and W-13 have less fluoride; samples W-1, W-5, W-7, W-8, and W-10 have higher manganese; and sample W-13 has more iron than the recommended limits.

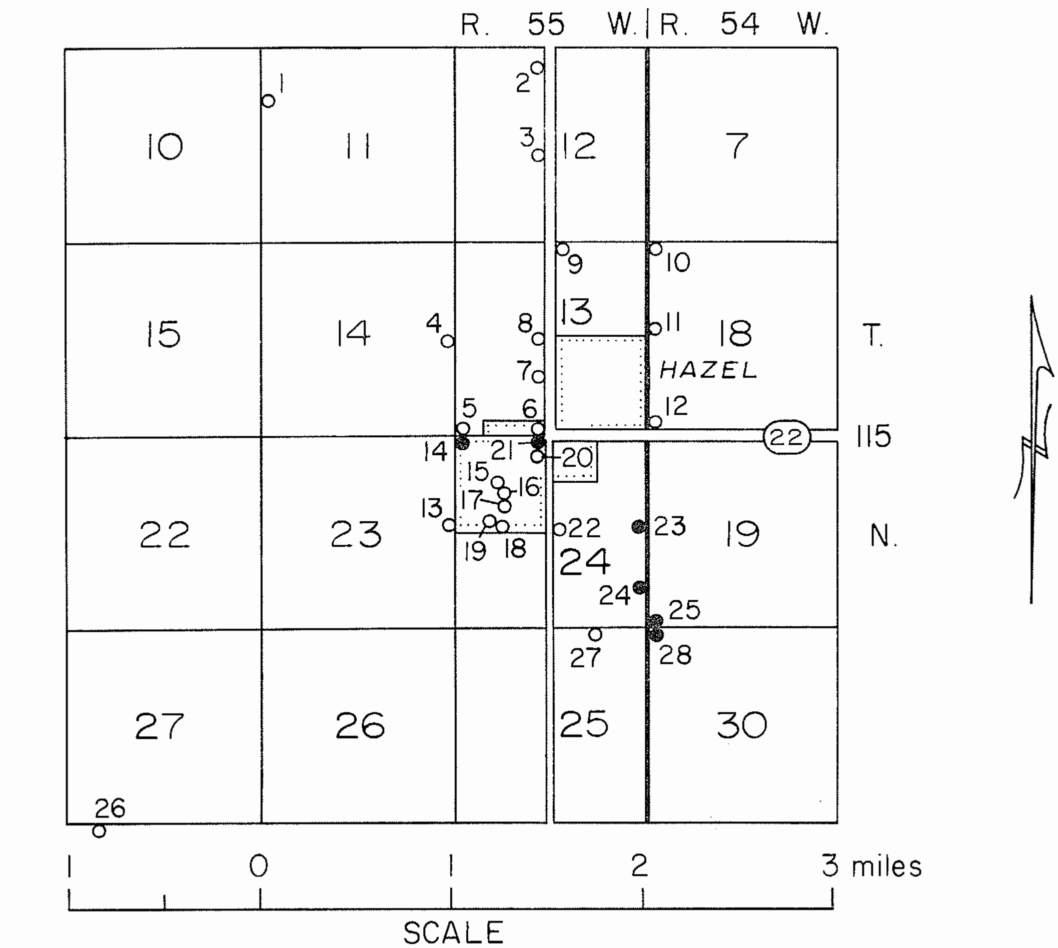
Samples W-3, W-6, W-9(?), W-11, and W-12 were collected from wells yielding water from deep buried deposits (approximately 500 feet below the land surface). In addition to higher sulfate and total solids in all samples in this class, samples W-3, W-6, and W-12 have higher iron than the recommended limits. Manganese is higher than the limits in samples W-9 and W-11. Also samples W-6, W-11, and W-12 have higher chloride than the recommended limits. Samples W-3, W-6, and W-12 have less fluoride than the limits set by the South Dakota Department of Health.

Sample W-14 was collected from a well yielding water from the Dakota Formation. This water in addition to higher sulfate and total solids has higher iron and fluoride than the recommended limits.

Table 2 shows the significance of some physical and chemical properties of drinking water.

DISCUSSION AND RECOMMENDATIONS

There are three possible sources of water in the Hazel area (table 1). These sources in order of depth from the ground surface are described and evaluated below:



EXPLANATION

3o Auger test hole
24● Rotary test hole
(Number refers to logs in Appendix A)

by Assad Barari, 1971

drafted by D. W. Johnson

Figure 3. Map showing location of rotary and auger test holes in the Hazel area.

Table 1 – Chemical analyses of water samples from the Hazel area

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magnesium	Chioride	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A		—	—	—	250	500[1]	0.3	0.05	10.0	0.9-1.7[2]	—	—	1000[1]
W-1	S	424		99.1	26.5	1810	0.15	0.20	6.5	1.46	7.7	1460	2580
W-2	S	313	80	160	43	1286	0.06	0	7.4	0.6		1438	2300
W-4	S	560	210	392	128	2118	0.2	0	108	1.0		3012	4944
W-5	S	677		153	143	1870	0.09	0.20	138	1.31	7.8	2310	3500
W-7	S	121		34.9	17.2	155	0.07	0.09	8.0	0.65	8.4	445	540
W-8	S	413		110	20.5	1940	0.09	0.13	4	1.58	8.0	1480	2600
W-10	S	370		163	84.2	1260	0.10	0.22	64	1.30	7.9	1590	2460
W-13	S	122	64	32	6	448	8.0	0	0	0.2		437	958
W-3	B	99	526	26	83	1130	1.3	0	4.2	0.2		354	2164
W-6	B	58	666	29	551	572	2.5	0	3.2	0.4		265	2288
W-9	B?	287		135	57.2	1690	0.06	0.09	6.5	1.23	8.0	1270	2610
W-11	B	88.2		22.4	478	525	0.12	0.27	5.5	1.09	8.3	312	2300
W-12	B	103	640	21	400	694	8.9	0	2.6	0		342	2264
W-14	D	28	1360	18	1060	1142	0.8	0	0	3.0		145	3902

A. Drinking water standards, U. S. Public Health Service (1962).

Samples W-1, W-5, W-7, W-8, W-9, W-10, and W-11 were analyzed by the South Dakota Geological Survey. All other samples were analyzed by the South Dakota Chemical Laboratory.

[1] Modified for South Dakota by the Department of Health (written communication, Water Sanitation Section, March 20, 1968).

[2] 1.2 is optimum for South Dakota.

Source: S, sand lenses or buried shallow outwash; B, buried deep outwash; D, Dakota Formation.

Location of Water Samples
(For map location, see fig. 4.)

W- 1. SE¼NE¼SE¼SE¼ sec. 11, T. 115 N., R. 55 W., R. Goerde, 80 feet deep, water table 54 feet.

W- 2. NE¼NE¼SE¼SW¼ sec. 12, T. 115 N., R. 55 W., A. Abraham, 28? feet deep, water table 12 feet.

W- 3. SE¼SE¼SE¼SW¼ sec. 14, T. 115 N., R. 55 W., C. Sour, 517 feet deep.

W- 4. SW¼SW¼SW¼NW¼ sec. 18, T. 115 N., R. 54 W., W. Parliament 70 feet deep, water table 55 feet.

W- 5. SW¼NW¼NE¼NE¼ sec. 23, T. 115 N., R. 55 W., H. Jorgensen, 75-80 feet deep.

W- 6. NE¼NW¼ sec. 24, T. 115 N., R. 55 W., schoolhouse, 520 feet deep.

W- 7. SE¼SE¼SE¼NW¼ sec. 24, T. 115 N., R. 55 W., C. Wattawa, 25 feet deep, water table 6 feet.

W- 8. SE¼NW¼NW¼NW¼ sec. 19, T. 115 N., R. 54 W., H. Adams, 72 feet deep, water table 50 feet.

W- 9. NE¼SE¼NE¼SE¼ sec. 26, T. 115 N., R. 55 W., A. Phillips, 900? feet deep.

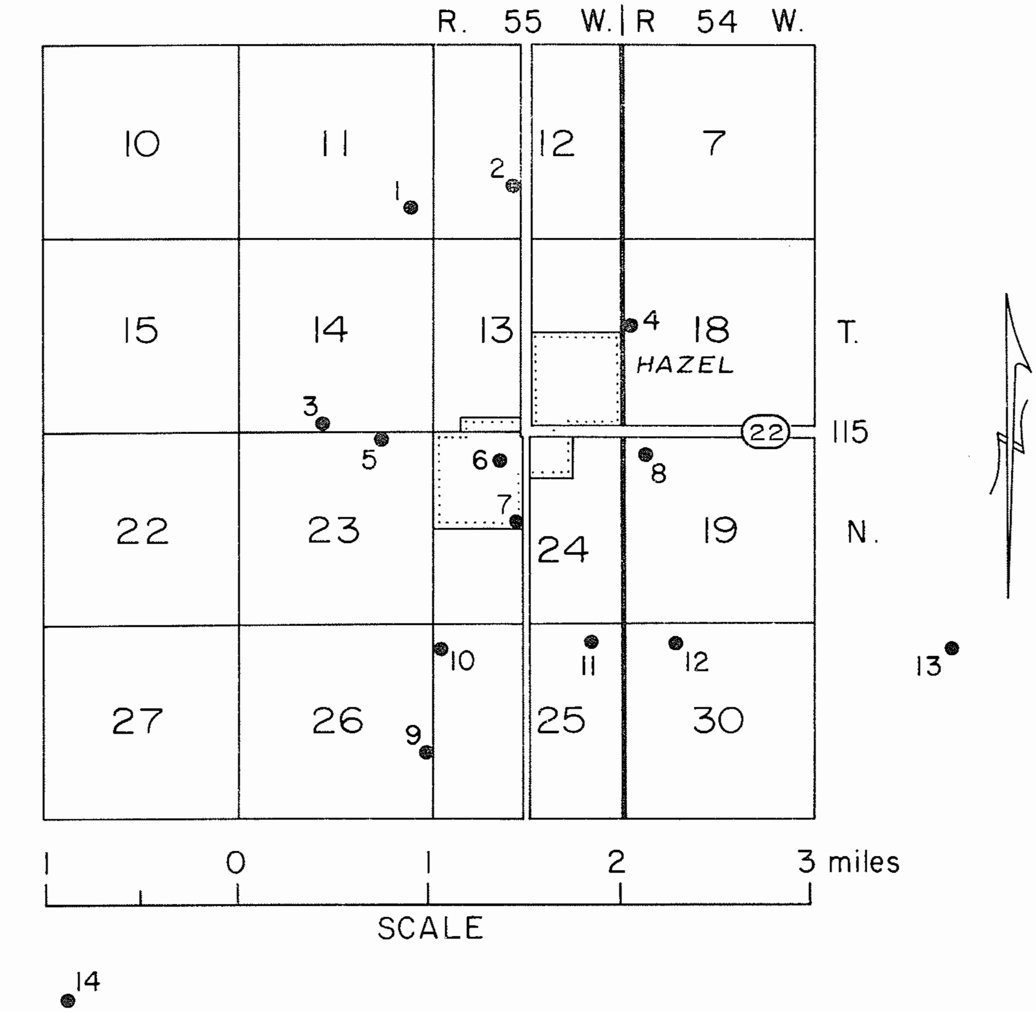
W-10. SE¼NW¼NW¼NW¼ sec. 25, T. 115 N., R. 55 W., W. Parliament 70 feet deep.

W-11. NW¼NE¼NE¼ sec. 25, T. 115 N., R. 55 W., W. Luken, 528 feet deep.

W-12. NW¼NE¼NW¼ sec. 30, T. 115 N., R. 54 W., H. Amrhien, 500 feet deep, water table 90-100 feet.

W-13. NE¼NW¼NE¼ sec. 29, T. 115 N., R. 54 W., L. Amrhien, 215 feet deep, water table 80 feet.

W-14. SW¼SW¼SW¼SW¼ sec. 34, T. 115 N., R. 55 W., Q. Beman, 1236 feet deep.



EXPLANATION

3● Water sample, *(Number refers to water sample in Table I)*

by Assad Barari, 1971

drafted by D. W. Johnson

Figure 4. Map showing location of water samples collected from the Hazel area.

Table 2.--Significance of some chemical and physical properties of drinking water.

Chemical Constituents	Significance	Recommended Limits (ppm)[1]
Calcium (Ca) and Magnesium (Mg)	Cause most of the carbonate hardness and scale-forming properties of water by combining with carbonate and bicarbonate present in the water. Seldom can be tasted except in extreme concentrations.	Ca–None Mg–None
Sodium (Na)	Large amounts in combination with chloride will give water a salty taste. Large amounts will limit water for irrigation and industrial use.	None
Chloride (Cl)	Large amounts in combination with sodium give water a salty taste. Large quantities will also increase corrosiveness of water.	250
Sulfate (SO_4)	Large amounts of sulfate in combination with other ions give a bitter taste to water and may act as a laxative to those not used to drinking it. Sulfates of calcium and magnesium will form hard scale. U. S. Public Health Service recommends 250 ppm maximum concentration.	500[2]
Iron (Fe) and Manganese (Mn)	In excess will stain fabrics, utensils, and fixtures and produce objectionable coloration in the water. Both constituents in excess are particularly objectionable.	Fe--0.3 Mn--0.05
Nitrogen (N)	In excess may be injurious when used in infant feeding. The U. S. Public Health Service regards 45 ppm as the safe limit of nitrate (NO_3) or 10 ppm nitrogen (N).	10
Fluoride (F)	Reduces incidence of tooth decay when optimum fluoride content is present in water consumed by children during period of tooth calcification. Excessive fluoride in water may cause mottling of enamel.	0.9-1.7[3]
pH	A measure of the hydrogen ion concentration; pH of 7.0 indicates a neutral solution, pH values lower than 7.0 indicate acidity, pH values higher than 7.0 indicate alkalinity. Alkalinity tends to aid encrustation and acidity tends to aid corrosion.	None
Hardness	Hardness equivalent to carbonate and bicarbonate is called carbonate hardness. Hardness in excess of this amount is noncarbonate hardness. Hardness in water consumes soap and forms soap curd. Will also cause scale in boilers, water heaters, and pipes. Water containing 0-60 ppm hardness considered soft; 61-120 ppm moderately hard; 121-180 ppm hard, and more than 180 ppm very hard. Good drinking water can be very hard.	None
Total Solids	Total of all dissolved constituents. U. S. Public Health Department recommends 500 ppm maximum concentration. Water containing more than 1000 ppm dissolved solids may have a noticeable taste; it may also be unsuitable for irrigation and certain industrial uses.	1000[2]

Modified from Jorgensen (1966).
[1] (ppm) parts per million.
[2] Modified for South Dakota by the South Dakota Department of Health (written communcation, Water Sanitation Section, March 20, 1968).
[3] 1.2 is optimum for South Dakota.

(1) **Shallow sand, gravel lenses, and outwash deposits** up to 200 feet below the surface; the most extensive layer of these deposits was penetrated by the drill in test holes approximately 1 to 1½ miles northeast and north of the town. These deposits are approximately 20 feet thick. Water from these deposits have higher sulfate and total solids than the recommended limits set by the South Dakota Department of Health. In addition, the water is very hard (samples W-2 and W-4, table 1). Sample W-7 was collected from a 25 foot deep well located one-eighth mile southwest of Hazel. This water sample has less dissolved chemicals than any other sample collected in the area, but because of limited areal extent, this deposit cannot be considered as a municipal water source. Sample W-13 was collected from a 215 foot well located 2½ miles southeast of Hazel. Except for low fluoride and very high iron, the rest of the chemicals are within the limits set by the South Dakota Department of Health. Additional testing is required to define the extent of this deposit.

(2) A second possible source, an **outwash deposit approximately 20 feet thick**, underlies Hazel at a depth of 500 feet below the land surface. A well drilled into this deposit is expected to yield water comparable to sample W-6 (table 1) which is from the schoolhouse well. This water has higher sulfate, chloride, iron, total solids, and less fluoride than the recommended limits. However, this water is softer than the water from the shallow sand and gravel north of town.

(3) Well logs from the area indicates that **the Dakota Formation** is present at a depth of approximately 1230 feet below the land surface; however, no test hole was drilled to this depth during the study. Sample W-14 was collected from a well that penetrates the Dakota Formation 3½ miles southwest of the town. The water has higher sulfate, chloride, iron, fluoride, and total solids than the recommended limits.

Generally the total dissolved chemicals in water from the Hazel area are high. Some of the chemicals can be removed easily from the water, but removal of others is costly. It is recommended that the city of Hazel consult an engineering firm with regard to the cost of water system and possible removal of some of the chemicals.

Because most of the water in the vicinity of Hazel have very high dissolved chemicals, it is also recommended that the town officials consult FHA for information concerning a community water system to serve the town and the farmers from a source of water at a distance from the town.

When an area is selected for water development, it is recommended that a test well be installed, and pump tests conducted by a qualified engineer or a hydrologist for a minimum of 72 hours. The results of this test are necessary to determine the expected yield, spacing of future wells, water quality, and final design of the well(s).

Before a permanent well is drilled, the county officials should contact the State Water Resources Commission to obtain water rights, a permit to drill a municipal well, and with the State Department of Health to determine biological and chemical suitability of the water.

REFERENCES CITED

Flint, R. F., 1955, Pleistocene geology of eastern South Dakota: U. S. Geol. Survey Prof. Paper 262, 173 p.

Jorgenson, D. G., 1966, Ground-water supply for the city of Lake Norden, S. Dak. Geol. Survey Special Report 34, 27 p., 6 figs.

Rothrock, E. P., 1943, A geology of South Dakota, part I: The surface: S. Dak. Geol. Survey Bull. 13, 88 p.

Tipton, M. J., 1958, Geology of the Henry quadrangle, South Dakota: S. Dak. Geol. Survey map and text.

U. S. Public Health Service, 1962, Drinking water standards: U. S. Public Health Service 956, 61 p.

APPENDIX A

Logs of test holes in the Hazel area
(For location, see fig. 3.)

Test Hole 1
Location: SW¼SW¼NW¼NW¼ sec. 11, T. 115 N., R. 55 W.
Depth to water: 4? feet

0- 2	Topsoil
2- 4	Clay, grayish-brown; some sand
4- 6	Sand, brown, coarse
6- 15	Clay, light-brown
15- 80	Clay, gray, pebbly

* * * *

Test Hole 2
Location: SE¼NE¼NE¼NW¼ sec. 12, T. 115 N., R. 55 W.
Depth to water: 13 feet

0- 3	Topsoil
3- 20	Clay, brown, pebbly
20- 60	Clay, gray, gravelly
60-100	Clay, sandy

* * * *

Test Hole 3
Location: NE¼NE¼NE¼SW¼ sec. 12, T. 115 N., R. 55 W.
Depth to water: 4 feet

0- 5	Sand, yellowish-gray, very fine
5- 10	Gravel, brown; some clay
10- 54	Clay, gray
54- 88	Sand, brown, medium to coarse
88-103	Sand, light-brown, fine
103-110	Gravel, fine; some clay
110-117	Clay, gray, pebbly

* * * *

Test Hole 4
Location: NE¼NE¼NE¼SE¼ sec. 14, T. 115 N., R. 55 W.
Depth to water: not measured

0- 1	Topsoil
1- 5	Clay, yellowish-brown
5- 21	Clay, brown
21- 43	Clay, sandy
43- 65	Clay, gray; some sand

* * * *

Test Hole 5
Location: SW¼SW¼SW¼SW¼ sec. 13, T. 115 N., R. 55 W.
Depth to water: 52? feet

0- 1	Topsoil
1- 10	Clay, brown, pebbly
10- 45	Clay, gray
45- 89	Clay, gray, gravelly

* * * *

Test Hole 6
Location: SE¼SE¼SE¼SW¼ sec. 13, T. 115 N., R. 55 W.
Depth to water: 40 feet

0- 1	Topsoil
1- 25	Clay, brown
25- 70	Clay, gray, some fine sand
70-104	Clay, gray, pebbly

* * * *

Test Hole 7
Location: SE¼SE¼NE¼SW¼ sec. 13, T. 115 N., R. 55 W.
Depth to water: 5 feet

0- 5	Clay, yellowish-brown
5- 17	Sand, brown, fine to medium
17- 45	Clay, gray, pebbly
45- 80	Clay, sandy

* * * *

Test Hole 8
Location: SE¼SE¼SE¼NW¼ sec. 13, T. 115 N., R. 55 W.
Depth to water: 47 feet

0- 3	Topsoil
3- 22	Clay, yellowish-brown
22- 85	Clay, gray

* * * *

Test Hole 9
Location: NW¼NW¼NW¼NE¼ sec. 13, T. 115 N., R. 55 W.
Depth to water: 8 feet

0- 1	Topsoil
1- 13	Clay, gray
13- 57	Clay, gray, pebbly
57-100	Clay, gray, gravelly

* * * *

Test Hole 10
Location: NW¼NW¼NW¼NW¼ sec. 18, T. 115 N., R. 54 W.
Depth to water: 66? feet

Test Hole 10 -- continued

0- 1	Topsoil
1- 21	Clay, brown
21- 57	Clay, gray
57- 67	Clay, sandy
67- 78	Sand, fine to medium
78- 95	Gravel, gray; much clay
95-112	Clay, gray, compact

* * * *

Test Hole 11
Location: SW¼SW¼SW¼NW¼ sec. 18, T. 115 N., R. 54 W.
Depth to water: 12 feet

0- 3	Topsoil
3- 35	Clay, yellowish-brown
35- 80	Clay, gray
80-102	Sand, brown, coarse; some clay
102-104	Clay, very fine

* * * *

Test Hole 12
Location: SW¼SW¼SW¼SW¼ sec. 18, T. 115 N., R. 55 W.
Depth to water: not measured

0- 2	Topsoil
2- 26	Clay, brown
26- 74	Clay, dark-gray, pebbly

* * * *

Test Hole 13
Location: SE¼SE¼SE¼NE¼ sec. 23, T. 115 N., R. 55 W.
Depth to water: dry hole

0- 3	Topsoil
3- 7	Clay, yellow
7- 31	Clay, brown
31-100	Clay, gray

* * * *

Test Hole 14 (Rotary Test Hole)
Location: NW¼NW¼NW¼NW¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: not measured

0- 1	Topsoil
1- 10	Clay, yellow
10- 31	Clay, gray, pebbly
31- 33	Sand, gray, fine to coarse
33-178	Clay, dark-gray, pebbly
178-225	Clay, yellowish-brown
225-227	Sand and gravel
227-229	Clay, yellowish-brown

Test Hole 16 – continued.

229-230	Sand and gravel
230-269	Clay, sandy
269-276	Sand and gravel
276-331	Clay, sandy
331-333	Rock
333-486	Clay, sandy
486-520	Gravel, better toward bottom
520-545	Shale, black

* * * *

Test Hole 15
Location: SE¼SE¼NW¼NW¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: not measured

0- 1	Topsoil
1- 5	Clay, brown
5- 8	Clay, sandy
8- 45	Clay, gray, pebbly

* * * *

Test Hole 16
Location: NW¼NW¼SE¼NW¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: 4 feet

0- 2	Topsoil
2- 5	Clay, yellow
5- 19	Gravel, reddish-brown; some clay
19- 30	Clay, gray, sandy

* * * *

Test Hole 17
Location: SW¼NW¼SE¼NW¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: 3 feet

0- 2	Topsoil
2- 6	Clay, yellow
6- 20	Clay, gray, compact

* * * *

Test Hole 18
Location: SW¼SW¼SE¼NW¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: 2 feet

0- 1	Topsoil
1- 6	Clay, grayish-yellow
6- 12	Gravel, reddish-brown
12- 14	Clay, gray

* * * *

Test Hole 19
Location: SE¼SE¼SW¼NW¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: 12 feet

0- 1	Topsoil
1- 5	Clay, grayish-yellow
5- 10	Clay, pebbly
10- 15	Clay, gray, compact

* * * *

Test Hole 20
Location: SE¼NE¼NE¼NW¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: 12 feet

0- 2	Topsoil
2- 10	Clay, yellow
10- 69	Clay, gray
69- 85	Clay, gray, sandy

* * * *

Test Hole 21 (Rotary Test Hole)
Location: NE¼NE¼NE¼NW¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: not measured

0- 2	Topsoil
2- 28	Clay, yellow, sandy
28- 33	Clay, brownish-gray
33- 37	Sand and gravel
37-215	Clay, gray, sandy
215-222	Clay, yellowish-brown, sandy
222-224	Sand and gravel
224-291	Clay, yellowish-brown
291-295	Sand
295-328	Clay, yellowish-brown
328-332	Rocks
332-502	Clay, sandy
502-518	Gravel and sand; some clay
518-545	Shale, black

* * * *

Test Hole 22
Location: NW¼NW¼NW¼SE¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: 2 feet

0- 1	Topsoil
1- 13	Clay, very pebbly
13- 99	Clay, gray, pebbly

* * * *

Test Hole 23 (Rotary Test Hole)
Location: SE¼SE¼SE¼NE¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: not measured

Test Hole 23 – continued.

0- 2	Topsoil
2- 17	Clay, yellowish-brown
17- 60	Clay, gray
60- 65	Sand and gravel
65-102	Clay, dark-gray
102-108	Sand and gravel; some clay
108-215	Clay, dark-gray, pebbly

* * * *

Test Hole 24 (Rotary Test Hole)
Location: NE¼NE¼SE¼SE¼ sec. 24, T. 115 N., R. 55 W.
Depth to water: not measured

0- 2	Topsoil
2- 15	Clay, yellow
15- 85	Clay, gray, gravelly
85-100	Clay, gray, sandy
100-200	Clay, gray; sand and gravel stringers

* * * *

Test Hole 25 (Rotary Test Hole)
Location: SW¼SW¼SW¼SW¼ sec. 19, T. 115 N., R. 54 W.
Depth to water: not measured

0 - 2	Topsoil
2 - 25	Clay, yellow, pebbly
25 - 75	Clay, gray
75 - 88	Sand and gravel, medium to coarse; some clay
88 -110?	Clay
110?-116	Sand and gravel
116 -127	Clay, gray
127 -130	Sand, coarse
130 -141	Clay, gray
141 -150?	Sand and gravel
150?-287	Clay, gray, pebbly
287 -288	Rock
288 -502	Clay, brownish-gray
520 -524	Sand and gravel
524 -530	Shale, black

* * * *

Test Hole 26
Location: NW¼NE¼NW¼NW¼ sec. 34, T. 115 N., R. 55 W.
Depth to water: dry hole

0- 2	Topsoil
2- 26	Clay, brown; some sand
26- 70	Clay, gray, pebbly

* * * *

Test Hole 27
Location: NE¼NE¼NW¼NE¼ sec. 25, T. 115 N., R. 55 W.
Depth to water: 2 feet

0- 2	Topsoil
2- 10	Sand, yellowish-brown
10- 15	Clay, gray, compact

* * * *

Test Hole 28 (Rotary Test Hole)
Location: NW¼NW¼NW¼NW¼ sec. 30, T. 115 N., R. 54 W.
Depth to water: not measured

0- 2	Topsoil
2- 35	Clay, yellowish-brown
35-103	Clay, gray, pebbly
103-110	Clay, gray; some gravel stringers
110-170	Clay, gray, pebbly

* * * *

APPENDIX B

Well Records in the Hazel Area

Use: D, domestic; DN, domestic, but not used for drinking; S, stock

Source: G, glacial outwash and gravel lenses; DF, Dakota Formation

Name	Location	Depth of Well (feet)	Depth of Water (feet)	Source	Use
Hallauer, E.	SE¼SW¼SE¼SE¼ sec. 27, T. 116 N., R. 54 W.	65	35	G	
Hallauer, E.	SE¼SW¼SE¼SE¼ sec. 27, T. 116 N., R. 54 W.	14		G	
Hallauer, E.	SE¼SW¼SE¼SE¼ sec. 27, T. 116 N., R. 54 W.	65	12	G	
Born, R.	SE¼SE¼SE¼SW¼ sec. 29, T. 116 N., R. 54 W.	96		G	
Schamens, A.	SW¼SW¼SW¼SE¼ sec. 31, T. 116 N., R. 54 W.	395	65?	G	D
Schamens, A	SW¼SW¼SW¼SE¼ sec. 31, T. 116 N., R. 54 W.	385		G	
Mischke, E.	NW¼NE¼NE¼SE¼ sec. 31, T. 116 N., R 54 W.	30	2?	G	D,S
Cypher, M.	NE¼NE¼NE¼NW¼ sec. 32, T. 116 N., R. 54 W.	90	45-50	G	D
Klatt, E.	NW¼NE¼NW¼NE¼ sec. 33, T. 116 N., R. 54 W.	96	21-55	G	D,S
Wolf, L.	SE¼NW¼SE¼SE¼ sec. 33, T. 116 N., R. 54 W.	70	30	G	S
Hallauer, B.	SE¼NW¼NW¼ sec. 34, T. 116 N., R. 54 W.	75	35	G	D,S
Staufer, L.	NE¼NE¼SE¼SE¼ sec. 34, T. 116 N., R. 54 W.	32	10	G	D,S
Paulson, A.	NW¼SE¼SE¼SW¼ sec. 25, T. 116 N., R. 55 W.	425	260?	G	D,S
Papka, B.	NE¼SW¼SE¼SE¼ sec. 25, T. 116 N., R. 55 W.	?	?	G	?
Paulson, E.	SW¼SW¼SE¼ sec. 26, T. 116 N., R. 55 W.	145		G	S

Name	Location	Depth of Well (feet)	Depth of Water (feet)	Source	Use
Bastian, E.	SE¼SE¼SE¼SE¼ sec. 29, T. 116 N., R. 55 W.	280		G	D,S
Eidsness, H.	SW¼NE¼SE¼SE¼ sec. 31, T. 116 N., R. 55 W.	70-90?		G	S
Eidsness, L.	SE¼NW¼SW¼NW¼ sec. 32, T. 116 N., R. 55 W.	70-90?		G	S
Thoreson, C.	NW¼NW¼NW¼SW¼ sec. 33, T. 116 N., R. 55 W.	90		G	S
Kittelson, F.	SW¼NW¼NE¼NW¼ sec. 34, T. 116 N., R. 55 W.	460		G	D,S
Florey, B.	SW¼NE¼NE¼ sec. 34, T. 116 N., R. 55 W.	430		G	D,S
Trumm, M.	SW¼NE¼SE¼ sec. 35, T. 116 N., R. 55 W.	70?		G	D,S
Mischke, D.	NE¼SW¼NW¼ sec. 2, T. 115 N., R. 54 W.			G	
Mischke, W.	NW¼SW¼SW¼ sec. 2, T. 115 N., R. 54 W.	85	50?	G	D
Klatt, V.	SE¼SW¼SW¼ sec. 3, T. 115 N., R. 54 W.	80?	30	G	D,S
Baxter, E.	NW¼NW¼NW¼NW¼ sec. 3, T. 115 N., R. 54 W.	40-50	20-30	G	D
Tarums,	SE¼SE¼NE¼NE¼ sec. 5, T. 115 N., R. 54 W.	32	4?	G	D
Tarums,	SE¼SE¼NE¼NE¼ sec. 5, T. 115 N., R. 54 W.	65		G	S
Fuerstenau,	SE¼SE¼NW¼NW¼, sec. 5, T. 115 N., R. 54 W.	140	40?	G	D
Fuerstenau, V.	SW¼SE¼NE¼NE¼ sec. 6, T. 115 N., R. 54 W.	60	30	G	D,S
Fuerstenau, M.	NE¼NE¼SE¼SE¼ sec. 6, T. 115 N., R. 54 W.	80	60?	G	D,S
Leiseth, H.	NE¼NE¼NE¼SE¼ sec. 7, T. 115 N., R. 54 W.	70		G	
Baxter, A.	NW¼NW¼SE¼SE¼ sec. 8, T. 115 N., R. 54 W.	20		G	S

Name	Location	Depth of Well (feet)	Depth of Water (feet)	Source	Use
Baxter, O.	NW¼NW¼SE¼SE¼ sec. 8, T. 115 N., R. 54 W.	60		G	S
DeVine, B.	NW¼NW¼NW¼NW¼ sec. 9, T. 115 N., R. 54 W.	38	20	G	
Griffin, D.	NE¼NE¼NW¼NE¼ sec. 9, T. 115 N., R. 54 W.	52	8?	G	
James, K.	SW¼SW¼SW¼NE¼ sec. 10, T. 115 N., R. 54 W.	55	43?	G	
Struckman, R.	NW¼NW¼NW¼SW¼ sec. 11, T. 115 N., R. 54 W.	42	27	G	D
Bevers, A.	SW¼NE¼NE¼NW¼ sec. 12, T. 115 N., R. 54 W.	72	60?	G	
Christman,	SW¼SE¼NW¼ sec. 14, T. 115 N., R. 54 W.	450		G	D
Mischke, A.	SW¼SW¼SW¼SW¼ sec. 15, T. 115 N., R. 54 W.	80	30	G	D
Mischke, H.	SW¼SW¼SE¼SE¼ sec. 17, T. 115 N., R. 54 W.	70-80	?	G	D
Ludtke,	SE¼NW¼SE¼NW¼ sec. 17, T. 115 N., R. 54 W.	58	44	G	D
Parliament, W.	SE¼SE¼SW¼SW¼ sec. 18, T. 115 N., R. 54 W.	70	55	G	S
Adams, H.	SE¼NW¼NW¼NW¼ sec. 19, T. 115 N., R. 54 W.	70	?	G	S
Adams, H.	SE¼NW¼NW¼NW¼ sec. 19, T. 115 N., R. 54 W.	72	54	G	S
Singrey, D.	NE¼NW¼SW¼NW¼ sec. 20, T. 115 N., R. 54 W.	80	60	G	D,S
Adams, E.	SE¼NE¼NE¼NW¼ sec. 21, T. 115 N., R. 54 W.	80	60	G	S
McNamara, H.	SW¼SE¼SE¼ sec. 22, T. 115 N., R. 54 W.	60	50?	G	S
McNamara, H.	NE¼SE¼NE¼ sec. 22, T. 115 N., R. 54 W.	49	44	G	D,S
Roe, L.	SE¼SE¼SE¼NE¼ sec. 27, T. 115 N., R. 54 W.	52	24	G	S

Name	Location	Depth of Well (feet)	Depth of Water (feet)	Source	Use
Wending, G.	NE¼SW¼SE¼SW¼ sec. 29, T. 115 N., R. 54 W.	80	55?	G	S
Amrhien, L.	NE¼NW¼NE¼ sec. 29, T. 115 N., R. 54 W.	215	80?	G	D,S
Amrhien, H.	NW¼NE¼NW¼ sec. 30, T. 115 N., R. 54 W.	500	90-100	G	D,S
Halzwarth, A.	NW¼SW¼NE¼NE¼ sec. 30, T. 115 N., R. 54 W.	494	?	G	D,S
Arnold, R.	NW¼NW¼NW¼SW¼ sec. 30, T. 115 N., R. 54 W.	80	?	G	D
Schlenken, F.	SE¼SE¼SE¼SE¼ sec. 31, T. 115 N., R. 54 W.	475	375	G	D,S
Burgman, D.	SE¼SE¼SW¼SE¼ sec. 32, T. 115 N., R. 54 W.	40	20	G	D,S
Stormo, N.	SW¼SW¼NE¼SE¼ sec. 33, T. 115 N., R. 54 W.	60	?	G	S
Anderson, J.	SE¼SE¼NE¼NE¼ sec. 33, T. 115 N., R. 54 W.	50-60	?	G	S
Lakness, M.	SW¼SE¼SE¼SW¼ sec. 34, T. 115 N., R. 54 W.	70	20	G	S
Green, E.	NE¼NW¼NW¼NW¼ sec. 35, T. 115 N., R. 54 W.	50	22	G	S
Green, E.	NE¼NW¼NW¼NW¼ sec. 35, T. 115 N., R. 54 W.	10	10	G	D
Abraham, C.	NE¼NE¼NE¼NW¼ sec. 1, T. 115 N., R. 55 W.	417	160	G	D,S
Kettwig, J.	SW¼NE¼NW¼NE¼ sec. 1, T. 115 N., R. 55 W.	200	?	G	D,S
Struckman, G.	SW¼NE¼NE¼NE¼ sec. 3, T. 115 N., R. 55 W.	15?	?	G	D,S
Giedd, C.	SW¼SW¼SW¼SE¼ sec. 4, T. 115 N., R. 55 W.	180		G	D,S
Roskam, A.	NE¼NE¼SE¼ sec. 5, T. 115 N., R. 55 W.	70		G	S
Lakness, A.	SE¼SW¼NW¼NW¼ sec. 5, T. 115 N., R. 55 W.	330		G	S

Name	Location	Depth of Well (feet)	Depth of Water (feet)	Source	Use
Johnson, N.	NE¼NE¼NE¼NE¼ sec. 5, T. 115 N., R. 55 W.	80?		G	S
Rider, L.	NW¼SE¼SE¼SE¼ sec. 8, T. 115 N., R. 55 W.	500?		G	D,S
Gjerde, R.	SE¼NE¼SE¼SE¼ sec. 11, T. 115 N., R. 55 W.	80	54?	G	S
Abraham, H.	NE¼NE¼SE¼SW¼ sec. 12, T. 115 N., R. 55 W.	28	12	G	S
Johnson, S.	SW¼NE¼NE¼ sec. 14, T. 115 N., R. 55 W.	70-80		G	S
Sour, C.	SE¼SE¼SE¼SW¼ sec. 14, T. 115 N., R. 55 W.	517		G	D,S
Gjerde, L.	NW¼NW¼NE¼NE¼ sec. 15, T. 115 N., R. 55 W.	80	66?	G	D,S
Kidman, R.	SE¼SW¼SW¼SW¼ sec. 16, T. 115 N., R. 55 W.	380?		G	D,S
Rider, D.	SW¼NE¼NE¼NW¼ sec. 17, T. 115 N., R. 55 W.	60		G	D,S
Fritz, E.	NW¼SE¼SE¼SW¼ sec. 17, T. 115 N., R. 55 W.	?	?	G	?
Abraham, H.	NE¼NE¼NE¼NE¼ sec. 20, T. 115 N., R. 55 W.	60-70	15-20	G	DN
Janssen, D.	NE¼SE¼SE¼SW¼ sec. 20, T. 115 N., R. 55 W.	72?		G	S
Singrey, V.	NE¼NE¼NW¼SE¼ sec. 22, T. 115 N., R. 55 W.	480-500		G	S
Jorgensen, H.	SW¼NW¼NE¼NE¼ sec. 23, T. 115 N., R. 55 W.	75-80		G	S
Wattawa, C.	SE¼SE¼SE¼NW¼ sec. 24, T. 115 N., R. 55 W.	25	6	G	D,S
Singrey, L.	NE¼SW¼SE¼SW¼ sec. 23, T. 115 N., R. 55 W.	560-580		G	DN,S
Luken, W.	NW¼NE¼NE¼ sec. 25, T. 115 N., R. 55 W.	528	?	G	?
Parliament, W.	SW¼NW¼NW¼NW¼ sec. 25, T. 115 N., R. 55 W.	70		G	S

Name	Location	Depth of Well (feet)	Depth of Water (feet)	Source	Use
Phillips, A. W.	NE¼SE¼NE¼SE¼ sec. 36, T. 115 N., R. 55 W.	900?		G	S
Kettwig, H.	NE¼NW¼NW¼SE¼ sec. 27, T. 115 N., R. 55 W.	110		G	D,S
Keatieng, R.	SE¼NW¼SW¼NW¼ sec. 28, T. 115 N., R. 55 W.	350		G	S
Bachek, O.	NW¼NE¼SE¼SE¼ sec. 28, T. 115 N., R. 55 W.	90		G	D,S
Bochuk, D.	NE¼SW¼NW¼SW¼ sec. 28, T. 115 N., R. 55 W.	200		G	D,S
Bochuk, D.	NE¼SW¼NW¼SW¼ sec. 28, T. 115 N., R. 55 W.	60		G	D,S
Bruha, J.	NE¼SW¼SE¼SE¼ sec. 29, T. 115 N., R. 55 W.	160?		G	D,S
Bachek, A.	NE¼NW¼SW¼NW¼ sec. 33, T. 115 N., R. 55 W.	90		G	S
Bachek, A.	NE¼NW¼SW¼NW¼ sec. 33, T. 115 N., R. 55 W.	26		G	S
Beman, Q.	SW¼SW¼SW¼SW¼ sec. 34, T. 115 N., R. 55 W.	1236		DF	D,S
Smith, F.	NE¼SW¼NE¼NW¼ sec. 34, T. 115 N., R. 55 W.	40?		G	D,S
Horn, L.	NW¼SE¼SE¼NE¼ sec. 35, T. 115 N., R. 55 W.	75		G	DN,S
Horn, L.	NW¼SE¼SE¼NE¼ sec. 35, T. 115 N., R. 55 W.	10		G	DN,S
Bevers, L.	SW¼NE¼SE¼SE¼ sec. 36, T. 115 N., R. 55 W.	72	62?	G	S
Everson, D.	SE¼SE¼SW¼SE¼ sec. 3, T. 114 N., R. 54 W.	60	25	G	D,S
Dudley,	SE¼SW¼SE¼SW¼ sec. 4, T. 114 N., R. 54 W.	60	?	G	
Stormo, M.	NW¼SW¼SW¼NW¼ sec. 4, T. 114 N., R. 54 W.	50	?	G	D,S
Hennings, E.	NW¼NE¼NE¼SE¼ sec. 4, T. 114 N., R. 54 W.	60		G	D,S

Name	Location	Depth of Well (feet)	Depth of Water (feet)	Source	Use
Find, W.	NE¼NW¼NW¼SW¼ sec. 5, T. 114 N., R. 54 W.	65	20?	G	S
Johnson, E.	NW¼NW¼SW¼SE¼ sec. 5, T. 114 N., R. 54 W.	50-60	?	G	S
Seppanen, S.	NE¼NE¼NE¼NE¼ sec. 7, T. 114 N., R. 54 W.	300	?	G	D,S
Find C.	NW¼NW¼NW¼NW¼ sec. 8, T. 114 N., R. 54 W.	16	10?	G	D,S
Buri, N.	NW¼NW¼NW¼NW¼ sec. 9, T. 114 N., R. 54 W.	60	20	G	D
Koistinen, W.	NW¼NW¼NW¼NW¼ sec. 10, T. 114 N., R. 54 W.	45	30	G	D,S
Bevers, A.	SW¼NE¼NE¼NW¼ sec. 12, T. 114 N., R. 54 W.	72	60	G	
Horn, W.	NW¼NW¼NW¼NE¼ sec. 1, T. 114 N., R. 55 W.	30	15	G	D,S
Luken, W.	NE¼NE¼NE¼NE¼ sec. 2, T. 114 N., R. 55 W.	494	?	G	D,S
Iverson, D.	NW¼SE¼SE¼SE¼ sec. 2, T. 114 N., R. 55 W.	75?		G	S
Yahn, L.	SE¼SE¼SE¼SE¼ sec. 3, T. 114 N., R. 55 W.	92		G	D,S
Knedle, E.	SE¼NE¼NW¼NE¼ sec. 4, T. 114 N., R. 55 W.	200		G	S
Wheelboy, C.	SW¼SW¼SW¼SW¼ sec. 4, T. 114 N., R. 55 W.	?		G	S
Rasmussen, A.	NW¼NW¼NW¼NW¼ sec. 9, T. 114 N., R. 55 W.	?	?	G	S
Gjerde, M.	SW¼NE¼NE¼NE¼ sec. 10, T. 114 N., R. 55 W.	58		G	S
Lien, R.	SE¼NW¼NE¼NW¼ sec. 11 T. 114 N., R. 55 W.	70?		G	S