STATE OF SOUTH DAKOTA
Nils Boe, Governor

SOUTH DAKOTA STATE GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 38

GROUND-WATER SUPPLY FOR THE CITY OF WESSINGTON SPRINGS, SOUTH DAKOTA

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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota Geological Survey from July 14 to August 13, 1965, in and around the city of Wessington Springs, Jerauld County, South Dakota (fig. 1). The purpose of the investigation was to locate aquifers in the area that could be used to supply ground water for future water needs of the city, and to determine the effect on the present water supply, if any, of irrigation wells in the area to the southwest of the city.

Wessington Springs presently obtains its water from three springs supplied by natural discharge on the Wessington Hills immediately west of the city. Although the present water supply is adequate for the city's needs, it was desired to determine the geologic and hydrologic relationship of the buried glacial aquifers in the area. For this reason, the services of the State Geological Survey were requested.

A survey of approximately 100 square miles was conducted in and around the city of Wessington Springs. The survey consisted of geologic mapping, obtaining a well inventory, drilling 19 rotary test holes, and 36 auger test holes and collecting three water samples for analysis (see fig. 2).

As a result of this survey, it is recommended that the city maintain and continue its present water supply which is of the best quality of any water in the area. It is further recommended that if numerous high-capacity wells are developed in the aquifer southwest of the city, observation wells be placed in both aquifers to determine whether there is a lowering of the water level or artesian pressure in the aquifer from which the city springs produce water. It is concluded from the information now available that the aquifer in which the city springs are developed and the aquifer southwest of town are separated by a buried bedrock ridge and are probably not interconnected.

The field work and preparation of this report were performed under the supervision of George Shurr and Fred V. Steece, geologists for the South Dakota Geological Survey. Lloyd R. Helseth and Robert Stach of the South Dakota Geological Survey drilled the rotary test holes in the area. Aldean Fickbohm and Ron Helwig operated the Survey's truck-mounted auger drill. Nat Lufkin of the Geological Survey analyzed the water samples collected for this project. Thanks is due the Wessington Springs City Council, and other residents of the area who provided helpful information during the course of the project.

Location and Extent of Area

The city of Wessington Springs is located in Jerauld County in central South Dakota and has a population of 1,488 (1960 census). The area studied is located partly in the James Basin division of the Central Lowland physiographic province and partly in the Coteau du Missouri division of the Great Plains physiographic province (fig. 1). An area of about 100

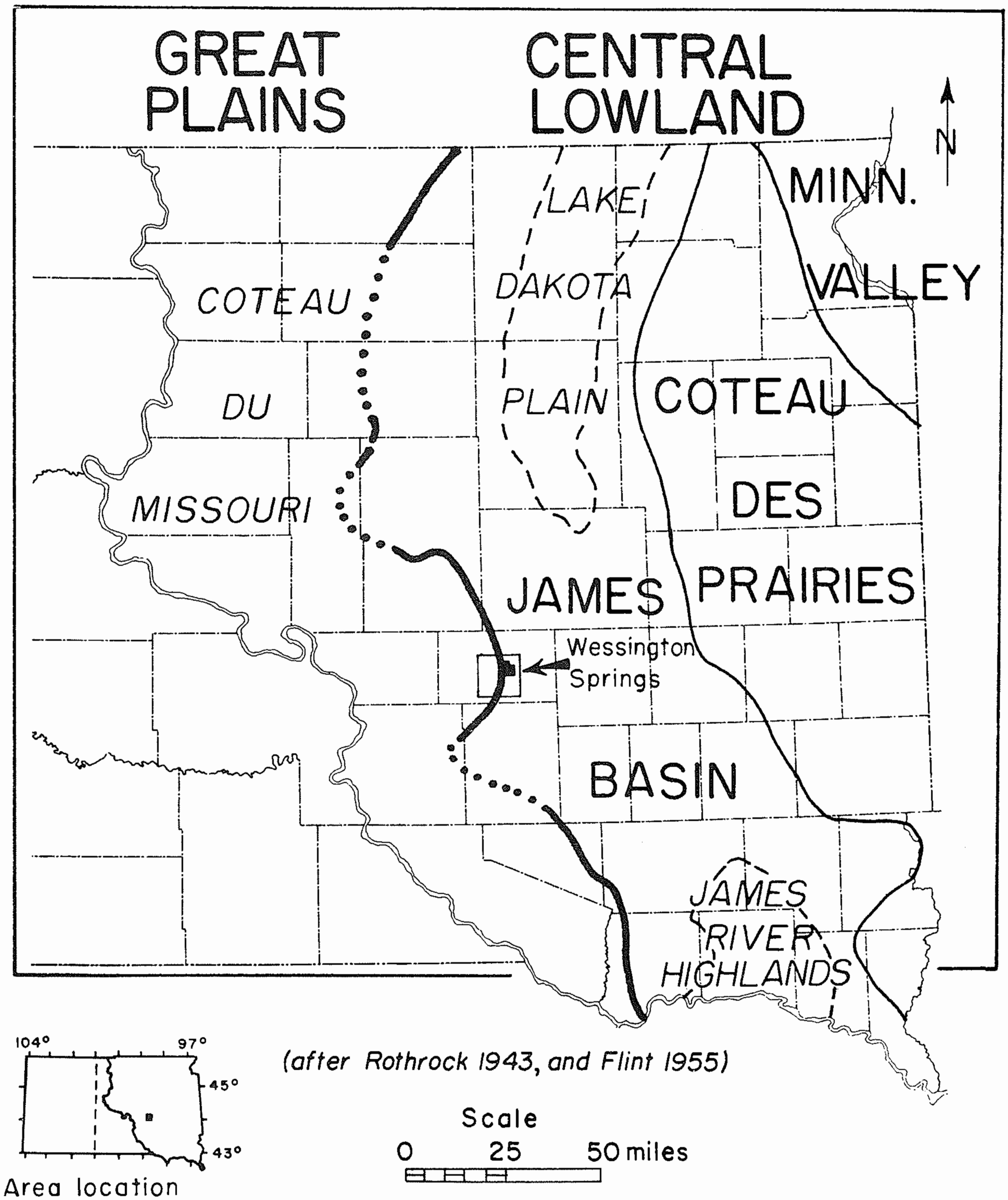

Figure I. Map showing location of the Wessington Springs area and the Physiographic divisions of eastern South Dakota.

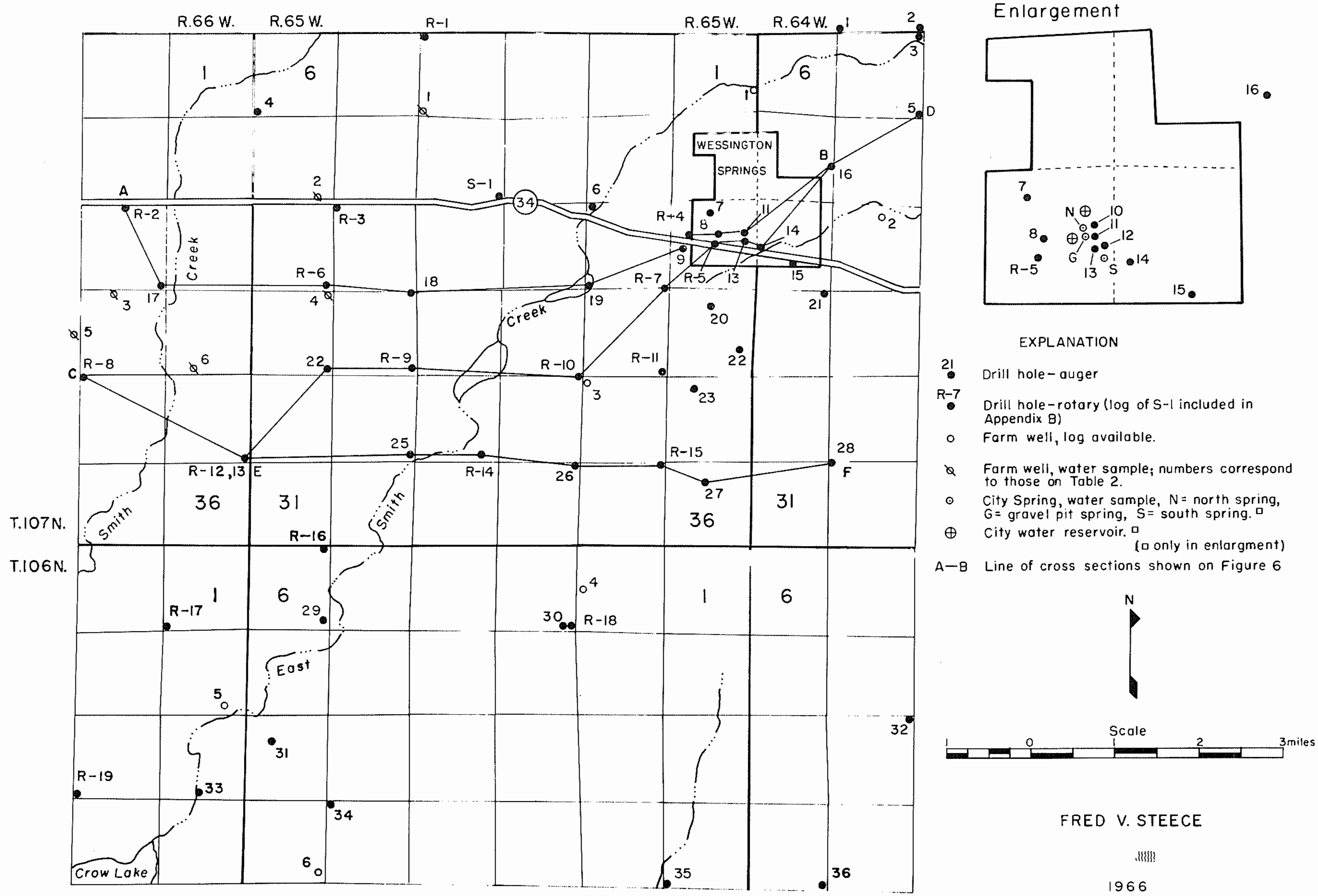

Figure 2. Data map of the Wessington Springs area.

square miles was studied for this project.

Climate

The climate is continental temperate, with large daily and seasonal fluctuations in temperature. The average daily temperature at Wessington Springs is about 47 degrees F., and the average annual precipitation is about 20 inches.

Topography and Drainage

The topography east of the Wessington Hills is mainly gently rolling plains. The topography west of the hills is hummocky, undrained and rugged.

Drainage in the area is controlled by Firesteel Creek east of the Wessington Hills and by Smith Creek and East Smith Creek west of the Wessington Hills.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Wessington Springs area are the result of continental glaciation during the Pleistocene Epoch, and from erosion and deposition since that time. The glacial deposits are collectively called drift, and are divided into till and outwash deposits. Till consists of clay and silt randomly mixed with boulders, pebbles, and sand, which were carried and deposited by glacial ice. Glacial till comprises the major portion of the surficial deposits in the Wessington Springs area (fig. 3). Outwash is better sorted than till and consists mainly of pebbles and sand with lesser amounts of silt, cobbles, and boulders. Outwash is the material deposited by meltwater streams from the wasting glacial ice. Only several small bodies of surface outwash are present in the western part of the area (see fig. 3). However, outwash deposits are present in the western and central parts of the area (fig. 4).

Colluvium consists of clay that is chiefly reworked shale and till deposited at the foot of the Wessington Hills by slope wash since the retreat of the glaciers (fig. 3). Alluvium is stream-deposited silt, sand, and clay laid down by recent streams also since the glaciers retreated. Alluvium is present in the mapped area along Smith Creek, East Smith Creek and along tributaries to Firesteel Creek that originate in the Wessington Hills.

Exposed Bedrock

Several small exposures of Tertiary age occur near the crest of the Wessington Hills less than a mile west of Wessington Springs. These deposits consist of sandstone, silt, and clay of the Valentine Formation (Green, 1965). Numerous exposures of Pierre Shale occur on the steep slope of the Wessington Hills, particularly where streams have cut deep ravines. As much as 50 feet of Pierre Shale is exposed in some of the ravines.

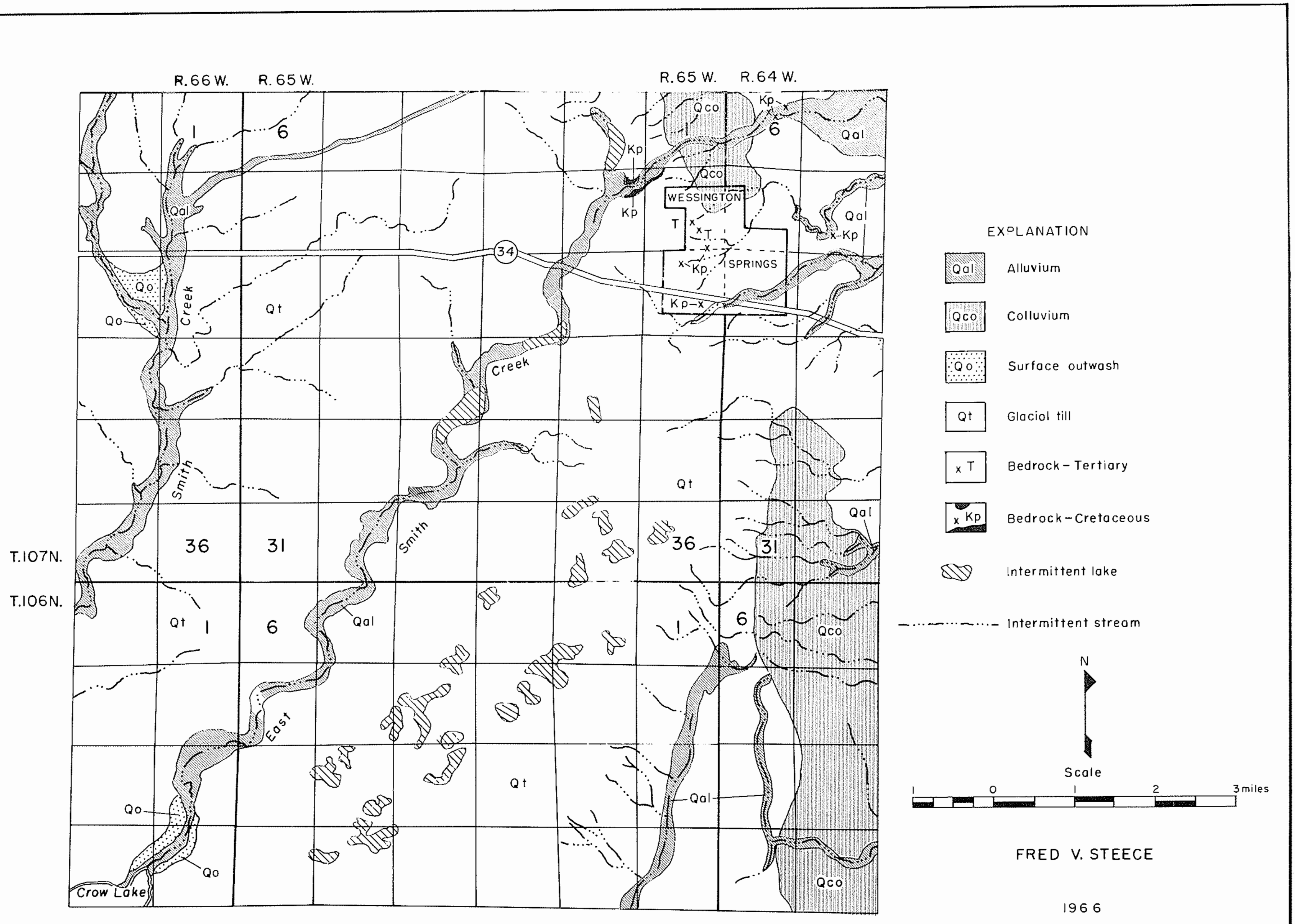

Figure 3. Geologic map of the Wessington Springs area.

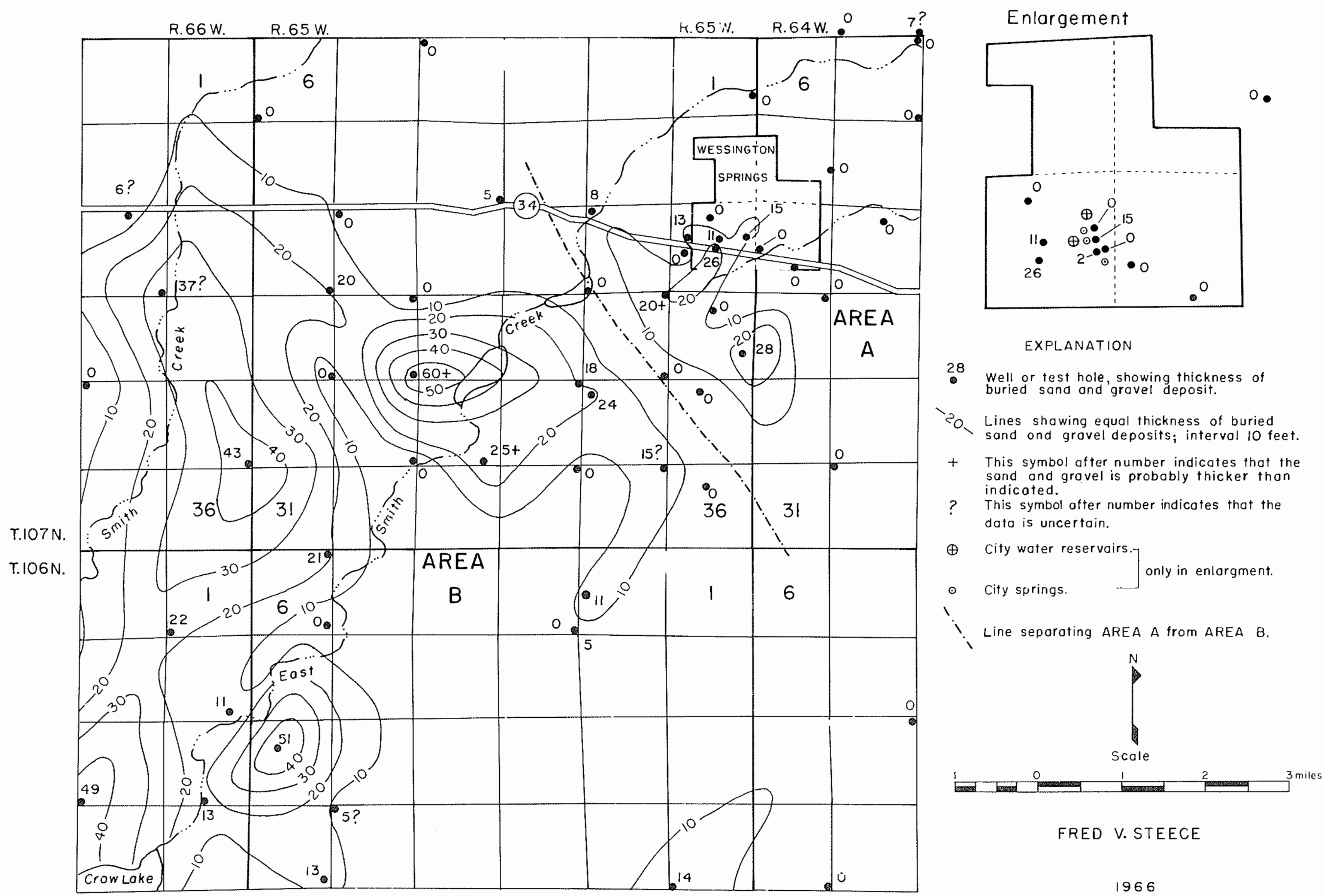

Figure 4. Map showing thickness of buried sand and gravel outwash deposits in the Wessington Springs area.

Subsurface Bedrock

Stratified rocks of Cretaceous age lie beneath the surface deposits in the Wessington Springs area. The Pierre Shale and several small areas of Tertiary rocks are found immediately beneath the glacial drift. The Pierre Shale is underlain in descending order by the Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Group, all of Cretaceous age and by Precambrian granite that is the basement rock. The Cretaceous rocks are approximately 1600 feet thick in the Wessington Springs area. Table 1 summarizes the sequence of bedrock formations, their character and their water-bearing properties.

Figure 5 is a contour map showing the approximate configuration of the surface of the bedrock as it would appear if all the glacial deposits were removed. This map shows that the surface of the bedrock is variable and is characterized by several topographic highs and lows. There is a bedrock ridge about two miles west of town. The bedrock surface slopes gradually east from this ridge for about two miles and then more steeply along the face of the Wessington Hills. This steep slope gives way to a more gradual slope about one mile east of town into the James Basin. The bedrock slopes southwestward from this buried bedrock ridge into a bedrock valley that trends southward leaving the area in the vicinity of Crow Lake.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Despite the common belief that ground water is found in "veins" crisscrossing the land in a haphazard maze, it is known that water occurs almost everywhere in the ground at a depth below the surface that varies from a few feet to tens, hundreds, or even thousands of feet. The top of this zone of water saturation is known as the water table.

Almost all ground water is derived from precipitation. Rain or melting snow either seeps 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 seeps to the ground-water table.

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

Discharge is the removal of ground water from storage in an aquifer, and is accomplished by evaporation and transpiration by plants, by lateral or upward seepage through springs or into surface bodies of water, by underflow of water in temporary storage, and by wells.

The volume of water capable of being stored in a saturated material is equal to the volume of voids or pore space of the material. A measurement of the ability of a material to store water is called porosity. Porosity is the ratio of the volume of voids to the volume of rocks. The shape and arrangement of grains in a material affects the porosity greatly, but size

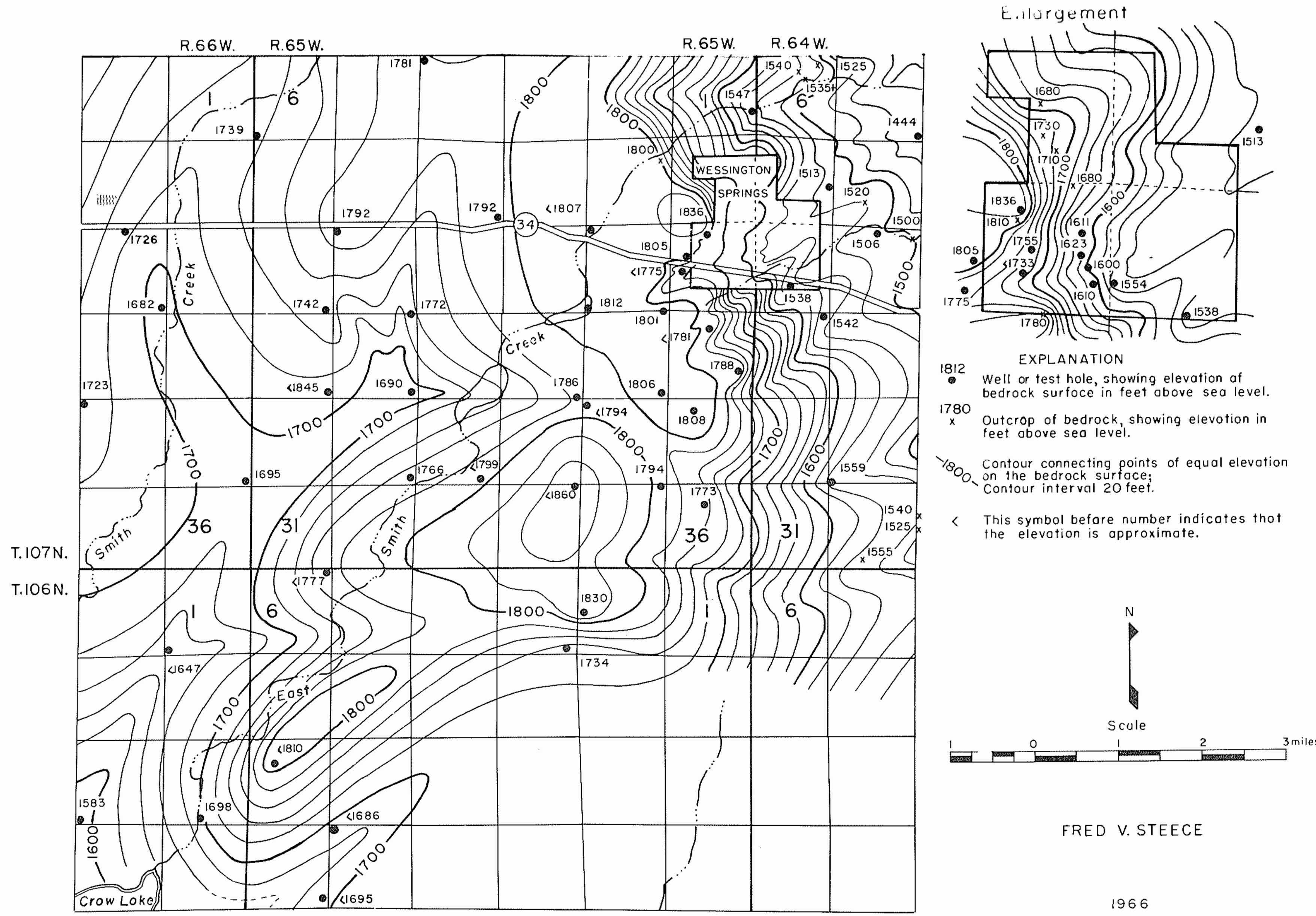

Figure 5. Map showing configuration of the buried bedrock surface in the Wessington Springs area.

Table 1.--Generalized columnar section of the Wessington Springs area, showing the subsurface rocks and their water-bearing properties.

System	Series	Geologic Unit	Thickness (feet)	Description	Water-bearing Properties
Quaternary	Recent	Alluvium and Colluvium	0- 20	Alluvium: Dark silt & clay, some Sand and gravel; fossils.	Permeable zones may contain ground water.
				Colluvium: Dark clay derived from Pierre Shale and till, compact.	Impermeable; not an aquifer.
	Pleistocene	Glacial Drift	0-215	Yellow to gray pebbly clay; sand and gravel; lake deposits.	Permeable sand and gravel layers contain ground water which readily yields water to wells & has a slight artesian pressure.
Tertiary	Pliocene	Valentine Formation	0- 50	Tan to green sandstone, silt, clay and sands; compact; fossils.	Impermeable; not an aquifer.
Cretaceous	Upper Cretaceous	Pierre Shale	450-660	Dark gray to black fissile to massive clay-shale; few fossils; some bentonite beds; some marl beds.	Impermeable; not an aquifer.
		Niobrara Marl	90	Gray calcareous shale or marl; abundant fossils; pyrite concretions; has speckled appearance.	Permeable zones may yield soft water to wells; slight artesian pressure.
		Carlile Shale	180	Gray to black noncalcareous fissile shale; few fossils; pyrite concretions.	Impermeable; not an aquifer.
		Greenhorn Limestone	50	Mainly brownish-gray calcareous shale or marl; some thin limestone beds; speckled appearance; abundant fossils.	Permeable zones may yield soft water to wells; slight artesian pressure.
		Graneros Shale	200	Gray to black fissile, noncalcareous shale; few thin limestone and sandstone beds; fossils; pyrite.	Mainly impermeable; sandy zones may yield water to wells.
	Lower ??	Dakota Group	270	Brown to tan sand and sandstone, fine to medium grained; thin shale layers.	Excellent aquifer; yields hard water to wells; artesian pressure; wells do not flow in this area.
Precambrian		Granite	78+	Weathered pink biotite granite.	Impermeable; not an aquifer.

of the grains has little effect. Therefore, if two identical containers are considered, one filled with sand and the other filled with gravel, and if the sand and gravel grains have the same shape and packing both would hold approximately the same amount of water. Sands and gravels usually have porosities that range from 20 to 40 percent, whereas sandstones usually have porosities of 15 to 25 percent. The lower porosity of sandstones results from closer packing and cementation of the grains.

The rate at which water under pressure will seep through an earth material is defined as the permeability of the substance. Water will pass through a material with interconnected pores but will not pass through material with pores that are not connected, even if the latter material is more porous. Therefore, permeability and porosity are not synonymous terms. As an example, glacial till, which has a high percentage of silt and clay, may have high porosity but yield only small amounts of water because of low permeability.

Ground Water in Alluvium

The alluvium along Smith and East Smith Creeks and in several small valleys in the southeast and northeast parts of the area consists of clay and silt with minor amounts of sand and gravel. This alluvium will not yield water readily to wells because of low permeability.

Ground Water in Glacial Deposits

Till does not yield water readily because of its highly unsorted nature and low permeability.

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

The surface outwash deposits along Smith and East Smith Creeks are too small to be considered as sources for high-yield water wells.

Buried outwash deposits occur in two main areas; one adjacent to the city of Wessington Springs (Area A, fig. 4), and the other in the central and western part of the area (Area B, fig. 4). The buried outwash in Area A is as much as 28 feet thick (fig. 4) and is the aquifer from which the city's springs are being fed. Area B is separated from Area A by a buried bedrock high (see figs. 5 and 6) and, therefore, the two areas are hydraulically independent of one another. Area B contains buried outwash deposits as much as 60 feet thick, and probably would yield large amounts of water to pumped wells.

Ground Water in Bedrock

The Niobrara Marl and Greenhorn Limestone are known to produce water in some parts of the State. Wells that produce from these formations usually have a low yield, and many times the water is of poor quality.

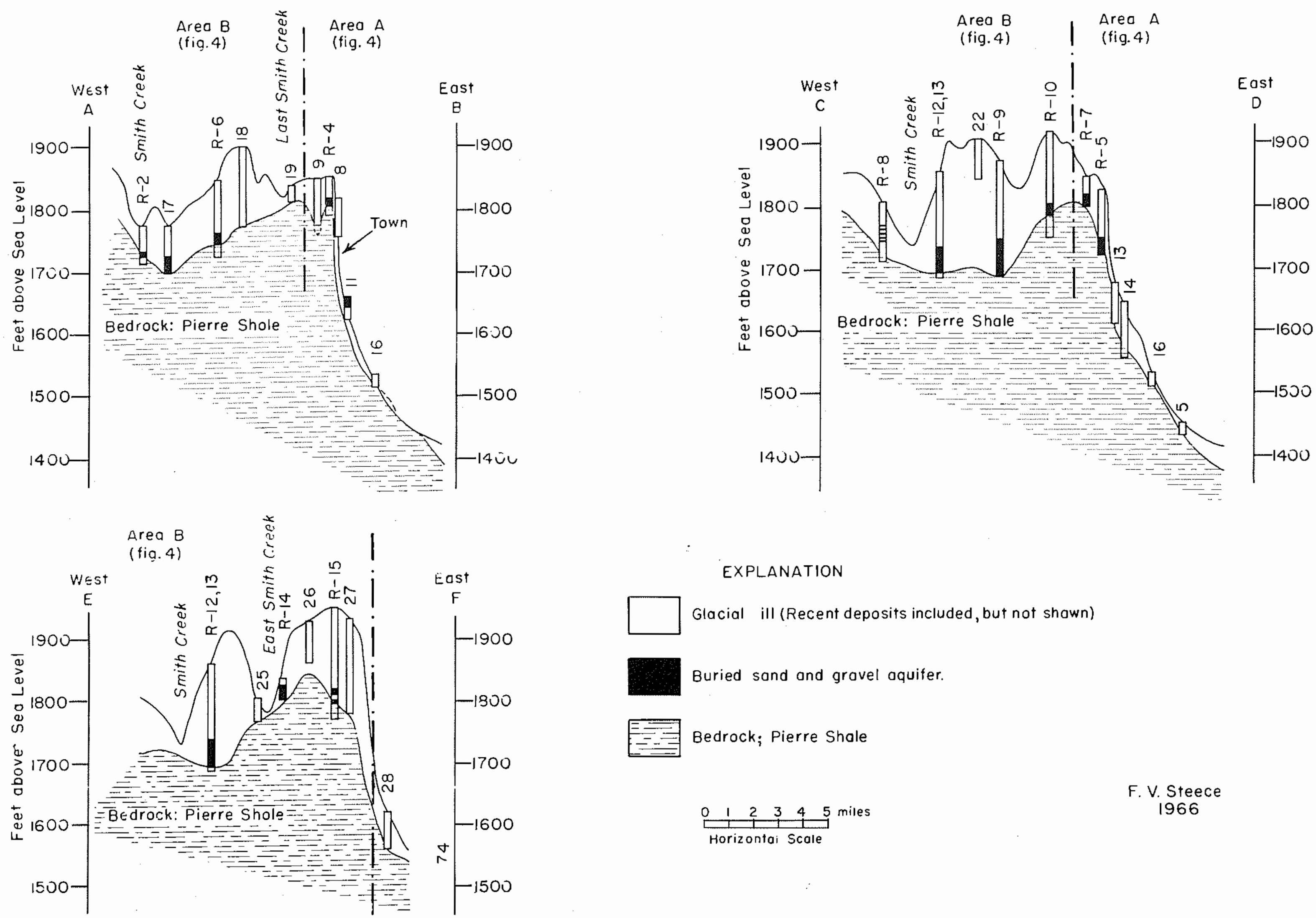

Figure 6. Cross sections of the Wessington Hills through the buried glacial aquifers, Area A and Area B.

Sandstones in the Dakota Group also produce water to wells within the area. The Dakota is about 1100 feet in depth at Wessington Springs. Water from the Dakota would probably rise in wells to within about 200 feet of the surface at Wessington Springs.

Quality of Ground Water

Precipitated water is nearly pure before it reaches the ground; however, all ground water contains minerals which are obtained: (1) from the atmosphere, (2) from soil and underlying deposits as the water percolates downward to the water table, and (3) from deposits below the water table in which the water is circulating. In general, it can be said that the more dissolved minerals a water contains, the poorer its quality. Table 2 is a comparison of various waters in the Wessington Springs area with the city water presently in use and with the Public Health Standards for drinking water. Table 2 shows that water from the three city springs generally is of better quality than any other ground water in the area. The water from gravel pit spring (sample G) exceeds the recommended limits (A, Table 2) in iron, and all three springs exceed the limits in manganese. In all other constituents the water from the three springs is below recommended limits. Samples 2, 3, 4, and 5 are all located in the buried glacial outwash of Area B (fig. 4) and are variable in quality. Sample 6 is the best in quality and exceeds the recommended limits only in manganese.

Samples 1, 7, and 8 are water from bedrock formations. Sample 1 is from sandstones in the Dakota Group and exceeds the recommended limits in sulfate, iron, fluoride, and total solids. Sample 7 is from the Niobrara Marl and exceeds the limits in chloride and total solids. Sample 8 is from the Greenhorn Limestone and exceeds the limits in sulfate, iron, fluoride and total solids. The water from the Dakota is hard, while that from both the Niobrara and Greenhorn is soft.

CONCLUSIONS AND RECOMMENDATIONS

Two glacial outwash aquifers exist in the Wessington Springs area. One aquifer (Area A, fig. 4) supplies water to the three city springs. The other aquifer lies west and southwest of town (Area B, fig. 4) and supplies water to farm wells in the central part of the county.

These aquifers are in buried glacial gravels and range in thickness from zero to 28 feet thick in Area A (fig. 4) and from zero to 60 feet thick in Area B (fig. 4). Test drilling has shown that the two aquifers are separated by a buried bedrock high (see figs. 5 and 6) and that they probably are not hydraulically connected to one another. That is, there is probably no interchange of ground water from Area A to Area B and vice versa.

Recharge to the aquifer in Area A seems adequate for the city's needs; this recharge is probably independent of recharge to Area B. Therefore, wells developed in the aquifer of Area B will probably have no effect on the amount of ground water available from Area A.

Table 2.--Chemical analyses of water from the Wessington Springs area.

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magne-sium	Chlorides	Sulfate	Iron	Manga-nese	Nitrate	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A		---	---	125	250	500*	0.3	0.05	10.0	0.9-1.7**	---	----	1000*
G	G	187	44[a]	42	10	319	0.7	1.6	None	0.2	7.0	645	945
N	G	188	69[a]	41	11	344	0.1	1.9	None	0.2	7.1	643	958
S	G	202	65[a]	52	14	420	None	1.8	None	0.2	7.2	720	1083
1	Kd	257	--	68	65	1217	0.7	None	--	4.5	--	894	2076
2	G	179	820	158	351	1704	0.02	None	55	0.4	--	1096	4216
3	G	158	600	39	250	1150	2.17	--	4	0.7	--	556	2340
4	G	140	660	20	500	800	0.52	--	None	0.5	--	430	2535
5	G	1350	--	1080	113	2335	--	--	--	--	8.4	7700	7800
6	--	57	35	26	None	159	0.08	0.3	None	0.2	--	251	498
7	Kn	21	729	6.7	826	42	0.10	0.05	4.7	0.9	7.7	80	1930
8	Kg	9.3	699	1.2	104	817	0.94	None	0.3	3.4	7.8	28	2060

G, glacial drift; Kd, Dakota Group; Kn, Niobrara Marl; Kg, Greenhorn Limestone.

a Reported as sodium and potassium.
* Modified for South Dakota by State Department of Health (written communication, February 5, 1962).
** Optimum

Samples G, N, and S were analyzed by South Dakota Department of Health.
Samples 1, 2, and 6 were analyzed by State Chemical Laboratory.
Samples 3 and 4 were analyzed by Station Biochemistry, South Dakota State University.
Sample 5 was analyzed by State Geological Survey.
Samples 7 and 8 were taken from Steece and Howells (1965); not shown on Figure 2.

Locations of Water Samples

A. U. S. Dept. of Public Health Drinking Water Standards (1961)
G. Gravel pit spring
N. North spring
S. South spring
1. Maynard Shyrock, SWSW sec. 4, T. 107 N., R. 65 W.
2. Gene Peterson, SESE sec. 7, T. 107 N., R. 65 W.
3. Arent Weaver, NENW sec. 23, T. 107 N., R. 66 W.
4. Mrs. Cleo Pagel, NENE sec. 19, T. 107 N., R. 65 W.
5. George Hodgson, NESE sec. 22, T. 107 N., R. 66 W.
6. Abandoned Farm, SESW sec. 24, T. 107 N., R. 66 W.
7. E. Nelson, SESE sec. 10, T. 108 N., R. 62 W.
8. D. Fredericks, SESW sec. 28, T. 107 N., R. 61 W.

Note: Numbers 7 and 8 are from Sanborn County.

In addition to the buried glacial outwash aquifers, several bedrock aquifers contain water of variable quality. The Niobrara Marl, the Greenhorn Limestone, and sandstones in the Dakota Group are known to produce mineralized water to wells in and near the Wessington Springs area. However, the Niobrara Marl and the Greenhorn Limestone do not yield enough water for a municipal supply. The Dakota Group could supply the city with water but several wells might be required to do so. One or two wells completed in the Dakota Group could be used to supplement the present city supply should the need for such additional water arise.

It is recommended that if a number of high-capacity wells are constructed in the aquifer of Area B that the city hire a licensed well driller to drill observation wells at selected intervals from Area B toward Area A, and to hire a reputable engineering firm to record and analyze any change in quality or amounts of water in the observation wells or the three city springs. If appreciable drawdown takes place in the observation wells or in the city springs because of large-scale pumping from the aquifer in Area B, the city could then take steps to safeguard its water supply by applying to the South Dakota Water Resources Commission for water rights. The aquifer testing described would be helpful should the city of Wessington Springs desire at some future time to draw water from the aquifer in Area B to supplement or replace the present city supply.

It is further recommended that the city maintain and continue using its present water supply.

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APPENDIX A

Logs of Auger Test Holes in the Wessington Springs Area

(for locations see Figure 2)

Test hole location: Letters stand for quarter section, first number for section, second for township north and third for range west.

Test Hole No. 1
Location: SWSW 32-108-64
Elevation: 1485 ± 5 feet
Depth to water: dry hole

0- 2	soil
2-13	till, oxidized, light-brown, very dry
13-29	till, oxidized, light- to dark-brown, hard drilling; gray below 25 feet
29-36	till, oxidized, light-brown, tough, hard drilling; turning to medium-gray at 36 feet
36-42	till, unoxidized, medium-gray, turning to blue-black at 42 feet, tough drilling
42-47	till, unoxidized, blue-black; resembles Pierre Shale but is till; very hard drilling

* * * * *

Test Hole No. 2
Location: SESE 32-108-64
Elevation: 1445 ± 5 feet
Depth to water: dry hole

0- 2	soil
2- 5	till, oxidized, light-brown, silty, sandy; some gravel
5-12	silt, sand and gravel; some clay
12-22	till, oxidized, light-brown
22-27	till, unoxidized, blue-black, tough

* * * * *

Test Hole No. 3
Location: NENE 5-107-64
Elevation: 1445 feet
Depth to water: not measured

0-14	alluvium, dark-brown
14-19	no cuttings

(continued on next page)

Test Hole No. 3--continued

19-24 silt, sandy, saturated and medium-brown clay
24-27 silt, saturated, sandy
27-34 sand, saturated, silty

* * * * *

Test Hole No. 4
Location: SWSW 6-107-65
Elevation: 1790.0 feet
Depth to water: not measured

0- 3	topsoil
3-19	clay, brown, moist; very few pebbles
19-34	clay, gray, moist; few pebbles
34-51	clay, gray, very moist
51	shale

* * * * *

Test Hole No. 5
Location: SESE 5-107-64
Elevation: 1465 feet
Depth to water: not measured

0- 4	colluvium, light- to dark-tan; rudimentary bedding
4- 9	silt, sandy, dark-brown; shale fragments
9-14	shale, weathered (colluvium of reworked shale)
14-21	clay, sandy; iron concretions
21-24	shale, sandy

* * * * *

Test Hole No. 6
Location: NWNW 14-107-65
Elevation: 1840 feet
Depth to water: approximately 9 feet

0- 4	topsoil
4- 9	clay, dark-brown, moist; very few pebbles
9-14	clay, brown, saturated; pebbles
14-24	clay, saturated; 10% coarse sand
24-33	gravel and large rocks
33	large rocks; hole abandoned

* * * * *

Test Hole No. 7
Location: NENW 13-107-65
Elevation: 1850 feet approximately
Depth to water: dry hole

0- 4	topsoil
4-14	clay, brown, moist; few pebbles
14-49	clay, yellow-gray, calcareous; pebbles
49-60	clay, gray, moist; few pebbles
60-75	shale

Note: Electric log available

* * * * *

Test Hole No. 8
Location: SWNE 13-107-65
Elevation: 1820 ± 25 feet
Depth to water: not measured

0- 4	clay, brown, dry; some pebbles
4-14	sand, yellow-brown, fine, dry
14-34	clay, dark-brown, moist; few pebbles
34-54	clay, gray, moist; fewer pebbles
54-65	clay, brown, saturated; 40% medium sand
65	shale

* * * * *

Test Hole No. 9
Location: NWSW 13-107-65
Elevation: 1820 ± 25
Depth to water: not measured

0- 2	topsoil
2- 9	clay, brown, moist; some pebbles
9-14	clay, brown, moist; 20% sand
14-44	clay, dark-brown, moist; few pebbles
44-75	clay, dark-gray; slightly moist, rocks, hard drilling

* * * * *

Test Hole No. 10
Location: SENE 13-107-65
Elevation: 1660 feet approximately
Depth to water: approximately 24 feet
(continued on next page)

Test Hole No. 10--continued

0-19	clay, brown, moist; some pebbles
19-24	clay, gray, moist; some pebbles
24-44	clay, gray, saturated; 10% medium sand
44	shale

* * * * *

Test Hole No. 11
Location: SENE 13-107-65
Elevation: 1660 feet approximately
Depth to water: approximately 4 feet

0- 4	topsoil
4-14	gravel, brown, saturated; some clay
14-19	gravel, fine, saturated
19-37	clay, brown, highly saturated; 20% coarse sand
37	shale

* * * * *

Test Hole No. 12
Location: SENE 13-107-65
Elevation: 1650 feet approximately
Depth to water: not measured

0- 2	topsoil
2- 9	clay, brown, dry; many small pebbles
9-34	clay, brown, moist; few pebbles
34-51	clay, gray, saturated; few pebbles
51	shale

* * * * *

Test Hole No. 13
Location: SENE 13-107-65
Elevation: 1680 feet approximately
Depth to water: flowing well

0- 4	topsoil
4- 9	clay, brown, moist; some pebbles
9-29	clay, brown, saturated; few pebbles
29-58	clay, gray, saturated; pebbles
58-64	clay, gray; some water flowing
64-66	sand, coarse
66	shale

* * * * *

Test Hole No. 14
Location: SWNW 18-107-64
Elevation: 1650 ± 5 feet
Depth to water: not measured

0- 4	clay, brown, dry; some pebbles
4- 9	clay, brown, moist
9-74	clay, gray, moist; few pebbles
74-91	clay, gray, very moist
91	shale

* * * * *

Test Hole No. 15
Location: NWSE 18-107-64
Elevation: 1620 ± 10 feet
Depth to water: not measured

0- 2	topsoil
2- 9	clay, brown, dry; many small pebbles
9-34	clay, brown, moist; pebbles
34-74	clay, gray, moist; few pebbles
74-82	clay, gray, saturated; few pebbles
82	shale

* * * * *

Test Hole No. 16
Location: NESE 7-107-64
Elevation: 1535 ± 5 feet
Depth to water: not measured

0- 2	topsoil
2-22	clay, brown, moist; some pebbles
22	shale

* * * * *

Test Hole No. 17
Location: SESE 14-107-66
Elevation: 1775 ± 25 feet
Depth to water: approximately 24 feet

0- 1	topsoil
1- 8	gravel, medium
8-24	clay, brown, moist; few pebbles
24-29	clay, brown, saturated; pebbles

(continued on next page)

Test Hole No. 17--continued

29-39	clay, brown; 40% coarse sand
39-49	clay, gray; 40% sand; water flowing
49-78	sand, medium; 25% gray clay
78	shale

* * * * *

Test Hole No. 18
Location: NENE 20-107-65
Elevation: 1902.2 feet
Depth to water: approximately 34 feet

0- 2	topsoil
2- 19	clay, brown, moist; few large pebbles
19- 34	clay, gray, moist; few pebbles
34- 39	clay, brown, saturated; 40% medium sand
39- 59	clay, gray, highly saturated; 30% coarse sand
59-130	clay, gray, saturated; 20% medium sand
130	shale

* * * * *

Test Hole No. 19
Location: NWNW 23-107-65
Elevation: 1840 ± 25 feet
Depth to water: approximately 19 feet

0- 4	topsoil
4- 9	clay, dark-brown, moist; few pebbles
9-19	clay, brown, moist; very few pebbles
19-28	clay, brown, saturated
28	shale

* * * * *

Test Hole No. 20
Location: NWNE 24-107-65
Elevation: 1850 ± 25 feet
Depth to water: not measured

0- 3	topsoil
3-24	clay, brown, moist; few pebbles
24-69	clay, gray, moist; few pebbles
69	same; hard drilling

* * * * *

Test Hole No. 21
Location: NENE 19-107-64
Elevation: 1510 ± 10 feet
Depth to water: not measured

0- 2	topsoil
2-14	clay, brown, dry; some pebbles
14-34	clay, brown, moist; few pebbles
34-38	clay, gray, moist; few pebbles
38	shale

* * * * *

Test Hole No. 22
Location: SESE 19-107-65
Elevation: 1910 ± 25 feet
Depth to water: not measured

0- 1	topsoil
1-34	clay, brown, moist; few pebbles
34-54	clay, brown, moist; many very large pebbles
54-65	clay, slightly moist; some small pebbles
65	same, dry; hard drilling

* * * * *

Test Hole No. 23
Location: NENW 25-107-65
Elevation: 1920 ± 25 feet
Depth to water: not measured

0- 2	topsoil
2- 9	clay, brown, dry; few pebbles
9- 34	clay, brown, moist; few pebbles
34- 54	clay, gray, moist; many pebbles
54- 74	clay, gray, saturated; few pebbles
74- 99	clay, gray, saturated; trace of fine sand
99-112	clay, gray, saturated; 10% fine sand
112	shale

* * * * *

Test Hole No. 24
Location: NESE 24-107-65
Elevation: 1870 ± 25 feet
Depth to water: not measured
(continued on next page)

Test Hole No. 24--continued

0- 1	topsoil
1-34	clay, brown, moist; many pebbles
34-49	clay, gray, saturated; 20% sand
49-54	clay, gray, saturated; 35% coarse sand
54-82	gravel, fine, saturated; pebbly
82	shale

* * * * *

Test Hole No. 25
Location: SESE 29-107-65
Elevation: 1802.7 feet
Depth to water: not measured

0- 1	topsoil
1-14	clay, brown, moist; some large pebbles
14-29	clay, brown, saturated; 10% fine sand
29-37	clay, gray, saturated; 10% fine sand
37	shale

* * * * *

Test Hole No. 26
Location: NENE 34-107-65
Elevation: 1925 ± 25 feet
Depth to water: not measured

0- 2	topsoil
2-19	clay, brown, moist; some large pebbles
19-65	clay, reddish-brown, moist; few pebbles

* * * * *

Test Hole No. 27
Location: SENW 36-107-65
Elevation: 1930 ± 25 feet
Depth to water: not measured

0- 3	topsoil
3- 24	clay, light-brown, moist; pebbles
24- 54	clay, dark-gray, moist; few pebbles
54- 74	clay, gray, saturated; 30% medium sand
74-109	clay, gray, saturated; 20% medium sand
109-152	clay, gray, highly saturated; 20% fine sand
152	shale

* * * * *

Test Hole No. 28
Location: NWNW 32-107-64
Elevation: 1620 ± 10 feet
Depth to water: not measured

0- 2	topsoil (alluvium)
2-14	clay, brown, dry; some pebbles
14-34	clay, brown, moist; some large pebbles
34-61	clay, gray, moist; few pebbles
61	shale

* * * * *

Test Hole No. 29
Location: SESE 6-106-65
Elevation: 1795 ± 25 feet
Depth to water: not measured

0- 2	topsoil
2-14	clay, brown, slightly moist; few pebbles
14-29	clay, red-brown, moist; few large pebbles
29-40	clay, brown, moist; very hard drilling

* * * * *

Test Hole No. 30
Location: SESE 3-106-65
Elevation: 1860 ± 25 feet
Depth to water: not measured

0- 1	topsoil
1- 19	clay, red-brown, moist; some large pebbles
19- 44	clay, gray, moist; few pebbles
44-120	clay, gray, very moist; few pebbles

* * * * *

Test Hole No. 31
Location: SENW 18-106-65
Elevation: 1869.3 feet
Depth to water: not measured

0- 4	gravel, brown, clayey; with cobbles
4- 6	sand, fine, silty, gray, dry
6-16	sand, clayey, and gravel
16-51	sand, silty, gray, moist

* * * * *

Test Hole No. 32
Location: NENE 17-106-64
Elevation: 1540 ± 25 feet
Depth to water: not measured

0- 2	topsoil
2-19	clay, light-brown, dry; some pebbles
19-34	clay, brown, moist; few pebbles
34-43	clay, gray, moist; few pebbles
43	shale

* * * * *

Test Hole No. 33
Location: SESW 13-106-66
Elevation: 1719.8 feet
Depth to water: approximately 4 feet

0- 4	topsoil (alluvium)
4- 9	clay, gray-brown, saturated; 30% coarse sand
9-22	gravel, saturated; 25% brown clay
22	shale

* * * * *

Test Hole No. 34
Location: NWNW 20-106-65
Elevation: 1789.8 feet
Depth to water: approximately 9 feet

0- 3	topsoil
3- 9	clay, brown, silty, moist; few pebbles
9- 14	clay, brown, saturated; 40% coarse sand
14- 24	clay, brown, saturated; 15% fine sand
24-104	clay, gray, highly saturated; 10% medium sand

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Test Hole No. 35
Location: NWNW 25-106-65
Elevation: 1660 ± 25 feet
Depth to water: approximately 9 feet

0- 4	gravel, dry
4- 9	gravel, fine, moist
9-12	gravel, saturated; medium pebbles
12-18	clay, saturated; gravel, pebbles
18	shale

* * * * *

Test Hole No. 36
Location: SESE 19-106-64
Elevation: 1590 ± 25 feet
Depth to water: not measured

0- 1	topsoil
1-44	clay, light-brown, moist; few pebbles
44-54	clay, gray, moist; few pebbles
54-62	clay, gray, saturated; 10% medium sand
62	shale

* * * * *

APPENDIX B

Logs of Rotary Test Holes in the Wessington Springs Area

(for locations see Figure 2)

Test Hole No. R-1
Location: NWNW 4-107-65
Elevation: 1896.3 feet
Depth to water: not measured

0- 30	clay, brown
30- 85	clay, gray, silty
85-115	clay, gray
115-125	shale

Note: Electric log available

* * * * *

Test Hole No. R-2
Location: NWNE 14-107-66
Elevation: 1775.0 feet
Depth to water: not measured

0- 3	topsoil, black
3-30	clay, brown
30-43	clay, gray
43-49	sand and gravel; clay stringers
49-65	shale

* * * * *

Test Hole No. R-3
Location: NWNW 17-107-65
Elevation: 1852.4 feet
Depth to water: not measured

0-25	clay, brown
25-60	clay, gray (probably gravel from 45 to 50 feet)
60-65	shale

Note: Electric log available

* * * * *

Test Hole No. R-4
Location: SWNW 13-107-65
Elevation: 1853.2 feet
Depth to water: not measured

0-10	clay, brown
10-30	clay, dark-brown
30-35	clay, light-brown
35-48	gravel
48-65	shale

* * * * *

Test Hole No. R-5
Location: SWNE 13-107-65
Elevation: 1837.8 feet
Depth to water: not measured

0- 33	clay, brown
33- 79	clay, gray
79-105	gravel, coarse, with large boulders; caving badly, abandoned hole

* * * * *

Test Hole No. R-6
Location: SESE 18-107-65
Elevation: 1848.6 feet
Depth to water: not measured

0- 5	clay, black
5- 33	clay, brown
33- 87	clay, gray
87-107	gravel
107-125	shale

Note: Electric log available

* * * * *

Test Hole No. R-7
Location: NENE 23-107-65
Elevation: 1851.1 feet
Depth to water: not measured
(continued on next page)

Test Hole No. R-7--continued

0-25	clay, dark-brown
25-30	clay, gray
30-35	gravel
35-50	sand, fine; caving badly, abandoned hole

* * * * *

Test Hole No. R-8
Location: NWNW 26-107-66
Elevation: 1810 ± 25 feet
Depth to water: not measured

0-30	clay, brown
30-35	clay, gray
35-65	clay, gray; gravel stringers
65-75	clay, gray
75-87	clay, gray, very silty. (Probably some interbedded gravel from 70 to 90 feet)
87-95	shale. (Electric log top at 90 feet)

Note: Electric log available

* * * * *

Test Hole No. R-9
Location: SESE 20-107-65
Elevation: 1883.9 feet
Depth to water: not measured

0- 10	clay, sandy, brown
10- 50	clay, brown
50- 85	clay, dark-brown
85-125	clay, gray
125-185	gravel, very coarse; abandoned hole because of caving

* * * * *

Test Hole No. R-10
Location: NENE 27-107-65
Elevation: 1918.8 feet
Depth to water: not measured

0- 60	clay, brown
60-115	clay, gray
115-133	gravel
133-170	clay, gray or shale

* * * * *

Test Hole No. R-11
Location: SESE 23-107-65
Elevation: 1926.1 feet
Depth to water: not measured

0- 35	clay, brown
35- 75	clay, gray
75-120	clay, dark-gray
120-155	shale

* * * * *

Test Hole No. R-12
Location: SESE 25-107-66
Elevation: 1858 feet
Depth to water: not measured

0- 27	clay, brown
27-100	clay, gray
100	rock; abandoned hole

Note: Electric log available

* * * * *

Test Hole No. R-13
Location: SESE 25-107-66
Elevation: 1857.6 feet
Depth to water: not measured

0- 35	clay, brown
35-120	clay, gray
120-163	gravel, fine; medium sand towards bottom
163-170	shale

* * * * *

Test Hole No. R-14
Location: SESE 28-107-65
Elevation: 1833.6 feet
Depth to water: not measured

0- 2	topsoil, black
2-10	clay, brown, silty
10-35	sand and gravel; abandoned because of caving

* * * * *

Test Hole No. R-15
Location: NENE 35-107-65
Elevation: 1949 feet
Depth to water: not measured

0- 8	clay, light-gray
8- 15	clay, brown
15-130	clay, gray
130-140	boulder concentration
140-150	clay, gray
150-155	gravel; clay
155-180	shale

* * * * *

Test Hole No. R-16
Location: NENE 6-106-65
Elevation: 1877.3 feet
Depth to water: not measured

0- 79	clay, silty, reddish-brown
79-100	gravel, boulders; abandoned because of caving

Note: Electric log available

* * * * *

Test Hole No. R-17
Location: SWSW 1-106-66
Elevation: 1852.2 feet
Depth to water: not measured

0- 65	clay, brown
65-150	clay, gray
150-155	sand, fine
155-165	clay, silty, gray
165-170	gravel, dirty
170-180	clay, silty, gray
180-185	gravel, fairly clean
185-198	clay, silty, gray
198-205	gravel; rock at 205 feet; hole abandoned

* * * * *

Test Hole No. R-18
Location: SESE 3-106-65
Elevation: 1878.9 feet
Depth to water: not measured
(continued on next page)

Test Hole No. R-18--continued

0- 26	clay, brown
26- 30	clay, gray
30- 32	sand and gravel
32-115	clay, gray
115-118	gravel
118-145	clay, gray; very thin gravel stringers
145-155	shale

Note: Electric log available

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Test Hole No. R-19
Location: SWSW 14-106-66
Elevation: 1797.5 feet
Depth to water: not measured

0- 30	clay, silty, brown
30- 55	clay, brown
55- 66	clay, sandy, brown
66- 85	sand and gravel; clay stringers
85- 98	gravel, good
98-108	clay, gray
108-118	gravel, fair; clay stringers
118-160	clay, gray
160-167	gravel
167-185	clay, gray; gravel stringers
185-215	clay, gray
215-220	shale

Note: Electric log available

* * * * *

Test Hole S-1
Schubert School Test Hole #1
Location: SESE 9-107-65
Elevation: 1910 feet (approximately)
Depth to water: not measured

0- 118	glacial drift
118- 770	Pierre Shale
770- 860	Niobrara Marl
860-1042	Carlile Shale
1042-1092	Greenhorn Limestone (limestone and marl)
1092-1295	Graneros Shale
1295-1565	Dakota Group (sandstone and shale)
1565-1665	Cambrian-Cretaceous weathered zone

(continued on next page)

Test Hole S-1--continued

1665-1698 Precambrian granite (pink biotite granite)

Note: Electric log available

* * * * *

APPENDIX C

Logs of Selected Wells in the Wessington Springs Area

(for location see Figure 2)

Well No. 1
Location: NESE 1-107-65
Elevation: 1560 ± 25 feet
Depth to water: not measured

0 - 2	soil, black
2 - 23	till, oxidized, brownish-yellow
23 -316	shale, blue-black to gray
316 -370	shale, light-gray, calcareous
370 -443	shale, blue-black
443 -475	Codell Sandstone Member of the Carlile Shale
475 -705(?)	shale, blue-gray
705(?)-740(?)	limestone; some shale
740(?)-922	shale, blue-black
922 -950	sandstone

* * * * *

Well No. 2
Location: NE 17-107-64
Elevation: 1520 ± 25 feet
Depth to water: 12 feet

0- 5	clay
5-14	no records
14-20	clay, sandy, or shale

Note: Drilled to 140 feet, but no water below 20 feet

* * * * *

Well No. 3
Location: NWNW 26-107-65
Elevation: 1880 ± 25 feet
Depth to water: not measured

Electric log interpretation
(No drillers log available)

0-42	probably till
42-45	probably sand

(continued on next page)

Well No. 3--continued

45-47	probably till
47-64	probably gravel, with a few clay layers
64-75	probably till
75-82	probably gravel (total depth of electric log)

* * * * *

Well No. 4
Location: SW 2-106-65
Elevation: 1880 ± 25 feet
Depth to water: 15 feet

0-34	clay
34-39	clay, gravelly
39-50	sand
50-60	shale

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Well No. 5
Location: SE 12-106-66
Elevation: 1750 ± 25 feet
Depth to water: 22 feet

0- 4	soil; clay
4-15	gravel
15-20	clay, soft
20-39	clay
39-43	sand

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Well No. 6
Location: SE 19-106-65
Elevation: 1800 ± 25 feet
Depth to water: 66 feet

0- 45	clay
45- 50	gravel
50-107	clay
107-115	sand

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APPENDIX D

Well Records in the Wessington Springs Area

Well location: Letters indicate quarter of section; first number is the section, the second the township north, and the third the range west.
Depth of well: a, about
Geologic source: Q, aquifer in glacial drift; Kp, Pierre Shale; Kd, Dakota Group sandstones; p€, granite
Water-bearing material: S, sand; sh, shale; cl, clay; ch, chalk; Gr, gravel
Depth to water: F, flowing
Use of water: D, domestic; S, stock
Year drilled: a, about; b, before

Well Location	Owner or Tenant	Reported Depth (feet)	Geo-logic Source	Water-bearing Material	Depth to Water (feet)	Use of Water	Year Drilled
SWNW-8-106-64	C. R. Ferren	968	Kd	S	70	S,D	1919
SWSE-17-106-64	V. Hinrichs	960	Kd	S	32	S,D	a1945
SWNW-4-106-65	H. Clemetson	283	Kp	sh	125	S,D	a1910
SWSW-4-106-65	H. Clemetson	23	Q	sh	7	S	1965
SWNW-7-106-65	F. R. VanBockel	12	Q	sh	6	S	1947
NENE-8-106-65	F. R. VanBockel	37	Q	sh	12	S	1958
SWNW-8-106-65	F. R. VanBockel	20	Q	sh	8	D	1956
NENW-9-106-65	H. Wenzel	245	Kp	sh	180	S,D	a1934
NWNW-10-65	F. J. Stratton	140	Q	cl,S	90	S,D	1940

Well Location	Owner or Tenant	Reported Depth (feet)	Geo-logic Source	Water-bearing Material	Depth to Water (feet)	Use of Water	Year Drilled
NWNW-13-106-65	D. Thompson	100-120	Q	--	a10	S	a1900
SENE-14-106-65	D. Thompson	100-120	Q	--	F	S,D	a1900
NWNE-15-106-65	B. Wilson	200	Kp?	ch	156	S,D	---
SESW-16-106-65	E. Westlake	160	Kp?	ch,S	--	S,D	---
NENE-19-106-65	V. Crist	a100	Q	--	a80	S,D	1905
SWSE-19-106-65	G. Villbrandt	90	Q	S	50	S	1963
SWNW-20-106-65	G. Villbrandt	165	Q	S	100	S,D	1955
SWNW-20-106-65	G. Villbrandt	100	Q	S	50	S	1943
SWNW-20-106-65	G. Villbrandt	165	Q	S	100	S,D	a1915
SWNW-21-106-65	J. W. Crist	104	Q	S	84	S,D	a1917
NENW-1-106-66	D. Barber	a172	Q	--	--	S,D	a1938
SESE-1-106-66	J. Sargent	a260-275	Kp?	sh	a240	S,D	1918
NENE-11-106-66	H. Barber	152	Kp?	--	--	S,D	a1938
SENE-12-106-66	J. Sargent	108	Q	Gr	a100	S	a1920
SWSW-12-106-66	M. Lindstedt	a87	Q	--	--	S	a1920

Well Location	Owner or Tenant	Reported Depth (feet)	Geo-logic Source	Water-bearing Material	Depth to Water (feet)	Use of Water	Year Drilled
SWSE-12-106-66	M. Lindstedt	47	Q	sh	17	S,D	1959
SWSE-12-106-66	M. Lindstedt	a65	Q	--	--	S	a1946
SE-12-106-66	D. Thompson	100- 120	Q	--	--	S	a1900
SWSE-13-106-66	J. & L. Dusek	a120	Q	--	a40	S,D	a1930
NWSW-24-106-66	C. Zavesky	16	Q	--	10	S,D	a1915
NWSW-24-106-66	C. Zavesky	160	Q	--	35	S,D	a1915
NENE-5-107-64	T. H. Shyrock	25	Q	S,Gr	a12-15	D	1962
NENE-5-107-64	T. H. Shyrock	25	Q	S,Gr	a12-15	S	1961
NENE-5-107-64	T. H. Shyrock	25	Q	S,Gr	a12-15	S	1930
NWSW-6-107-64	J. Rogers	24	Q	S,cl	a16	S,D	a1940
NWSW-8-107-64	E. Jenner	933	Kd	S	50	S,D	1927
SENE-18-107-64	B. Burma	940	Kd	--	70	S,D	1943
SENE-30-107-64	F. Caffee	980	Kd	--	120	S,D	1928
NWSE-30-107-64	I. Giles	a1010	Kd?	--	158	S	---

Well Location	Owner or Tenant	Reported Depth (feet)	Geo-logic Source	Water-bearing Material	Depth to Water (feet)	Use of Water	Year Drilled
NWSE-30-107-64	I. Giles	55	Q	--	50	D	---
NWNW-32-107-64	G. H. Hauck	a950	Kd	--	a100	S,D	a1925
NWSW-32-107-64	B. Fuerst	950	Kd	--	a100	S,D	1940
NESE-1-107-65	H. Grohs	950	Kd	S	72	S	a1935
NESE-1-107-65	H. Grohs	950	Kd	S	72	D	1962
NENE-4-107-65	F. Elias	44	Q	S	a20	S,D	a1936
NWNW-5-107-65	J. Kogel	180	Kp	ch	120	S,D	1957
NENE-6-107-65	E. Matson	210	Kp	cl	a40	S,D	b1920
SESE-7-107-65	G. Peterson	a70	Q	cl	--	S,D	b1954
NWSW-9-107-65	R. Linn	20	Q	S	F	S,D	a1927
SESW-10-107-65	W. Wenzel	a165	Q	--	--	S	---
SESW-10-107-65	W. Wenzel	45	Q	--	--	S,D	---
SWSE-10-107-65	R. H. Powell	65	Q	S	--	S,D	---
NENW-15-107-65	D. Roetman	1465	p€	S	200	S	1961

Well Location	Owner or Tenant	Reported Depth (feet)	Geo-logic Source	Water-bearing Material	Depth to Water (feet)	Use of Water	Year Drilled
NENW-15-107-65	D. Roetman	60	Q	S	30	D	1959
NWNE-19-107-65	D. Pagel	208	Kp	--	--	S,D	1953
SESE-19-107-65	R. Winegar	a260	Kp	sh	a240	S	a1920
NENW-20-107-65	P. E. Messmer	250	Kp	cl	a100	S,D	1958
SENE-22-107-65	E. Easton	280	Kp	sh	a280	S,D	1924
SWSE-22-107-65	A. Fry	283	Kp	sh	253	S,D	1911
NWSW-23-107-65	E. Liedtke	290	Kp	--	190	S,D	---
NWNW-26-107-65	T. Lindstedt	87	Q	--	--	S,D	a1925
SESE-26-107-65	M. Powell	77	Q	S	58	S,D	1950
NESW-26-107-65	M. Winegar	a260	Kp	sh	a240	S	a1925
SESE-29-107-65	L. Schaffer	12	Q	--	a2	S	---
NESE-31-107-65	R. Winegar	175	Q	S	a160	S	a1920
SENE-32-107-65	M. Winegar	20	Q	--	17	S	1958
SENE-33-107-65	R. Clementson	a230	Q	Gr	a100	S	---

Well Location	Owner or Tenant	Reported Depth (feet)	Geo-logic Source	Water-bearing Material	Depth to Water (feet)	Use of Water	Year Drilled
SENE-33-107-65	R. Clementson	a100	Q	--	--	D	---
SENE-34-107-65	C. Gunderson	75	Q	S	70	S,D	a1925
NENW-34-107-65	P. Heisel	83	Q	--	30	S,D	1935
NENW-34-107-65	P. Heisel	10	Q	--	F	S	1940
NWSE-34-107-65	C. Gunderson	75	Q	S	70	S	1963
NWNW-1-107-66	C. Deneke	44	Q	Gr	18	S,D	a1915
SWSW-1-107-66	A. Rudeen	25	Q	Gr	a8	S	1961
SWSW-1-107-66	A. Rudeen	16	Q	Gr	a8	D	1951
SWSW-1-107-66	A. Rudeen	24	Q	Gr	a8	S	1961
NENE-2-107-66	E. Linn	35	Q	Gr	18	S,D	a1915
NENE-11-107-66	M. Powell	18	Q	Gr	a13	S	a1925
NENE-11-107-66	M. Powell	18	Q	Gr	a13	D	a1925
SESW-12-107-66	P. Bult, Jr.	60	Q	S,Gr,cl	--	S	a1925

Well Location	Owner or Tenant	Reported Depth (feet)	Geo-logic Source	Water-bearing Material	Depth to Water (feet)	Use of Water	Year Drilled
SESW-12-107-66	P. Bult, Jr.	25	Q	S	7	S	1962
SESW-12-107-66	P. Bult, Jr.	35	Q	S,Gr,cl	20	S,D	a1925
SWSE-13-107-66	J. Bult	15	Q	Gr	5	S	1962
SWSE-13-107-66	J. Bult	70	Q	Gr,S	55	S,D	a1920
NWNW-24-107-66	M. Winegar	16	Q	Gr	8	S	1965
SWSW-24-107-66	M. Winegar	80	Q	Gr	a70	S	1961
SWNW-35-107-66	A. Barber	a100	Q	--	--	S,D	a1920
SWSE-35-107-66	D. Peterson	a150	Q	--	--	S,D	a1920