STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 30

GROUND WATER SUPPLY FOR THE CITY OF BOWDLE, SOUTH DAKOTA

by
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Vermillion, South Dakota
1964

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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota State Geological Survey from August 1 to August 20, 1963, in and around the city of Bowdle, in Edmunds and Walworth counties, South Dakota (fig. 1), for the purpose of assisting the city in locating a future water supply. Bowdle now receives its water from four wells which in recent years have not produced the quantity of water needed by the city. The wells obtain their water from a basal sand at a depth of 85 to 102 feet. All wells are located within the city limits.

A survey of the ground water possibilities was made of a 63 square mile area around the city and consisted of reviewing the geologic mapping by Lee (1957), a well inventory, the drilling of 40 test holes and the taking of 15 water samples for analysis. As a result of this investigation, the aquifer from which the city now receives its water was found to thicken to the south of the city. The quality of water in the aquifer to the south of the city is comparable to the present city supply. An aquifer 3 miles southwest of the city also was located.

The field work and preparation of this report were performed under the supervision of Lynn Hedges, staff ground water geologist. The aid of Keith Munneke and John Cassens who drilled test holes averaging 96 feet in depth with the Survey's hydraulic drilling rig is gratefully acknowledged.

The cooperation of the residents of the Bowdle area, especially Mayor Helmer Leno is gratefully appreciated. The writer also wishes to thank Nat Lufkin of the State Geological Survey and the State Chemical Laboratory for analyzing water samples.

Location and Extent of Area

The city of Bowdle is located in Edmunds County in north-central South Dakota, and has a population of 673 (1960 census). The area is in the Coteau du Missouri division of the Great Plains physiographic province (fig. 1).

Climate

The climate is continental temperate, with large daily and seasonal fluctuations. The mean annual temperature is 42.0° F. at the U. S. Weather Station in Eureka. The average annual precipitation is 20.40 inches, at the U. S. Weather Station in Bowdle.

Topography and Drainage

At Bowdle and to the west, the topography is a gently sloping surface of fine silt and sand. East of Bowdle the topography is an extremely undulating surface with knobs and kettles.

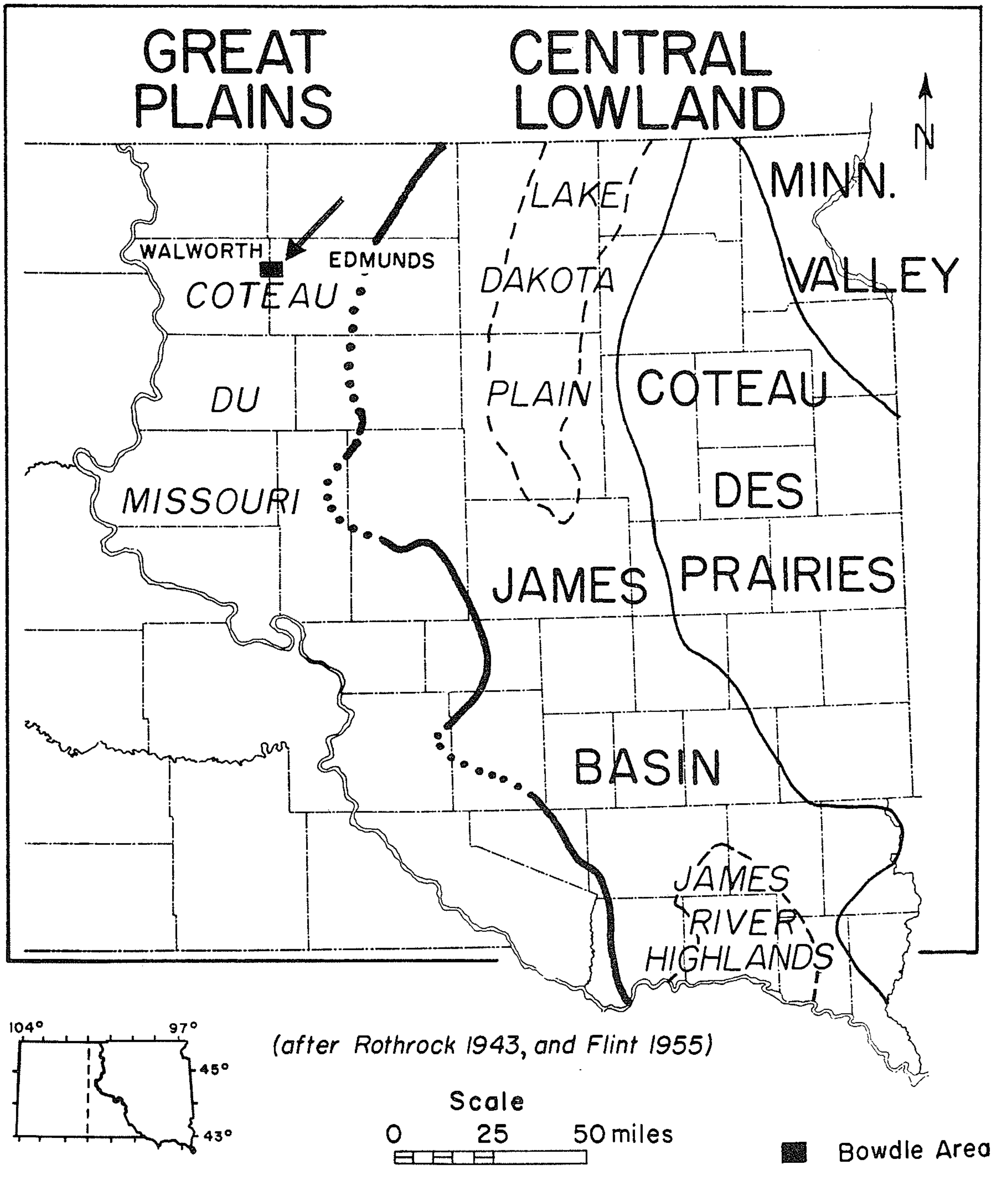


Figure I. Major Physiographic Divisions of Eastern South Dakota showing location of the Bowdle Area.

The drainage of the area is very poor. There are few streams; all are intermittent and flow in a southerly direction. Swan Creek, the longest stream in the mapped area, follows the broad outwash valley to the west of Bowdle (fig. 2).

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Bowdle area are chiefly the result of glaciation late in the Pleistocene Epoch. The glacial deposits, collectively termed drift, can be divided into till and outwash sediments.

Till consists of a jumbled mixture of clay, silt, sand, pebbles, and boulders, carried and deposited by the ice itself. Till covers most of the surface north, east, and south of Bowdle (fig. 2).

The outwash material, which consists primarily of sands and gravels, was deposited by meltwater streams from the wasting glaciers. Some surface outwash occurs west and southwest of Bowdle. An outwash buried below the surface outwash and till occurs south and west of Bowdle. Hereafter this buried outwash is called the basal sand.

Alluvial material has been deposited along much of Swan Creek since the retreat of the glaciers. The alluvium consists of clay and silt with minor amounts of fine and medium sand.

Subsurface Bedrock

Stratified rocks of Cretaceous and Jurassic age lie beneath the surface deposits in the Bowdle area. The Pierre Shale lies directly beneath the glacial drift and is underlain in descending order by the Niobrara, Carlile, Greenhorn, and Graneros Formations, and the Dakota Group of Cretaceous age, and shales and sandstones of Jurassic age.

Figure 3 is a contour map showing the configuration of the surface of the Pierre Shale as it would appear if all the glacial deposits were removed. A valley eroded into the Pierre Shale trends northeast-southwest through the city of Bowdle.

The Pierre Formation consists of light-gray fissile shale with bands of iron concretions.

The Niobrara Formation in the subsurface consists of light-gray chalk and light- to medium-blue-gray shale which contains numerous microscopic white calcareous specks.

The Carlile Formation consists of light- to dark-gray bentonitic shale with pyrite concretions and layers of fine brown siltstone.

The Greenhorn Formation consists of a hard layer of white to cream limestone containing numerous fossil fragments.

The Graneros Formation is hard light- to dark-gray siliceous shale.

The Dakota Group contains alternating layers of sandstones and shales and is from 1,800 to 2,000 feet below the surface in this area.

Underlying the Dakota Group are shales and sandstones of Jurassic age.

Figure 2. Generalized Geologic Map of the Bowdle Area.

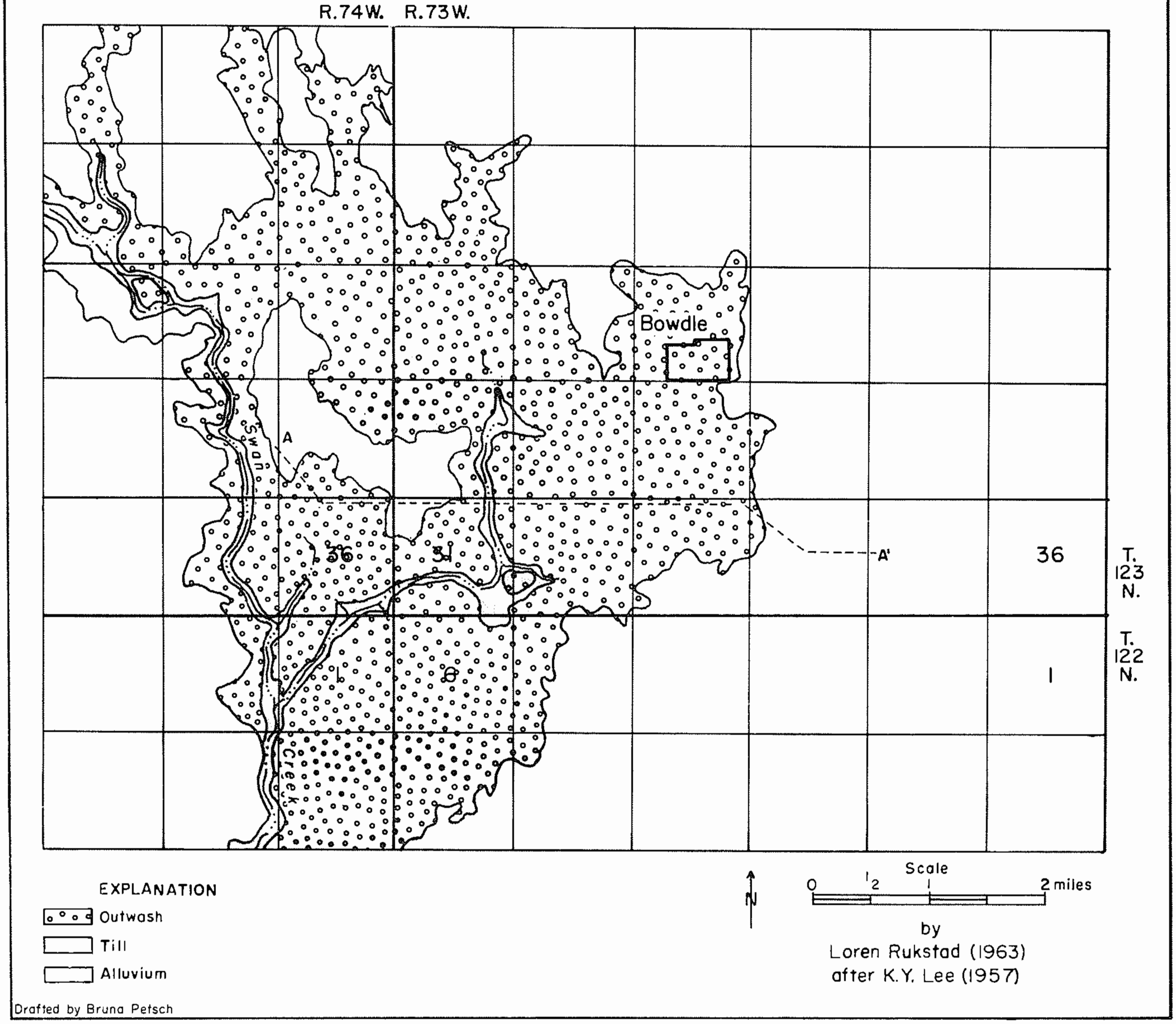
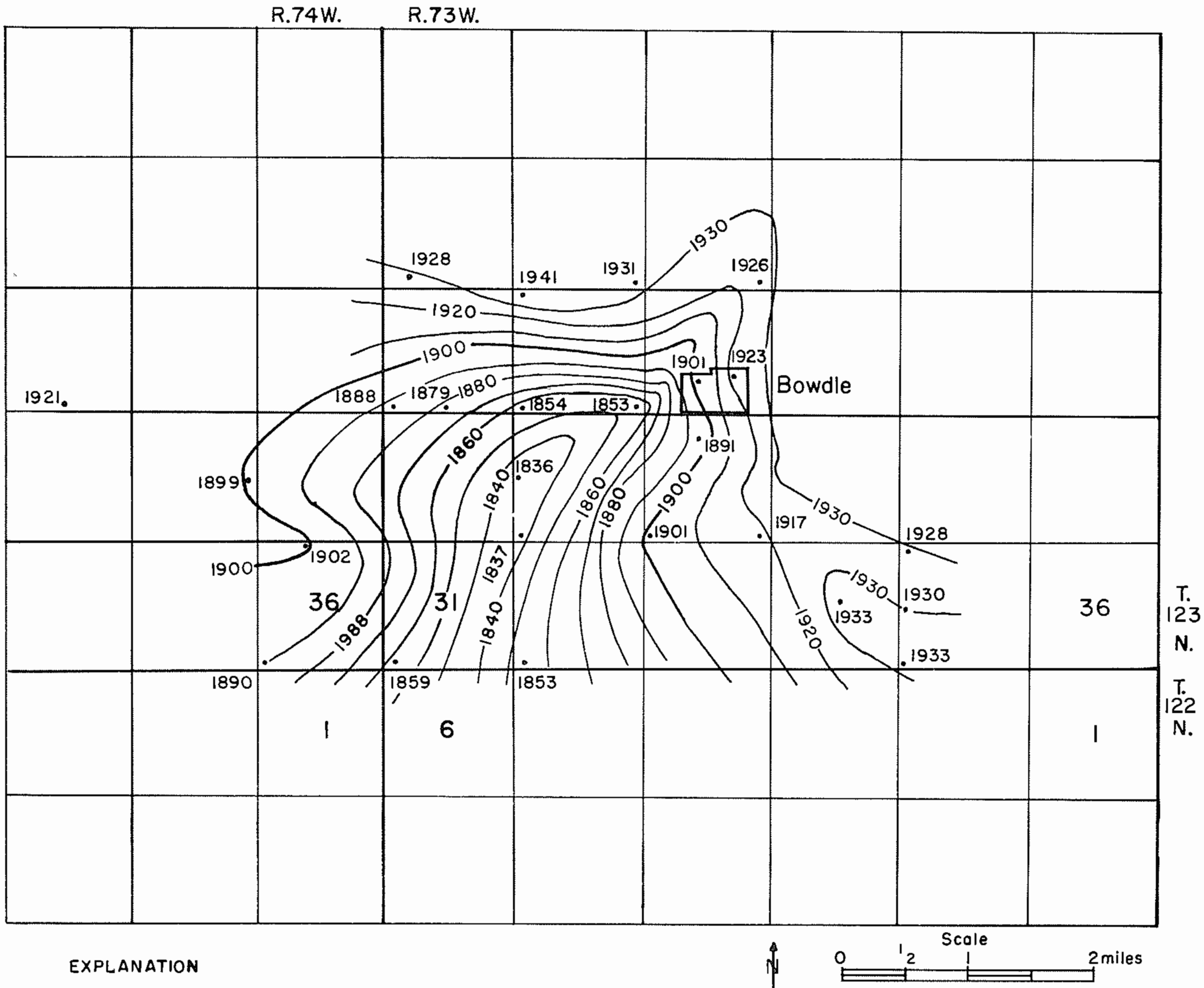


Figure 3. Contour Map of the buried Pierre Shale Surface.



EXPLANATION

—1850—

Contour showing lines of equal elevation above Sea Level; interval 10 feet.

by

Loren Rukstad (1963)

Drafted by Bruno Petsch

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Contrary to popular belief, ground water does not occur in "veins" that criss-cross the land at random. Instead, it can be shown that water occurs nearly everywhere beneath the surface, but at varying depths. The top of this zone of saturation is known as the water table.

Nearly all ground water is derived from precipitation. Rain or melting snow either percolates downward to the water table and becomes ground water or drains off as surface water. Surface water may percolate downward and become ground water, or it may evaporate or drain to the sea by means of streams. In general, ground water moves laterally down the hydraulic gradient and is in transient storage.

Recharge is the addition of water to an aquifer (water-bearing material) and is accomplished in a number of ways: (1) by downward percolation of precipitation from the land surface, (2) by downward percolation from surface bodies of water such as lakes and streams, and (3) by lateral movement of water in transient storage.

Discharge of ground water from a water-bearing material is accomplished in four main ways: (1) by evaporation and transpiration of plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water in transient storage, and (4) by pumping.

The amount of water that can be stored in a saturated material is equal to the amount of voids or pore spaces in that material. A measurement of the capability of a material to store water (or any other liquid) is called porosity. Porosity depends entirely on the shape and arrangement of the particles in a material and is not affected by size. Sands and gravels usually have porosities of 20-40 percent whereas sandstones normally have porosities of 15-25 percent; this lower porosity of sandstone is due to closer packing and the cementation of the particles.

Permeability is the rate at which a fluid will pass through a substance. If the pore spaces of a material are connected, the permeability of that material will be high. If the pore spaces are not connected, the permeability will be low. Thus, a material may have high porosity and still not yield water readily because of low permeability. Sands and gravels, however, tend to have both high porosity and high permeability. Thus, the geologist is not concerned with finding a "vein" when looking for a good water supply; but because water occurs almost everywhere in the ground, he is searching instead for a sand or gravel deposit that lies beneath the water table and will yield water readily.

Ground Water in Alluvium

Alluvium is found along the intermittent streams and their tributaries. It is made up of clay, silt, and some lenticular sands with fine laminations and faint cross-bedding. Because of the low permeability of alluvium it does not yield water readily.

Ground Water in Glacial Deposits

Glacial deposits can be divided into till and outwash. Till does not yield water readily because of its unsorted nature and low porosity and permeability. Outwash, on the other hand, is a good source of ground water because of its high porosity and permeability.

A surface outwash occurs in the Bowdle area (fig. 2). Test drilling showed a maximum thickness of 29 feet (Test Hole 6, Appendix A) of which 26 feet was saturated. The average thickness of the surface outwash is 10-15 feet as shown on the geologic cross section (fig. 4) and only locally is saturated. These deposits produce sufficient water for farm wells but would not yield enough water for a city well.

A basal sand aquifer is present between the base of the till and the shale in the Bowdle area. This aquifer consists of fine to very fine sand and is the source of water for four of the present city wells. Test Holes 19, 27, 28, 29, 30, 31, 36, and 40 (fig. 5) were drilled through this sand. This basal sand lies just above the Pierre Shale and therefore tends to follow the topography of the shale. There is from 60 to 90 feet of drift above this sand and it was found to be from 7 to 20 feet thick in the area south of Bowdle.

Another basal sand was located about 3 miles west of Bowdle. This aquifer was penetrated by Test Holes 14, 22, and 24. This aquifer is from 14 to 29 feet thick and is very similar to the aquifer south of Bowdle. Figure 4 shows the two basal sands in cross section and it is postulated that at one time they were connected, although the present investigation showed no such connection.

Ground Water in Bedrock

A few farms in the area obtain water from the Pierre Shale. However, this water is usually of rather poor quality and the wells yield low quantities of water.

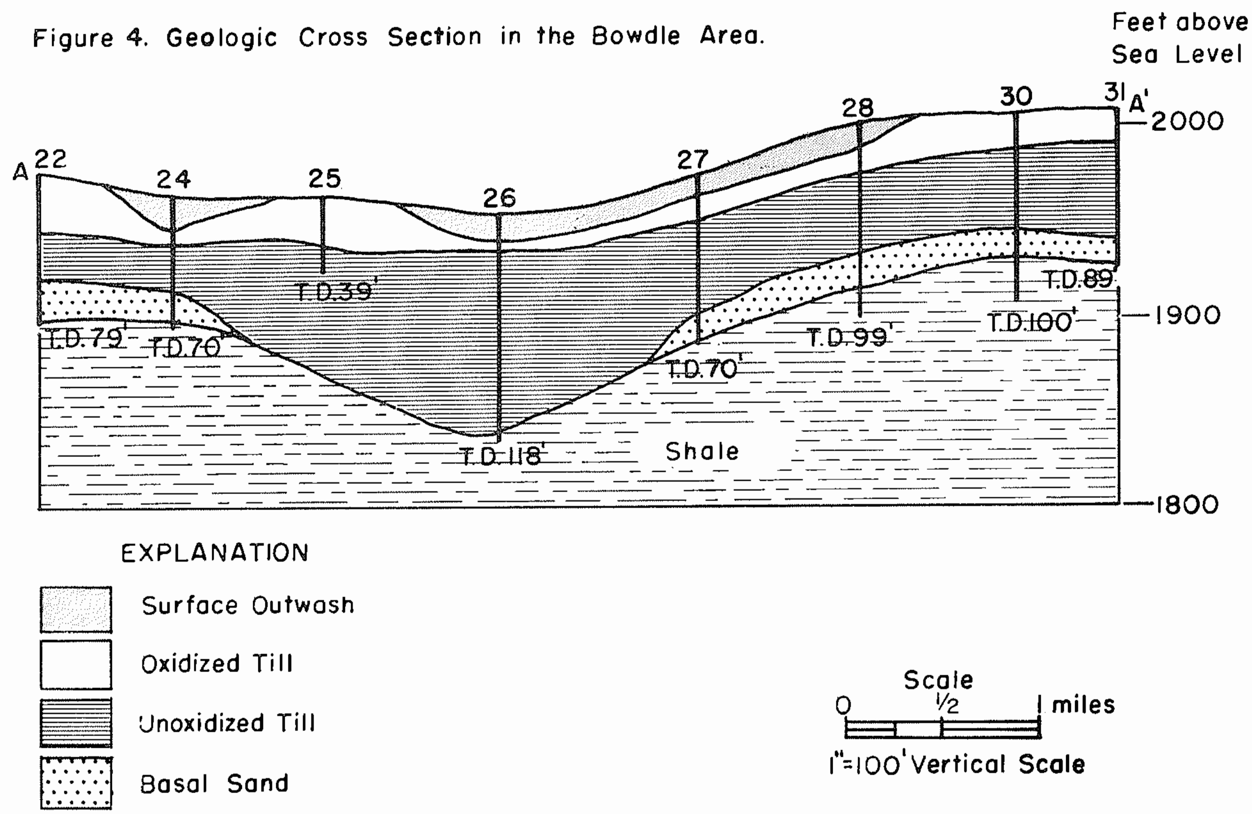
The sandstones of the Dakota Group and the Jurassic sandstones are the only other bedrock in the Bowdle area which yield water. The Dakota sandstone is at a depth from 1,800 to 2,000 feet below the surface and the waters are under artesian pressure. The Jurassic sandstones and shales directly underlie the Dakota Group. Few farms in the Bowdle area use these aquifers as a source of water.

The recharge for these sandstones in South Dakota is believed to come from the Rocky Mountains or the Black Hills where they crop out at a much higher elevation than in the Bowdle area and this produces the pressure head necessary to cause the wells to flow.

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 depths below the water

Figure 4. Geologic Cross Section in the Bowdle Area.



(See Figure 5 for location of test holes and Figure 2 for location on Geologic Map.)

Drafted by Bruno Petsch

Figure 5. Data Map of the Bowdle Area.

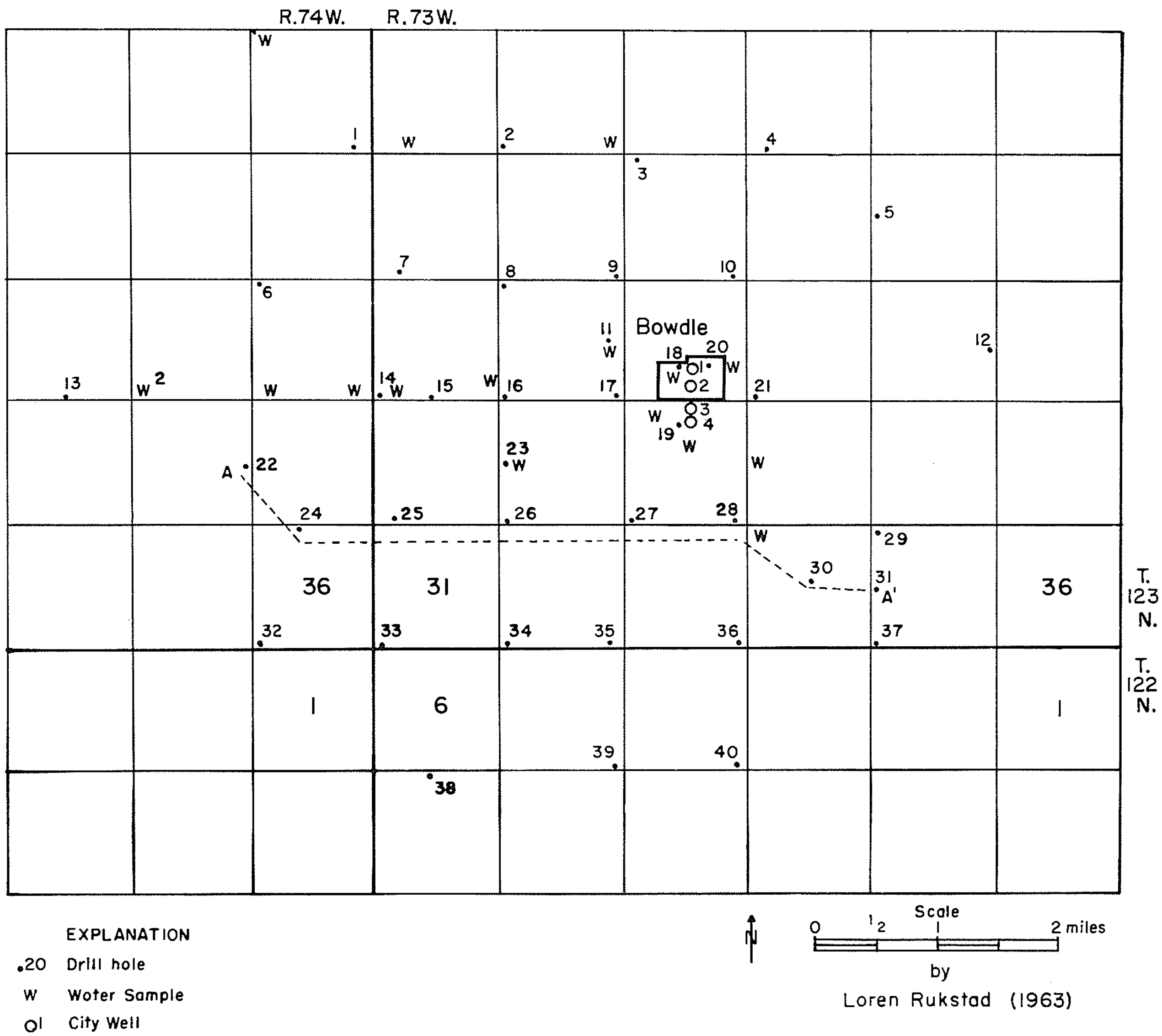


table in which the water is circulating. In general, it can be said that the more minerals a water contains, the poorer its quality. The water in the Dakota sandstones and the Jurassic sandstones is usually of a poorer quality than that in the glacial deposits because of the greater amounts of minerals contained in the water.

Table 1 shows the chemical properties of various waters in the Bowdle area compared with the present city water (samples B, C, D, and E) and with standards for drinking water established by the U. S. Department of Public Health (sample A) (1961).

Samples B, F, I, and J were all collected from existing wells which are believed to be pumping from the basal sand aquifer south of Bowdle. Samples B, F, and I are within the limits established by the U. S. Department of Health in all chemicals except for iron and manganese. The iron content in sample B is at the maximum limit, while the manganese content exceeds the limits. Sample F is within the limits although no test was made for manganese. Sample I is high in both iron and manganese. Sample J is high in manganese and is considerably harder than samples B, F, and I. However, this sample is from the marginal area of the aquifer and may not be a representative sample of the aquifer. It appears that the quality of water in the aquifer south of Bowdle is fairly consistent and comparable in quality to the water in City Well 4.

Samples G and H are from the buried aquifer three miles west of Bowdle. Sample G was collected from an existing farm well and sample H was pumped from South Dakota Geological Survey Test Hole 14. Sample H is high in total solids and both samples have some iron. Sample G also has a high sulfate content. No test was run for manganese.

The water from this aquifer is of slightly poorer quality than the aquifer south of Bowdle; however, the water would be suitable for a municipal water supply.

CONCLUSIONS AND RECOMMENDATIONS

Two glacial aquifers are potential sources of additional municipal water supplies in the Bowdle area. The first aquifer lies under and to the south of Bowdle, and is the source of water for the four city wells. The wells producing from this aquifer have yields ranging from 20 gallons per minute in City Wells 1, 2, and 3, to 45 gallons per minute in Well 4. The quality of water in this aquifer generally is good except for a slightly high iron and manganese content. As shown in figure 6, the present city wells are near the boundary of the aquifer. City Well 4 was reported to have 9 feet of sand, and Geological Survey Test Hole 19 penetrated 7 feet of sand. Test Holes 27, 28, 30, 31, 36 and 40 penetrated 14 to 20 feet of sand.

City officials reported that City Well 4 was drilled with a reverse-circulation drill, reamed, and heavily gravel-packed.

It is recommended that the city test for additional water supplies in the aquifer south of Bowdle. The testing should be done in an area

Table 1.--Chemical Analyses of Ground Water Samples from the Bowdle Area (for location of wells, see next page)

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magne-sium	Chloride	Sulfate	Iron	Manga-nese	Nitrate	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A		---	---	50	250	500*	0.3	0.05	10.0*	0.9-1.7**	---	---	1000*
B	Basal Sand	61	55	21	14	80	0.3	0.5	0.0	0.3		241	452
C		66	68	23	37	82	0.0	0.1	0.0	0.3		260	512
D		86	55	33	37	189	0.0	0.3	0.5	0.3		351	632
E		66	59	23	26	74	0.0	0.1	0.4	0.3		260	496
F		225		78	8	88	0.0				8.1	250	657
G		211		84	20	974	Tr.				8.4	190	805
H		310		146	36	192	0.4				8.0	190	1205
I		67	6	20	11	30	1.2	0.1	1.8	0.6		250	362
J		144	15	67	42	352	0.3	0.1	4.5	0.2		636	858
K	Surface Outwash	296		25	28	242	0.0				8.1	640	1282
L		324		110	20	130	0.0				8.2	370	835
M		240		82	0	78	Tr.				8.2	270	643
N		212		57	17	113	0.0				8.2	300	683
O		310		44	232	165	0.0				8.1	950	1933
P	Sand Lens	254		76	0	78	0.0				8.2	330	843
Q		352		42	68	680	Tr.				7.6	1050	2403
R		268		130	20	58	Tr.				8.3	150	950
S	?	298		36	168	195	Tr.				7.7	890	2330
T	?	296		158	312	0	Tr.				7.9	110	1640

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

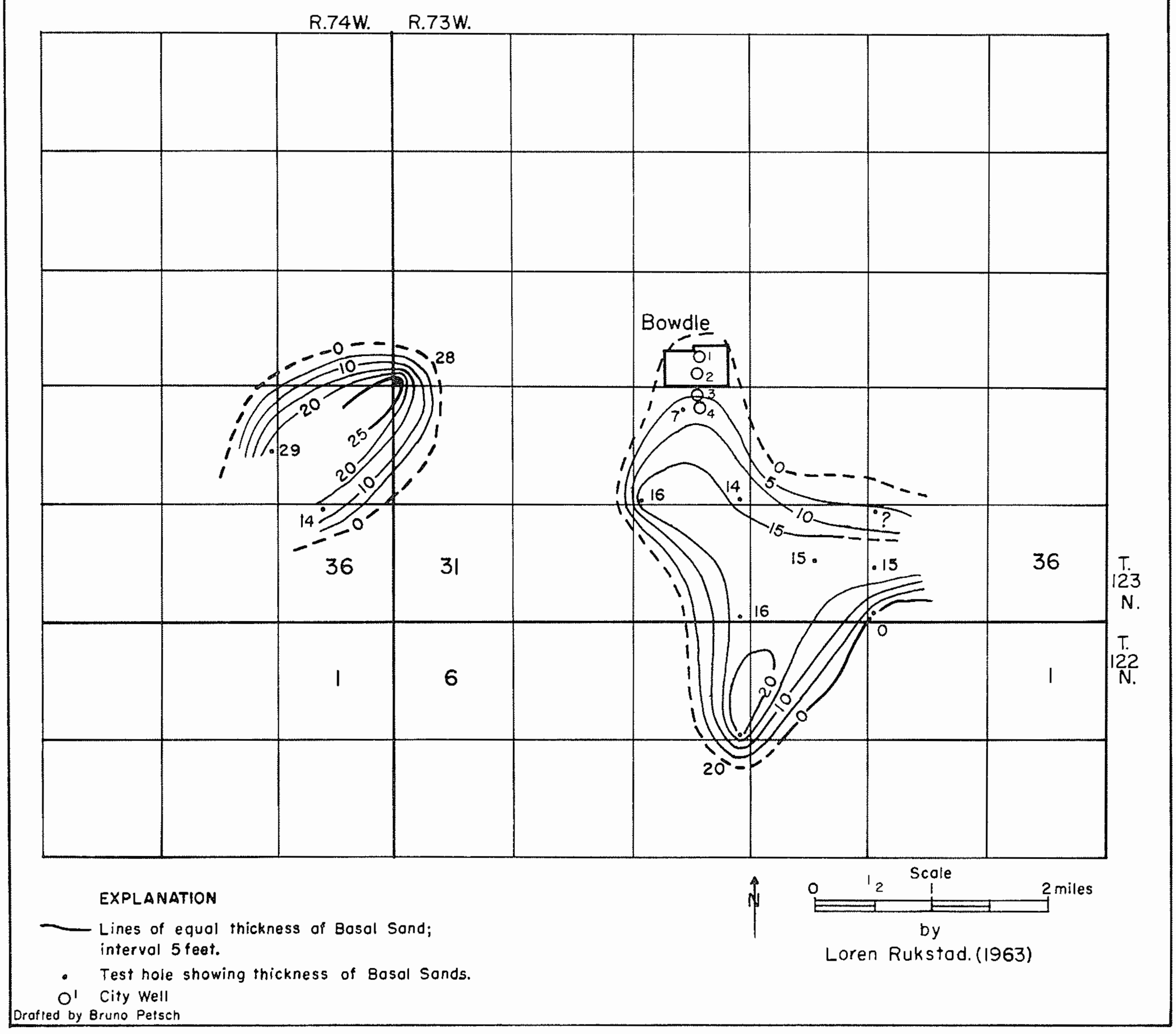
** Optimum

Samples I and J were analyzed by the State Chemical Laboratory; samples B, C, D, and E were taken from South Dakota Public Water Supply Date (1961), and all other samples were analyzed by the Geological Survey's field test kit.

Locations of Water Samples

		Depth (in feet)
A.	U. S. Dept. of Public Health Drinking Water Standards (1961)	
B.	City Well #4, NWNE Sec. 28, T. 123 N., R. 73 W.	90
C.	City Well #3, NWNE Sec. 28, T. 123 N., R. 73 W.	85
D.	City Well #2, NWSE Sec. 21, T. 123 N., R. 73 W.	96
E.	City Well #1, NWSE Sec. 21, T. 123 N., R. 73 W.	102
F.	Bowdle Livestock Comm., SWNE Sec. 28, T. 123 N., R. 73 W.	80
G.	H. Schlecht, SWSW Sec. 24, T. 123 N., R. 74 W.	70
H.	Test Hole #14, SWSW Sec. 19, T. 123 N., R. 73 W.	64
I.	Domestic well, NWNW Sec. 34, T. 123 N., R. 73 W.	65
J.	Domestic well, NWSW Sec. 27, T. 123 N., R. 73 W.	70
K.	Donald Aldinger, NESE Sec. 21, T. 123 N., R. 73 W.	25
L.	C. Schumacher, SESE Sec. 24, T. 123 N., R. 74 W.	25
M.	E. M. Mertz, SESE Sec. 19, T. 123 N., R. 73 W.	37
N.	Melvin Bollinger, NESW Sec. 21, T. 123 N., R. 73 W.	25
O.	L. Erbe, SWSW Sec. 23, T. 123 N., R. 74 W.	20
P.	Harold Nies, NWNW Sec. 12, T. 123 N., R. 74 W.	90
Q.	R. Lemke, SESE Sec. 8, T. 123 N., R. 73 W.	61
R.	Carl Haupt, SESW Sec. 7, T. 123 N., R. 73 W.	145
S.	L. Erbe, SWSW Sec. 23, T. 123 N., R. 74 W.	60
T.	Karl Nickisch, SENE Sec. 20, T. 123 N., R. 73 W.	185

Figure 6. Map showing Distribution and Thickness of the Basal Sand Aquifers in the Bowdle Area.



south of City Well 4 in the southern one-half sec. 28, T. 123 N., R. 73 W., where test-drilling indicates about 15 feet of sand. This location is close enough to City Well 4 to use the present water main, but far enough away so that a new well would probably not interfere with the present city wells. It is further recommended that any new well be similar in construction to City Well 4. It is doubtful that high capacity wells could be obtained from this aquifer; however, it is probable that wells capable of yielding at least the quantity of water City Well 4 now yields could be expected if the wells are properly engineered and constructed.

The second area which is a potential additional municipal supply is the basal aquifer 3 miles west of town (fig. 6). Several farm wells presently obtain their water supply from this aquifer. Although the quality is slightly poorer than the present city supply, it would be acceptable if the iron and manganese content were not too high. Test drilling showed up to 29 feet of saturated fine sand which is four times the thickness of aquifer at City Well 4. It does not necessarily follow, however, that four times the quantity of water could be obtained. If a well were to be constructed in this aquifer, it is recommended that the well construction be similar to City Well 4. Factors to consider in developing this aquifer are its distance from the city and the apparent restricted areal extent.

It is recommended that after deciding which aquifer is best suited for the city, several additional test holes be drilled in the above recommended locations to determine the extent and thickness of the aquifer. On the basis of these test holes, a location may be picked and a test well installed and test pumped. This test-pumping should be conducted by licensed engineers for a minimum of 72 hours. This test is important to determine the quantity and quality of water, and also to determine the type of permanent well to be constructed.

It is suggested that the city contact a commercial drilling company licensed by the State of South Dakota to test-drill the areas recommended. The city officials should consult the State Water Resources Commission with regard to obtaining a water right and a permit to drill a city well, and the State Department of Public 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.

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APPENDIX A

Logs of Auger Test Holes in the Bowdle Area

(for location see figure 5)

Test Hole No. 1
Surface elevation: not measured
Depth to water: caved in

0-4	till, brown
4-9	till, turning blue
9-99	till, blue

* * * * *

Test Hole No. 2
Surface elevation: 2,020 feet
Depth to water: 2.5 feet

0-4	till, brown, some pebbles
4-24	till, brown
24-49	till, blue, saturated
49-84	clay, blue, very dense

* * * * *

Test Hole No. 3
Surface elevation: 2,060 feet
Depth to water: 9.5 feet

0-19	till, brown, few pebbles
19-49	till, dark brown
49-92	clay, blue, some medium sand, moist

* * * * *

Test Hole No. 4
Surface elevation: not measured
Depth to water: 6 feet

0-4	topsoil
4-19	clay, brown
19-24	till, brown
24-64	no cuttings, easy drilling
64-104	clay, blue, saturated
104-109	shale

* * * * *

Test Hole No. 5
Surface elevation: not measured
Depth to water: not measured

0-34	till, brown
34-104	till, blue, some sand
104-120	shale

* * * * *

Test Hole No. 6
Surface elevation: not measured
Depth to water: 4 feet

0-3	sand, gravel, clay, red
3-14	sand, gravel, some clay, saturated, red
14-29	sand, gravel, some clay, saturated, brown
29-34	clay, sand, some pebbles, blue-gray
34-104	clay, blue, some sand

* * * * *

Test Hole No. 7
Surface elevation: 2,007 feet
Depth to water: 9 feet

0-14	clay, some gravel, brown
14-44	clay, sand, fine, saturated
44-59	clay, blue
59-79	till, blue
79-99	shale

* * * * *

Test Hole No. 8
Surface elevation: 2,025 feet
Depth to water: 11 feet

0-19	clay, gravel, sand, brown, unsorted
19-39	till, blue
39-84	till, blue, saturated
84-99	shale

* * * * *

Test Hole No. 9
Surface elevation: 2,020 feet
Depth to water: 7 feet

0-2	topsoil
2-9	clay, gravel, brown
9-19	clay, gravel, red-brown, saturated
19-79	till, blue
79-89	till, gray
89-94	shale

* * * * *

Test Hole No. 10
Surface elevation: 2,004 feet
Depth to water: 4 feet

0-9	gravel (road fill?)
9-14	till, brown, sandy, saturated
14-19	till, blue
19-34	no cuttings, believed to be till
34-78	medium sand, 25% clay, gray, saturated
78-94	shale

* * * * *

Test Hole No. 11
Surface elevation: 2,010 feet
Depth to water: 24 feet

0-9	clay, brown, few pebbles
9-34	till, yellow to brown, damp
34-94	till, blue

* * * * *

Test Hole No. 12
Surface elevation: not measured
Depth to water: not measured

0-9	till, brown
9-64	till, blue
64-79	drills like shale

* * * * *

Test Hole No. 13
Surface elevation: 2,000 feet
Depth to water: 17 feet

0-24	till, brown
24-79	till, blue
79-84	shale

* * * * *

Test Hole No. 14
Surface elevation: 1,980 feet
Depth to water: 3.5 feet

0-4	clay, gray
4-9	till, gray
9-19	till, black, saturated
19-64	till, blue
64-92	sand, fine, gray-brown
92-99	shale

* * * * *

Test Hole No. 15
Surface elevation: 1,983 feet
Depth to water: 4.5 feet

0-12	clay, sand, unsorted, brown
12-39	till, blue
39-104	till, blue, saturated
104-109	shale

* * * * *

Test Hole No. 16
Surface elevation: 1,969 feet
Depth to water: 13 feet

0-22	clay, sand, gravel, brown, unsorted
22-74	clay, gray
74-115	clay, gray, saturated
115-135	shale

* * * * *

Test Hole No. 17
Surface elevation: 1,983 feet
Depth to water: plugged

0-8	sand, gravel, unsorted, some clay, dry
8-24	sand, clay, unsorted, saturated
24-89	till, blue
89-130	clay, gray
130-140	shale

* * * * *

Test Hole No. 18
Surface elevation: 2,000 feet
Depth to water: 11 feet

0-4	gravel (road fill)
4-24	clay, some sand, brown
24-94	till, blue
94-99	clay, blue
99-104	shale

* * * * *

Test Hole No. 19
Surface elevation: 1,990 feet
Depth to water: 10.5 feet

0-19	clay, sand, gravel, unsorted
19-24	clay, sand, gravel, saturated
24-54	clay, blue
54-91	clay, blue, becoming more sandy
91-99	sand, gray, fine to very fine
99-104	shale

* * * * *

Test Hole No. 20
Surface elevation: 1,997 feet
Depth to water: 15.5 feet

0-14	till, brown
14-24	till, blue
24-39	clay, sand, gravel, saturated
39-59	clay, blue, less sand
59-74	clay, blue, no sand
74-84	shale

* * * * *

Test Hole No. 21
Surface elevation: not measured
Depth to water: 26.5 feet

0-29	clay, sand, gravel, unsorted
29-54	clay, sand, gravel, saturated
54-64	clay, some sand
64-79	clay, very dense, moist

* * * * *

Test Hole No. 22
Surface elevation: 1,977 feet
Depth to water: 16 feet

0-10	clay, brown, no sand
10-29	clay, gray
29-54	clay, blue
54-78	sand, gray, very fine
78-79	shale

* * * * *

Test Hole No. 23
Surface elevation: 1,956 feet
Depth to water: not measured

0-29	sand, gravel, reddish-brown, high clay content
29-120	till, blue
120-124	shale

* * * * *

Test Hole No. 24
Surface elevation: 1,966 feet
Depth to water: 7 feet

0-9	clay, sandy, dark brown
9-19	sand, gravel, brown, unsorted, saturated
19-49	clay, blue
49-64	sand, very fine, saturated
64-69	shale

* * * * *

Test Hole No. 25
Surface elevation: not measured
Depth to water: caved in

0-24	clay, brown, little sand, dry
24-39	till, blue, saturated

* * * * *

Test Hole No. 26
Surface elevation: 1,955 feet
Depth to water: plugged

0-14	clay, gravel, sand, dark brown
14-64	till, blue
64-118	till, blue, saturated
118-	shale

* * * * *

Test Hole No. 27
Surface elevation: 1,975 feet
Depth to water: 9 feet

0-24	clay, gravel, brown, dry
24-44	clay, more gravel
44-74	clay, and gravel, saturated
74-90	sand, fine to very fine
90-	shale

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Test Hole No. 28
Surface elevation: 2,001 feet
Depth to water: caved in

0-9	clay, pea-size gravel, brown, dry
9-14	sand, fine, saturated
14-29	till, blue
29-70	sand, very fine, silty
70-84	sand, very fine, cleaner
84-89	shale?

* * * * *

Test Hole No. 29
Surface elevation: 2,017 feet
Depth to water: not measured

0-14	till, brown
14-49	till, blue
49-89	very fine cuttings, easy drilling
89-100	shale?

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Test Hole No. 30
Surface elevation: 2,007 feet
Depth to water: not measured

0-4	topsoil
4-34	till, brown
34-59	clay, sandy, saturated
59-74	gravel, clay, saturated, sand, very fine
74-89	no cuttings, shale (?)
89-100	shale

* * * * *

Test Hole No. 31
Surface elevation: 2,008 feet
Depth to water: 8 feet

0-4	till, black
4-19	till, brown
19-63	till, blue
63-78	sand, very fine, small lens of pea-size gravel
78-84	shale

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Test Hole No. 32
Surface elevation: 1,944 feet
Depth to water: plugged

0-4	topsoil
4-14	alluvium
14-24	clay, some sand, saturated
24-54	till, blue
54-59	shale

* * * * *

Test Hole No. 33
Surface elevation: 1,953 feet
Depth to water: 8.5 feet

0-3	topsoil
3-9	clay, dark brown
9-19	clay, dark brown, saturated
19-34	clay, gray
34-94	clay, blue
94-99	shale

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Test Hole No. 34
Surface elevation: 1,953 feet
Depth to water: 2 feet

0-9	clay, and unsorted sand
9-19	clay, and unsorted sand, saturated
19-54	clay, brown, some sand and gravel
54-100	clay, little sand
100-135	shale

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Test Hole No. 35
Surface elevation: not measured
Depth to water: dry

0-9	clay, little sand
9-39	till, brown, dry
39-	could not penetrate

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Test Hole No. 36
Surface elevation: 1,990 feet
Depth to water: 14.5 feet

0-24	clay, brown, dry
24-34	till, blue
34-84	till, blue, little sand
84-100	sand, very fine

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Test Hole No. 37
Surface elevation: 2,007 feet
Depth to water: not measured

0-19	till, dark brown
19-54	till, blue
54-64	no cuttings
64-74	till, brown
74-94	drills like shale

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Test Hole No. 38
Surface elevation: not measured
Depth to water: 11 feet

0-4	topsoil
4-9	clay, sandy, brown
9-19	till, brown
19-24	till, blue
24-39	clay, some sand and gravel
39-129	till, blue

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Test Hole No. 39
Surface elevation: not measured
Depth to water: 8 feet

0-4	topsoil
4-49	till, green to gray
49-64	till?, some sand and gravel, poor cuttings
64-84	till, blue
84-100	drills like shale

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Test Hole No. 40
Surface elevation: not measured
Depth to water: not measured

0-29	till, dark brown
29-74	till, blue
74-94	sand, very fine, silty
95-	shale

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APPENDIX B

Table 2.--Records of Wells in the Bowdle Area

Well location: Letters stand for quarter-section, first number for section, second for township north, third for range west.
Type of well: D, drilled; B, bored; Du, dug
Water-bearing material: S, sand; G, gravel; C, clay; Sh, shale
Geologic Source: Till; O, outwash; SD, stratified drift; Kp, Pierre Shale; B.Sand, basal sand

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Water-Bearing Material	Geologic Source
NE-2-122-73	A. Eisenbeisz	B	30	G	O
NE-3-122-73	M. Eisenbeisz	B	70	S?	B. Sand
NW-4-122-73	H. Geidt	B	40	C	Till
NW-5-122-73	W. Thurb	B	24	S,G	O
NW-8-122-73	E. Schnaible	B	72	S,G,C	O, Till
NW-9-122-73	V. Karst	B	?	G	O
NW-10-122-73	L. Nies	B	19	G	O
NW-1-122-74	R. Bollinger	B	12	G	O
SE-4-123-73	A. Geier	B	100	G,Sh	O, Kp
SE-4-123-73	A. Geier	B	14	G	O
SE-5-123-73	M. Schock	B	60	G	O
SE-7-123-73	C. Haupt	D	145	S,Sh	O, Kp
SE-8-123-73	R. Lemke	B	61	C,S,G	Till, SD
SE-9-123-73	A. Rieger	D	125	C,S	Till, O
SE-9-123-73	A. Rieger	B	77	C,S	Till, O
SW-11-123-73	A. Thomas, Jr.	B	70	C,S	Till, O

Appendix B-Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Water-Bearing Material	Geologic Source
NE-11-123-73	A. Thomas	B	65	C	Till
SW-15-123-73	J. Weisjhaar	B	30	C,S,G	Till, SD
SE-15-123-73	M. Maier	B	65	C	Till
NE-18-123-73	O. Buechler	D	171	C,S,G	Till, SD
SE-19-123-73	E. M. Mertz	B	37	S,G	O
NE-20-123-73	K. Nickisch	D	185	S,G	?
City of Bowdle Well #1		D	102	S	B. Sand
City of Bowdle Well #2		D	96	S	B. Sand
City of Bowdle Well #3		D	85	S	B. Sand
City of Bowdle Well #4		D	90	S	B. Sand
SW-21-123-73	Melvin Bollinger	B	25	S,G	O
SE-21-123-73	Edward Huber	Du	22	G	O
SW-22-123-73	J. Voller	B	25	C,S,G	Till, SD
NE-24-123-73	G. Blumhardt	B	108	G	O
NE-24-123-73	G. Blumhardt	B	80	G	O
NW-25-123-73	E. Beitelspacher	B	80	G	O
NW-26-123-73	R. Serr	B	80	G	O
NW-27-123-73	E. Merkel	B	28	C,S,G	Till, SD
SW-27-123-73	A. Albrecht	B	70	C,S,G	B. Sand
SE-29-123-73	M. Hoffman	B	18	S,G	O
NE-31-123-73	T. Leidholt	B	12	C,S,G	Till, O

Appendix B-Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Water-Bearing Material	Geologic Source
SW-31-123-73	A. Schuh	B	10	S,G,C	O, Till
SW-33-123-73	J. P. Bieber	B	50	C,S,G	Till, SD
NW-34-123-73	M. J. Gutjahn	B	70	S,G	Till, SD
SW-10-123-74	E. Mertz	B	20	S,G	O
NW-11-123-74	A. J. Weiszhaar	B	70	S,G,Sh	O, Kp
NW-12-123-74	E. Lorenz	B	48	S,G,C	O, Till
NE-12-123-74	A. Schick	B	28	S,G	O
SE-12-123-74	E. Buechler	D	115	S,G,C	SD, Till
NE-14-123-74	J. Greger	B	58	S,G,C	SD, Till
SW-14-123-74	J. Greger	B	31	C	Till
SW-23-123-74	L. Erbe	B	60	S,G	B. Sand
SW-23-123-74	L. Erbe	B	20	S,G	O
SW-24-123-74	H. Schlecht	B	70	S,G,C	SD, Till
SE-24-123-74	C. Schumacher	B	25	S,G	O
NW-26-123-74	A. Leidhold	B	8	S,G,C	O, Till
SW-26-123-74	A. Leidhold	B	8	S,G	O
NE-30-123-74	O. Bollinger	B	11	S,G	O
SE-34-123-74	A. Fleck	B	45	C,S,G	SD, Till
NW-35-123-74	J. Lassle	B	40	C,S	Till, SD