STATE OF SOUTH DAKOTA
Nils Boe, Governor

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

Special Report 36

GROUND WATER SUPPLY FOR THE CITY OF WINNER, SOUTH DAKOTA

by
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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota State Geological Survey from June 14 to July 16, 1965, in and around the city of Winner, Tripp County, South Dakota (fig. 1), for the purpose of assisting the city in locating a future water supply.

Winner now obtains its water from 9 wells which are producing from the Valentine Sand, and are located approximately eight miles south of the city (fig. 2).

A survey of the ground-water possibilities was conducted in the Winner area. Included in this survey was a review of the geology as mapped by the South Dakota State Geological Survey (Sam G. Collins, 1957a, b), the drilling of 64 test holes, and collection of five water samples for analysis. Also included was surveying of the present city wells. As a result of the ground-water survey, a new area for future ground-water development is being recommended about one mile west of the present well field.

The field work and preparation of this report were performed under the supervision of Merlin J. Tipton, Assistant State Geologist, with the help of Cleo M. Christensen and Lynn S. Hedges, ground-water geologists. J. C. Harksen, stratigrapher with the State Geological Survey, spent a day in the area and gave helpful advice for this project.

Drillers for the project were Ronald W. Little and Mark Huenemann. Robert P. Larimer and his assistant John Moore did the surveying. The writer wishes to thank the State Chemical Laboratory for analyzing the water samples collected for this project.

The cooperation of the residents of Winner, especially Mayor Rollin Key, and Catherine M. Kelley, City Auditor, is greatly appreciated. Special thanks are due to Harold Dreyer, local well driller, for making his well records available.

Location and Extent of Area

The city of Winner is located in south-central South Dakota in Tripp County and has a population of 3,705 (1960 census). The area is in the Pierre hills and Tertiary tablelands sections of the Great Plains physiographic province (fig. 1).

Climate

The climate is typical of the temperate high plains with a large daily and seasonal fluctuation in temperature. The average daily temperature is 49.1 degrees F., and the average annual precipitation is 19.09 inches at the U. S. Weather Bureau Station in Winner.

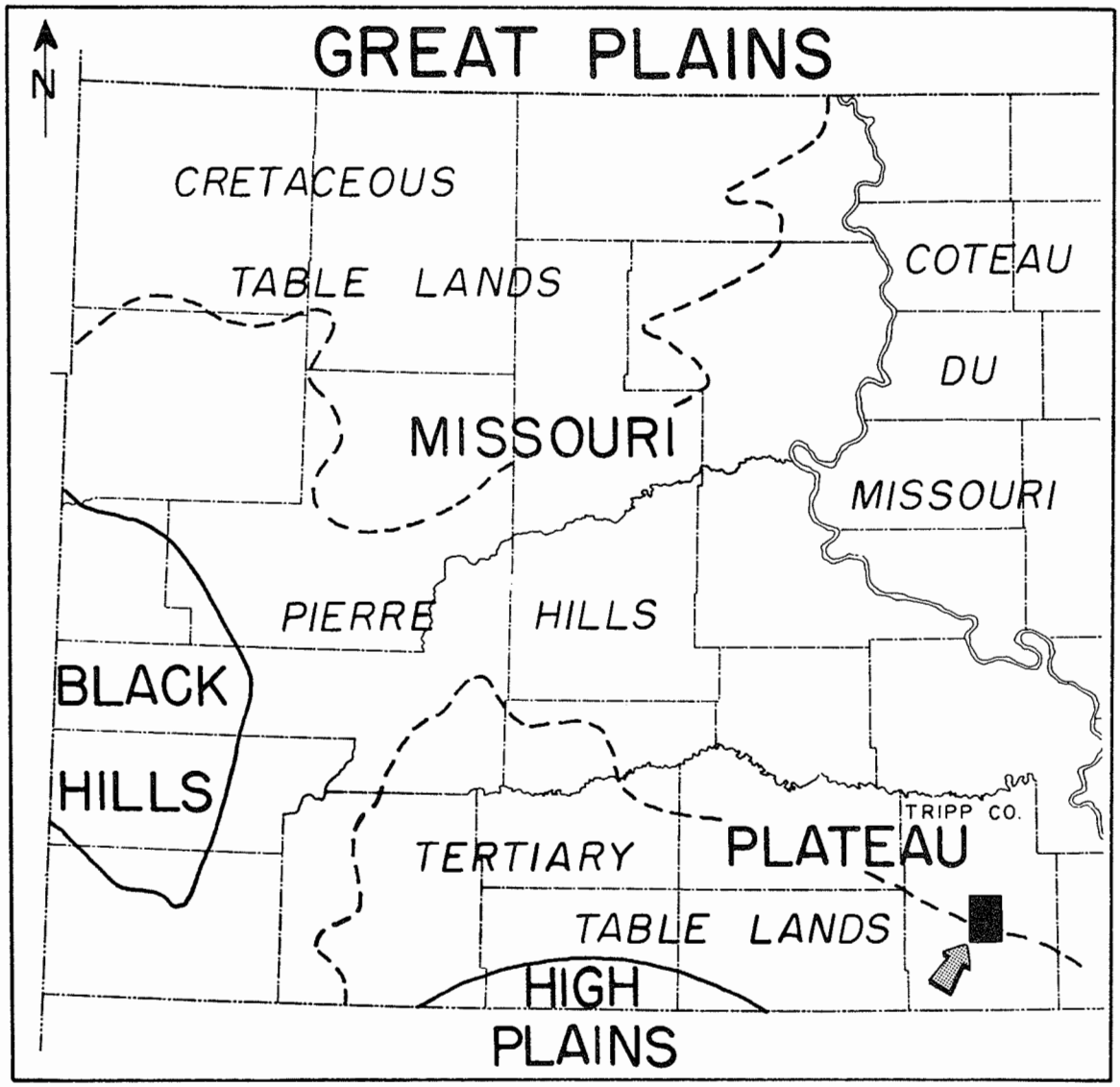


Figure I. Major Physiographic Divisions of western South Dakota and location of the Winner area.

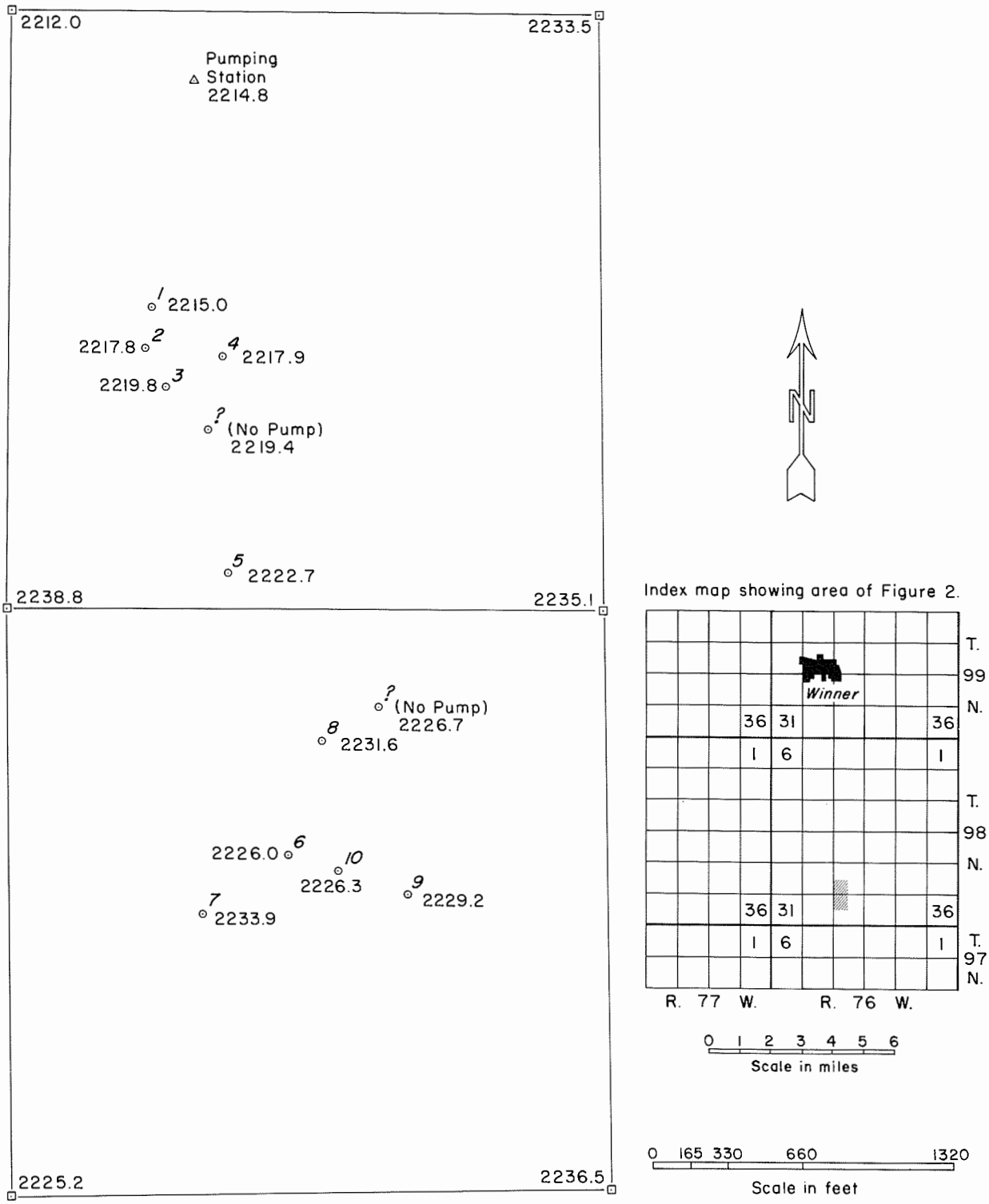


Figure 2. Map showing location and elevation of city wells in the Winner area.

Topography and Drainage

The Winner area is characterized by rolling plains of relatively low relief, developed on the marine rocks of the Pierre Shale. Toward the southern part of the area the surface rises into butte and mesa topography typical of the Tertiary tablelands.

The area is drained by intermittent northward-flowing streams. The major streams are Dog Ear Creek and its tributary Big Hollow Creek to the west and Thunder Creek to the east of the city. These streams are tributary to the White River.

Data Point Numbering System

Data-collection points (test holes and wells, fig. 3) are located in accordance with the United States Bureau of Land Management's system of land subdivision. The first numeral of a point designation indicates the township, the second the range, and the third the section in which the point is situated. Lower case letters after the section number indicate location within the section; the first letter denotes the 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. The letters a, b, c, and d are assigned in a counterclockwise direction, beginning in the northeast corner of each tract. The number of lower case letters indicates the accuracy of the point location; if the point can be located within a 10-acre tract, three lower case letters are shown in the point number. For example, data collection point 98-76-33aaa is in the $NE\frac{1}{4}NE\frac{1}{4}NE\frac{1}{4}$, sec. 33, T. 98 N., R. 76 W. The method of designation is shown in Figure 4.

GENERAL GEOLOGY

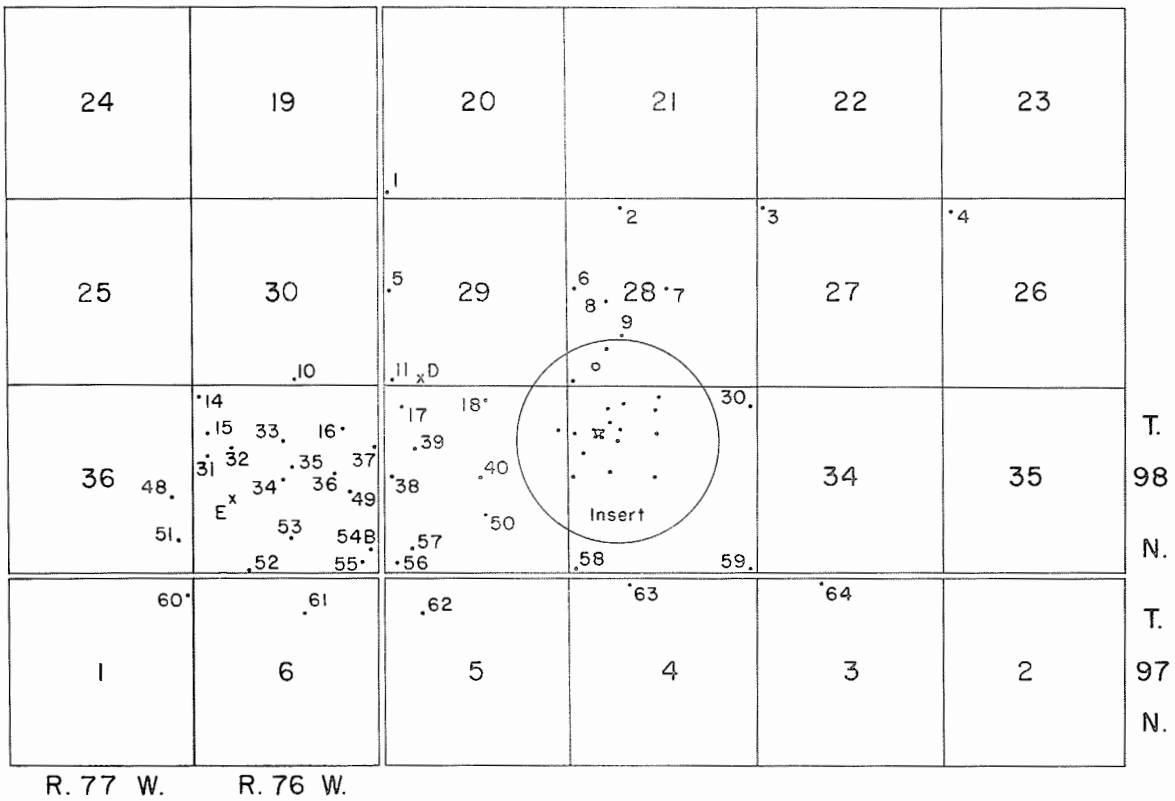
Surficial Deposits

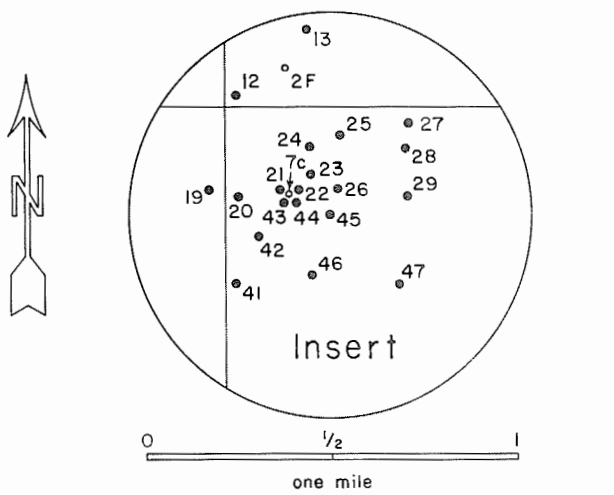
The surficial deposits of the Winner area include Pleistocene terrace deposits, and alluvium along present drainages (fig. 5). Alluvium consists of silt and sand deposited in present stream valleys and attains a maximum thickness of 6 feet (Collins, 1957a).

Terrace deposits consist of locally derived silt, sand and gravel capping small hills. Maximum thickness of these deposits is 12 feet (Collins, 1957a).

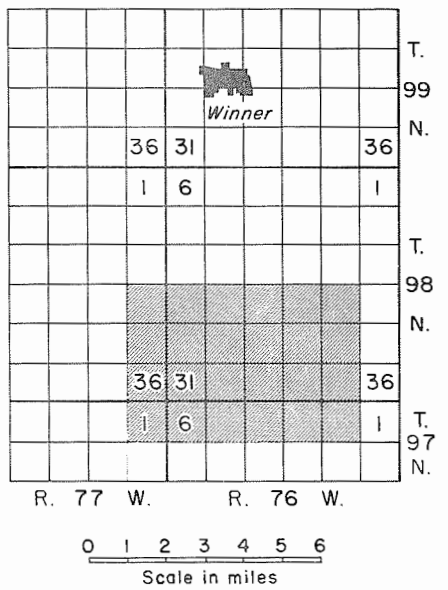
Exposed Bedrock

The Cretaceous Pierre Shale, a thick marine sediment, underlies the entire area and crops out at lower altitudes over much of the area investigated. At higher altitudes in the southern part of the area, the Pierre is overlain by the Tertiary continental deposits of the Oligocene Brule





Index map showing area of Figure 3.



EXPLANATION

.15 Test hole

°2F City well

xD Farm well

Letter following test hole or well designation indicates a water sample and corresponds to sample in Table 2.

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Figure 3. Map showing location of test holes and water samples in the Winner area.

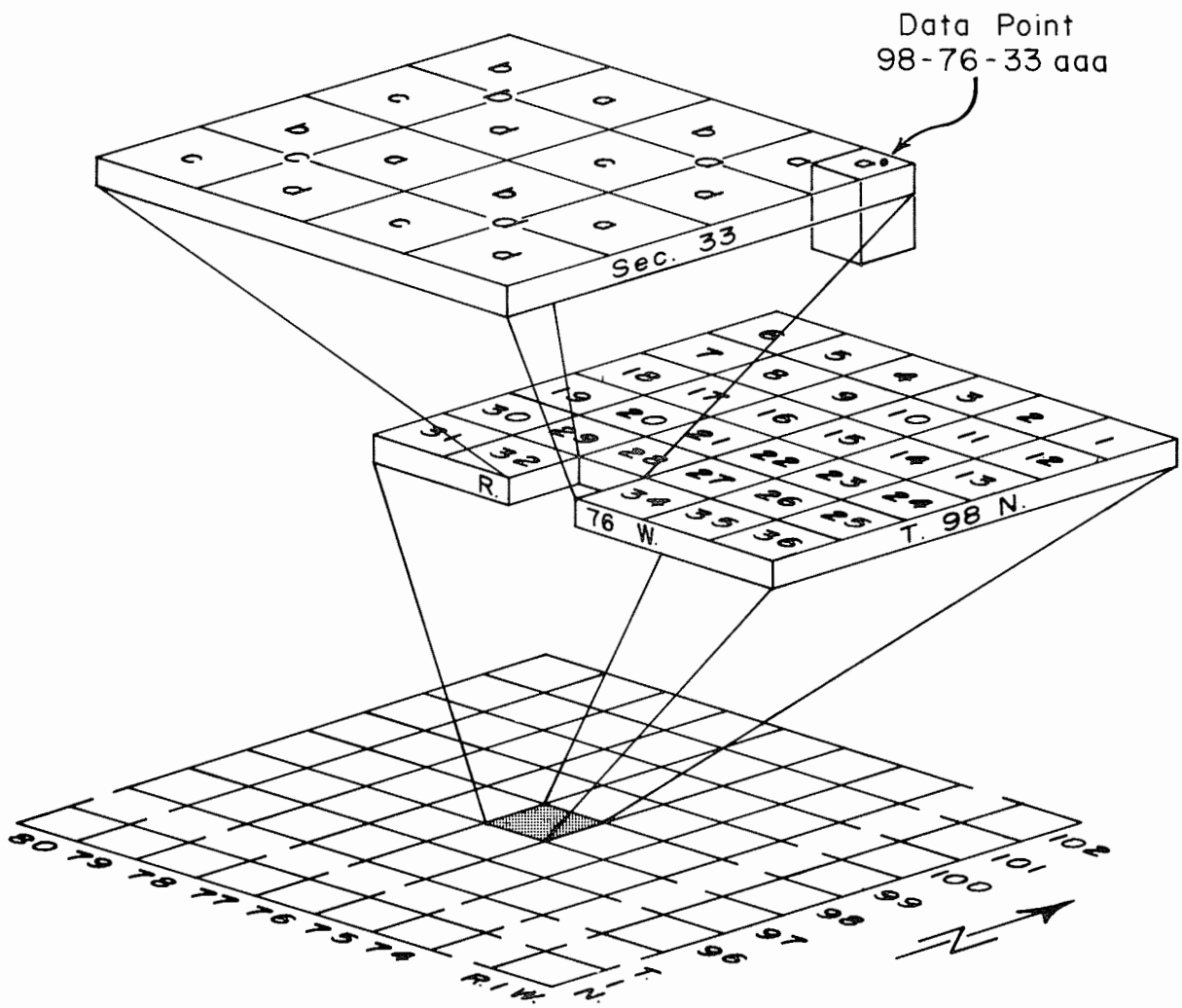
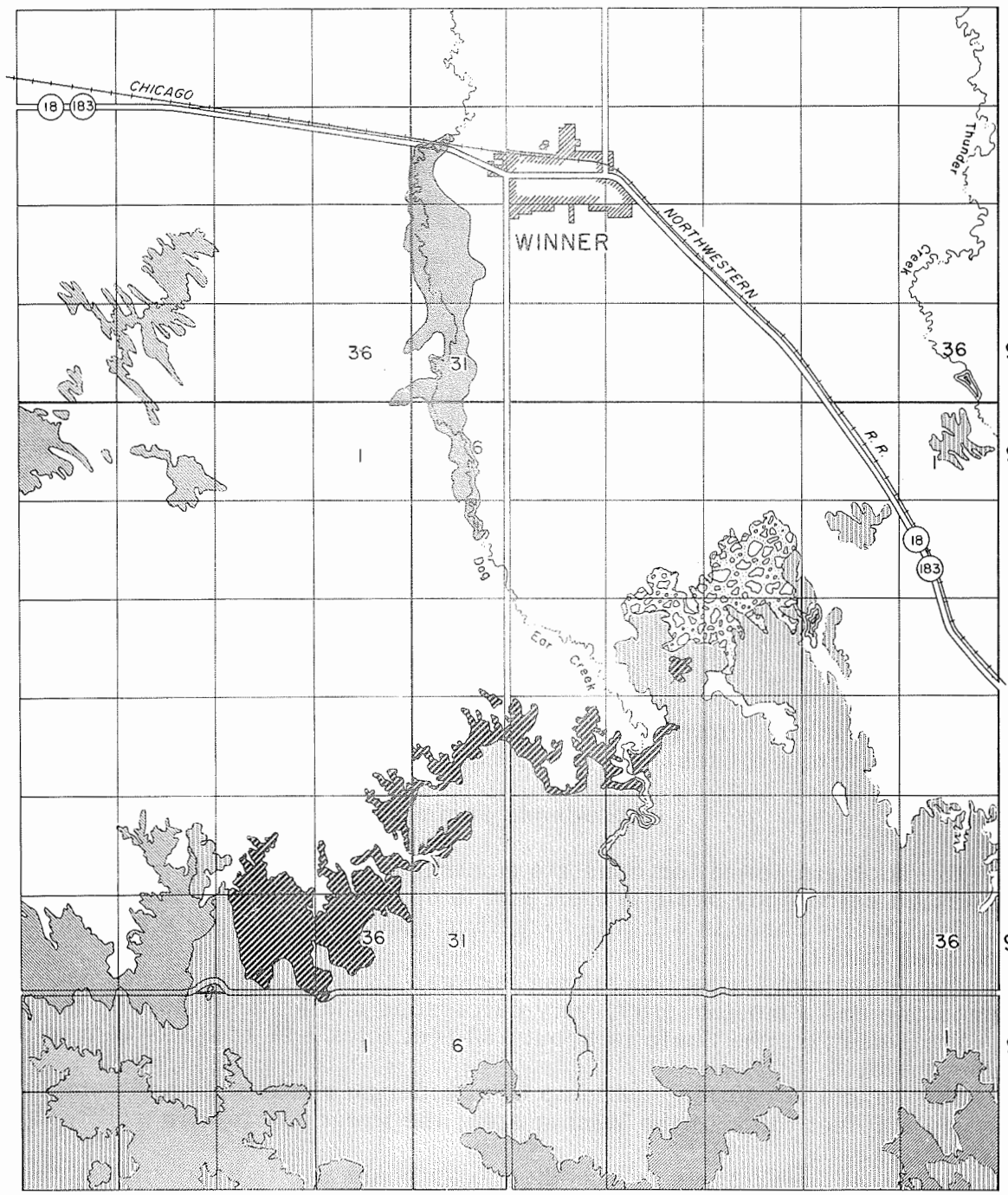


Figure 4. Data point numbering system.



drafted by D. W. Johnson

by
A. Barari,
1965

Figure 5.
Geologic Map of the Winner Area.
(modified from S. G. Collins, 1957 *a* and *b*.)

Formation and the Pliocene Ogallala Group respectively, which is represented in the Winner area by the Valentine Formation (and Bijou facies) and the Ash Hollow Formation (fig. 5).

The Ash Hollow Formation consists of medium gray to light olive-greenish calcareous sandstones forming caps on the buttes and the high undrained divides. The thickness of this unit in the Winner area is 35 feet (Collins, 1957b).

The Valentine Formation is a greenish-tan to tan, fine to medium grained, poorly consolidated arkosic sandstone. This formation is at the surface throughout much of the southern part of the study area (fig. 5). The thickest sequence of this formation penetrated in test drilling was less than 100 feet, although Collins (1957a) lists the maximum thickness as 140 feet. Included in the Valentine Formation is the Bijou facies, a gray to greenish fine grained opaline arkosic sandstone which is silica cemented. Maximum thickness of this unit is 5 feet (Collins, 1957a).

The Pierre Shale is a dark, platy marine clay shale, calcareous in the lower part and contains thin layers of dark limestone and siderite. Maximum exposed thickness is 398 feet (Collins, 1957a), although the total thickness may be as much as 1000 feet in the Winner area.

Subsurface Bedrock

The subsurface information is extrapolated to the Winner area from the Kucera #1 Bartels oil test, six miles north of Winner.

Cretaceous Sediments

The Niobrara Formation consists mostly of light- to medium-gray, white speckled calcareous shale or marl and is approximately 140 feet thick.

The Carlile Shale is a light- to medium-gray, plastic shale and is about 280 feet thick.

The Greenhorn Limestone ranges between a nearly white fragmental limestone and a medium gray, very calcareous shale and is 40 feet thick.

The Belle Fourche Shale is about 150 feet thick and consists of medium gray shale.

The Dakota Formation, made up of alternating shale and sandstone, is nearly 420 feet thick in the Winner area; the lower 130 feet is mostly sandstone.

The Skull Creek Shale is a medium gray shale and is approximately 40 feet thick.

The Inyan Kara Group consists of alternating beds of shale and sandstone and is at least 300 feet thick.

Paleozoic Sediments

The Pennsylvanian System is represented by the Roundtop Formation, which in this area is about 75 feet of varicolored shale, and the Fairbank Formation which is 140 feet of sandstone.

The Mississippian System is represented by 25 feet of carbonates in the Lodgepole Formation.

The Devonian-Silurian Systems consist of a 40-foot sand section.

The Ordovician System is represented by 60 feet of sandy and porous Red River carbonates.

The Cambro-Ordovician sands attain a thickness of approximately 60 feet and overlie the Precambrian granite.

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 directly downward to the water table and becomes ground water or drains off as surface water. Surface water either evaporates, escapes to the ocean by streams, or percolates downward to the ground-water table. The permeable rocks (including the soil) that lie above the zone are also filled with water, but the water is either held in them by molecular attraction or is moving downward toward the zone of saturation. Water within the ground moves downward through the unsaturated zone under the action of gravity, whereas in the saturated zone it moves in a direction determined by the surrounding hydraulic head.

Recharge is the addition of water to an aquifer (formation having structures that permit appreciable water to move through them under ordinary field conditions), and is accomplished in four main ways: (1) downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, and (3) by lateral underflow of water in transient storage, and (4) by artificial recharge, which occur 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 of plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water in transient storage, (4) by pumping from the wells which constitutes the major artificial discharge of ground water.

The porosity of a rock or soil is a measure of the contained interstices, and it is expressed as the percentage of void space to the total volume of the rock. The porosity of a sedimentary deposit depends chiefly on

(1) the shape and arrangement of its constituent particles, (2) the degree of assortment of its particles, (3) the cementation and compaction to which it has been subjected since its deposition, (4) removal of mineral matter through solution by percolating waters, (5) the fracturing of the rock, resulting in joints and other openings. Thus, size of the material has little effect on porosity if all other factors are equal.

The permeability of a rock is its capacity for transmitting a fluid (water). 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. Unconsolidated sand and gravel usually have both high porosity and high permeability. Therefore, a geologist in his search for ground-water supplies is concerned with locating an extensive sand or gravel deposit that lies below the water table.

Ground Water in the Surficial Deposits

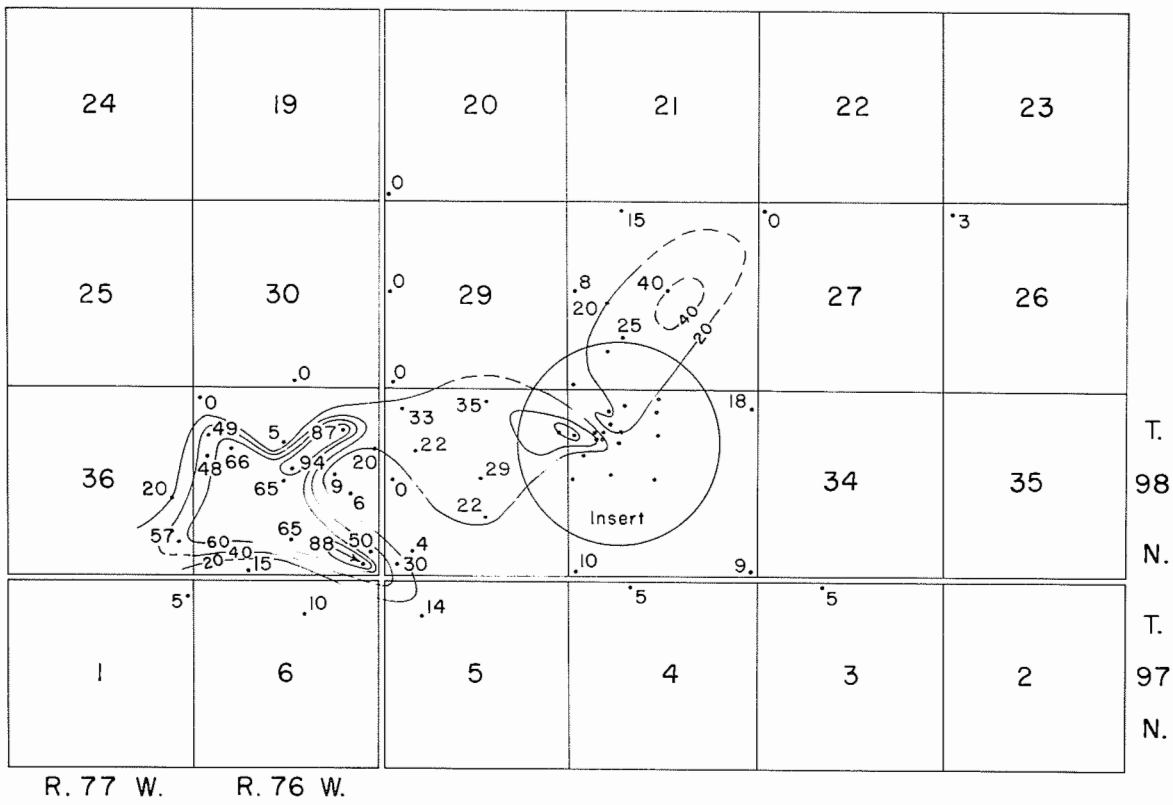
The surficial deposits in the area consist of alluvium and Pleistocene terrace sands and gravels. These deposits have a restricted areal extent, are quite thin, and therefore should not be considered a potential city supply, although there may be enough water available locally for limited stock and domestic use.

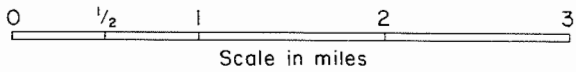
Ground Water in Exposed Bedrock

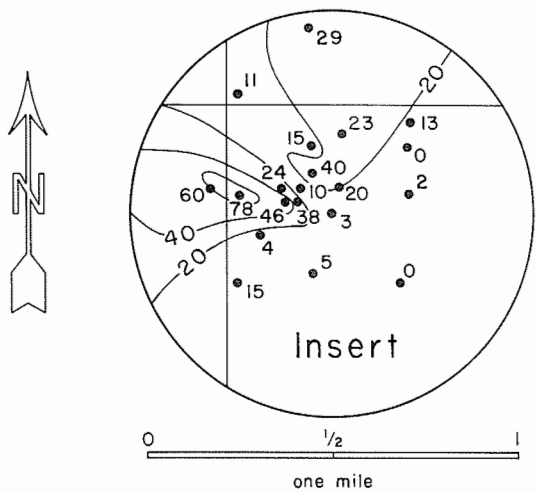
In the study area the Ash Hollow Formation is thin, has a restricted areal extent, and is found only capping buttes or on the highest undrained divides. Locally, stock and domestic wells may yield an adequate supply of water. However, in the study area this formation would not yield an adequate supply of water for the city of Winner.

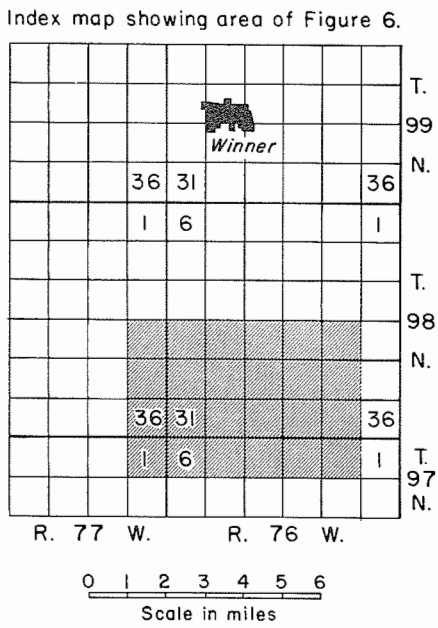
The Valentine Formation comprises the main aquifer in the study area south of Winner. The extent of the formation can be seen on Figure 5. Although the formation is extensive, the sand unit which comprises the best aquifer varies locally in thickness (fig. 6). The greatest thickness of saturated sand encountered in the study area was 94 feet in Test Hole 35 (Appendix); however, the sand thins to less than 20 feet within one-half mile of this location. The somewhat linear pattern and rapid thinning and thickening of the sand unit (fig. 6) in the study area is strongly suggestive of a channel deposit. For this reason it requires extensive test drilling to delineate the areal distribution and thickness. Table 1 gives some of the physical and hydrologic characteristics of the sand unit.

The Brule Formation underlies the Valentine Formation in the study area and furnishes water to many stock and domestic wells. However, it does not readily yield large quantities of water due to its high silt and clay content.









EXPLANATION

Lines showing equal thickness of saturated sand, contour interval = 20 feet

·30 Test hole showing thickness of saturated sand

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Figure 6. Map showing thickness of saturated sand in the Winner area.

Table 1.--Some physical and hydrologic properties of the Valentine Sand. (Laboratory analyses by U. S. Geological Survey Hydrologic Laboratory, Denver, Colorado)

Sample No.	Location	Depth (feet)	Total Porosity(%)	Specific Yield (%)	Coefficient of Permeability (gpd per sq. ft.)
1.	98-76-31dd	5- 55	38.2	32.7	67
2.	98-76-31ac	2- 99	40.2	32.6	34
3.	98-76-33bc	8- 33	38.8	32.3	54
4.	98-76-31dcb	50-100	38.1	33.4	86
5.	98-76-33bc	45- 60	39.1	32.6	48

Samples 3 and 5 taken from Winner City Well 7, at 90 feet and 30 feet respectively.

The Pierre Shale underlies the entire area either at the surface or in the subsurface. It does not readily yield large quantities of water due to its high clay content.

Ground Water in Subsurface Bedrock

The Dakota Formation and the Inyan Kara Group are the only Cretaceous sediments that can supply an adequate quantity of water for the city of Winner. The top of the Dakota Formation is at a depth of about 1300 feet at Winner. The basal 130 feet of the Dakota Formation would probably supply the greatest amount of water. The top of the Inyan Kara Group is at a depth of approximately 1800 feet at Winner.

The top of the Paleozoic rocks is at a depth of about 2050 feet at Winner. All the Paleozoic formations except the upper Roundtop Formation are potential aquifers.

More than one well in any of the subsurface bedrock formations would probably be required to provide an adequate quantity of water for the city of Winner.

Quality of Ground Water

Ground water always contains minerals in various quantities. These minerals 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 deposits below the water table, where the water is circulating. In general, the more minerals that a water contains, the poorer its quality.

Table 2 is a comparison of the quality of water from five wells producing from the Valentine Formation in the Winner area, with the Public Health Standards for drinking water. It can be seen from this table that the five analyses are within the Public Health Standards, except for the high iron content in Sample E, and low fluoride content in all samples. Sample E is from an unused well which had only a hand pump. Even though the well was pumped for several minutes before sampling, the high iron content may be due to concentration in the unused well.

No quality of water data is listed for the subsurface bedrock formations at Winner; however, data from surrounding areas indicate the water is highly mineralized and would probably require treatment for use as a municipal supply.

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the city of Winner test for future water supplies in the Valentine Formation in the area outlined in 98-76-31 (fig. 6)

Table 2.--Chemical analyses of water samples in the Winner area. (For location see fig. 3.)

Sample	Parts Per Million											
	Calcium	Sodium	Magnesium	Chlorides	Sulfate	Iron	Manganese	Nitrate	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A	--	--	50	250	500*	0.3	0.05	10.0	0.9-1.7**	---	---	1000*
B	59	5	2	4	36	Trace	0	0.8	0.6	7.7	158	260
C	69	5	3	0	30	0.2	0	0.7	0.6	7.5	184	290
D	46	4	3	5	36	0	0	3.5	0.4	7.5	130	244
E	30	5	1	0	18	0.7	0	0.4	0.4	8.0	80	184
F	52		2	Trace	0	0				7.5	140	237

A. Drinking Water Standards, U. S. Public Health Service, (1962)
B. Location: 98-76-31dda
C. City Well No. 7
D. Location: 98-76-29ccd
E. Location: 98-76-31cba
F. City Well No. 2

Samples B, C, D, and E were analyzed by State Chemical Laboratory. Sample F was analyzed by the State Geological Survey.

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

showing the greatest thickness of saturated sand. Although there is a fairly thick sand in the area of the present well field, the present city wells are closely spaced and additional wells would probably interfere with the present city wells. The only manner in which a safe distance between wells can be determined is by means of pump tests. These pump tests should be conducted by qualified engineers and run for a minimum of 72 hours.

If the city decides to construct a new well, it is recommended they contract a commercial well drilling company to drill additional test holes to locate the best site for future development. On the basis of all test drilling, a site should be selected to run a pump test to determine yield, drawdown, and recovery. A proper well and water system can then be designed from data obtained in the pump tests.

If the city should decide to develop a ground-water supply from the subsurface bedrock formations, it is recommended that a test well be drilled through the Cretaceous sediments and tests be made to determine the quantity and quality of water from the Dakota Formation and the Inyan Kara Group. If the results of these tests are unsatisfactory, the test hole can be deepened and the underlying Paleozoic sediments can be tested for quantity and quality. The results of the preliminary tests will afford a basis for developing the best water horizon and for proper well design.

The city officials should consult with the State Water Resources Commission with regard to obtaining a water right and a permit to drill a city well, and the State Department of Health with regard to the biological and chemical suitability of the water.

REFERENCES CITED

Collins, S. G., 1957a, Geology of the Winner quadrangle, South Dakota: S. Dak. Geol. Survey, map and text.

_____1957b, Geology of Wewela quadrangle, South Dakota: S. Dak. Geol. Survey, map and text.

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

Rothrock, E. P., 1943, A geology of South Dakota, Part I: The surface: S. Dak. Geol. Survey Bull. 13, 88 p., 30 pl., 3 maps.

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

APPENDIX

Logs of Test Holes in the Winner Area

(For location see Figure 3)

Test Hole No. 1
Location: 98-76-20ccc
Depth to water: 27 feet

0- 2	topsoil, black
2-19	sand, medium, subrounded, tan, some clay
19-34	clay, sandy, gray

* * * * *

Test Hole No. 2
Location: 98-76-28bab
Depth to water: 5 feet

0- 1	topsoil, sandy
1- 3	sandy, clayey
3-15	sand, medium, brown
15-16	clay, brown
16-17	rock
17-20	clay, brown
20-25	sand, medium
25-30	clay, brown

* * * * *

Test Hole No. 3
Location: 98-76-27bbb
Depth to water: no water

0- 3	topsoil, sandy, brown
3- 4	sand, medium, clayey
4-14	clay, tan

* * * * *

Test Hole No. 4
Location: 98-76-26bbb
Depth to water: 6 feet

0- 2	topsoil, sandy
4- 9	sand, brown, clayey
9-19	clay, some sand

* * * * *

Test Hole No. 5
Location: 98-76-29bcc
Depth to water: 27 feet

1- 2	topsoil, sandy
2- 4	sand, very fine, tan
4- 7	clay, sandy, tan
7-19	sand, medium, some clay
19-31	clay, sandy, gray

* * * * *

Test Hole No. 6
Location: 98-76-28bcc
Depth to water: 7 feet

0- 2	topsoil
2-15	sand, medium, brown, clayey
15-24	clay, tan

* * * * *

Test Hole No. 7
Location: 98-76-28acc
Depth to water: 10 feet

0- 1	topsoil, sandy
1-50	sand, medium, tan
50-59	clay, tan

* * * * *

Test Hole No. 8
Location: 98-76-28cba
Depth to water: 15 feet

0- 2	topsoil
2- 5	clay, sandy, brown
5-10	sand, fine to medium, tan, some clay
10-35	sand, clayey
35-36	rock
36-44	clay, tan

* * * * *

Test Hole No. 9
Location: 98-76-28cac
Depth to water: 15 feet
(continued on next page)

Test Hole No. 9--continued

0- 1	topsoil, black
1-40	sand, medium, tan
40-44	clay, tan

* * * * *

Test Hole No. 10
Location: 98-76-30dcc
Depth to water: no water

0- 2	topsoil
4-13	clay, brown
13-	rock

* * * * *

Test Hole No. 11
Location: 98-76-29ccc
Depth to water: 29.5 feet

0- 1	topsoil, sandy
1- 4	clay, sand, green
4-14	sand, fine, layer of green clay
14-19	sand, medium, tan, some clay
19-24	sand, fine, clayey
24-59	clay, tan

* * * * *

Test Hole No. 12
Location: 98-76-28ccc
Depth to water: 13 feet

0- 1	topsoil, sandy
1- 24	sand, medium, tan, little clay
24- 65	clay, tan, sandy
65-125	shale, gray

* * * * *

Test Hole No. 13
Location: 98-76-28cca
Depth to water: 6 feet
(continued on next page)

Test Hole No. 13--continued

0- 2	topsoil
2-10	sand, clayey
10-35	sand, medium, tan
35-44	clay

* * * * *

Test Hole No. 14
Location: 98-76-31bbb
Depth to water: no water

0- 2	topsoil
2-13	sand, medium
13-	rock

* * * * *

Test Hole No. 15
Location: 98-76-31bbc
Depth to water: 5 feet

0- 2	topsoil
2-54	sand, medium, subrounded, tan
54-69	clay, tan

* * * * *

Test Hole No. 16
Location: 98-76-31aac
Depth to water: 8 feet

0- 2	topsoil
2- 95	sand, medium, subrounded, tan
95-100	clay, tan

* * * * *

Test Hole No. 17
Location: 98-76-32bba
Depth to water: 15 feet

0- 2	topsoil, dark brown
2-45	sand, fine to medium, tan, some clay
45-50	rock
50-53	sand?
53-80	clay, tan

* * * * *

Test Hole No. 18
Location: 98-76-32abb
Depth to water: 15 feet

0- 1	topsoil, black
1- 3	clay, brown
3- 8	sand, fine, clayey
8-30	sand, medium, tan, some clay
30-50	sand, medium, tan
50-	rock

* * * * *

Test Hole No. 19
Location: 98-76-32aad
Depth to water: 10 feet

0- 2	topsoil, black
2- 9	sand, medium, brown
9-19	sand, clayey, gray
19-70	sand, medium, subrounded, tan
70-	clay, tan

* * * * *

Test Hole No. 20 (Observation Well #4)
Location: 98-76-33bbc
Depth to water: 15 feet

0- 2	topsoil, black
2- 5	sand, medium
5-17	sand, clayey, black
17-25	sand, medium, gray-brown, some clay
25-93	sand, medium
93-99	clay

* * * * *

Test Hole No. 21
Location: 98-76-33bbd
Depth to water: 9 feet

0- 2	topsoil, sandy
2- 8	sand, clayey, black
8-33	sand, medium
33-44	clay

* * * * *

Test Hole No. 22 (Observation Well #1)
Location: 98-76-33bbd
Depth to water: 15 feet

0-16	sand, clayey, black
16-20	clay, tan
20-30	sand, medium
30-34	clay, tan

* * * * *

Test Hole No. 23 (Observation Well #2)
Location: 98-76-33bbd
Depth to water: 10 feet

0- 2	topsoil, clayey
2-15	sand, clayey, black
15-50	sand, medium, tan
50-54	clay

* * * * *

Test Hole No. 24 (Observation Well #3)
Location: 98-76-33bba
Depth to water: 20 feet

0- 2	topsoil, black
2-35	sand, medium
35-42	clay
42-	rock

* * * * *

Test Hole No. 25
Location: 98-76-33bab
Depth to water: 20 feet

0- 2	topsoil, black
2-10	sand, medium
10-11	rock
11-39	sand, medium, brown
39-43	sand, medium, brown, some clay
43-49	clay

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Test Hole No. 26
Location: 98-76-33bac
Depth to water: 4 feet

0- 3	topsoil
3-24	sand, medium, tan
24-29	clay

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Test Hole No. 27
Location: 98-76-33baa
Depth to water: 7 feet

0- 1	topsoil, dark brown
1-20	sand, medium
20-29	clay

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Test Hole No. 28
Location: 98-76-33baa
Depth to water: 15 feet

0- 2	topsoil
2- 6	sand, fine, some clay
6-12	sand, medium, tan
12-15	clay, tan

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Test Hole No. 29
Location: 98-76-33bad
Depth to water: 5 feet

0- 1	topsoil
1- 7	sand, medium
7-19	clay

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Test Hole No. 30
Location: 98-76-33aad
Depth to water: 16 feet

0- 2	topsoil, black
2- 5	sand, medium, brown
5-10	sand, clayey, dark brown
10-20	sand, clayey, tan
20-34	sand, medium
34-39	clay

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Test Hole No. 31
Location: 98-76-31bcb
Depth to water: 5 feet

0- 2	topsoil
2-53	sand, medium, tan
53-59	clay

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Test Hole No. 32
Location: 98-76-31bca
Depth to water: 9 feet

0- 2	topsoil, black
2- 5	clay, black
5- 8	clay, some pebbles, brown
8-75	sand, medium, tan
75-84	clay

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Test Hole No. 33
Location: 98-76-31bda
Depth to water: 10 feet ?

0- 2	topsoil
2- 5	clay, tan
5-15	sand, medium
15-29	clay, sandy
29-44	clay

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Test Hole No. 34
Location: 98-76-31bdd
Depth to water: 7 feet

0- 2	topsoil
2-20	sand, medium
20-22	sand, clayey
22-72	sand, medium
72-79	clay

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Test Hole No. 35
Location: 98-76-31acc
Depth to water: 5 feet

0- 2	topsoil, black, sandy
2- 35	sand, medium, tan
35- 99	sand, medium, light brown
99-104	clay

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Test Hole No. 36
Location: 98-76-31acd
Depth to water: 15 feet

0- 2	topsoil, sandy
2-24	sand, clayey

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Test Hole No. 37
Location: 98-76-31ada
Depth to water: 15 feet

0- 2	topsoil, black
2- 5	sand, very fine, light gray
5-10	sand, fine to medium, some clay
10-35	sand, medium, tan
35-49	clay, tan

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Test Hole No. 38
Location: 98-76-32bcc
Depth to water: no water

0-2	topsoil
2-	rock

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Test Hole No. 39
Location: 98-76-32bca
Depth to water: 3 feet

0- 2	topsoil, sandy, brown
2-25	sand, medium, brown
25-30	clay, tan

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Test Hole No. 40
Location: 98-76-32acc
Depth to water: 20 feet

0- 1	topsoil, sandy, black
1-26	sand, medium, tan, some clay
26-27	rock
27-35	sand, medium, tan
35-45	rock
45-60	sand, medium, tan

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Test Hole No. 41
Location: 98-76-33bcc
Depth to water: 2 feet

0- 2	topsoil
2-17	sand, medium
17-24	clay

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Test Hole No. 42
Location: 98-76-33bcb
Depth to water: 6 feet

0- 2	topsoil, black
2-10	sand, medium, brown
10-19	clay

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Test Hole No. 43
Location: 98-76-33bca
Depth to water: 20 feet

0- 4	topsoil, sandy
4-25	sand, clayey, black
25-66	sand, medium
66-69	clay

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Test Hole No. 44
Location: 98-76-33bca
Depth to water: 10 feet
(continued on next page)

Test Hole No. 44--continued

0- 2	topsoil, sandy
2- 5	sand, some clay
5-15	sand, clayey, black
15-48	sand, medium
48-54	clay

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Test Hole No. 45
Location: 98-76-33bdb
Depth to water: 1 foot

0- 2	topsoil
4- 7	sand, medium
7-14	clay

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Test Hole No. 46
Location: 98-76-33bcd
Depth to water: 1 foot

0- 2	topsoil
2- 6	sand
6-14	clay

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Test Hole No. 47
Location: 98-76-33bdd
Depth to water: 2 feet

0-1	topsoil
1-9	clay, brown

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Test Hole No. 48
Location: 97-77-36daa
Depth to water: 2 feet

0- 2	topsoil
2-20	sand, dark brown, clayey
20-38	clay
38-	rock

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Test Hole No. 49
Location: 98-76-31dab
Depth to water: 14 feet

0- 2	topsoil, black
2-20	sand, medium
20-35	clay, tan

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Test Hole No. 50
Location: 98-76-32dbc
Depth to water: 10 feet

0- 2	topsoil
2- 5	sand, medium
5-32	sand, clayey
32-39	clay

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Test Hole No. 51
Location: 99-77-36dda
Depth to water: 5 feet

0- 1	topsoil
1- 5	sand, clayey, greenish
5- 6	rock
6-62	sand, medium, clayey
62-70	clay, tan

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Test Hole No. 52
Location: 98-76-31cdc
Depth to water: 10 feet

0- 2	topsoil
2-25	sand, medium, greenish, clayey
25-34	clay, tan

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Test Hole No. 53
Location: 98-76-31dcb
Depth to water: 10 feet
(continued on next page)

Test Hole No. 53--continued

0- 2	topsoil
2-75	sand, medium, little clay
75-89	clay, tan

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Test Hole No. 54
Location: 98-76-31dda
Depth to water: 5 feet

0- 1	topsoil
1- 3	sand, medium, brown, some clay
3- 5	sand, medium, gray
5-55	sand, medium, brown
55-60	clay, tan

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Test Hole No. 55
Location: 98-76-31ddd
Depth to water: 17 feet

0- 2	topsoil
2- 20	sand, brown, clayey
20-105	sand, medium, brown
105-115	clay, tan

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Test Hole No. 56
Location: 98-76-32ccc
Depth to water: 5 feet

0- 1	topsoil
1- 5	sand, medium, tan, some clay
5-35	sand, medium, gray
35-45	clay

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Test Hole No. 57
Location: 98-76-32cca
Depth to water: 5 feet

0- 2	topsoil, black
2- 9	sand, medium, tan, little clay
9-19	clay, green

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Test Hole No. 58
Location: 98-76-33ccc
Depth to water: 4 feet

0- 2	topsoil
2-14	sand, medium, brown, some clay
14-20	clay, sandy, brown
20-29	clay

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Test Hole No. 59
Location: 98-76-33ddd
Depth to water: 10 feet

0- 2	topsoil, sandy, brown
2-14	sand, medium, tan
14-19	sand, fine to medium, clayey
19-49	clay, tan
49-69	shale

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Test Hole No. 60
Location: 97-77-1aaa
Depth to water: 10 feet

0- 2	topsoil, black
2-15	sand, medium, tan
15-16	rock
16-20	clay, tan
20-	rock

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Test Hole No. 61
Location: 97-76-6abc
Depth to water: 7 feet

0- 1	topsoil
1- 5	clay, tan
5- 8	sand, fine, some clay
8-17	sand, fine to medium, clayey
17-20	clay, tan

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Test Hole No. 62
Location: 97-76-5bbd
Depth to water: 5 feet

0- 2	topsoil
2- 9	sand, medium, tan
9-19	sand, dark brown, clayey
19-34	clay

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Test Hole No. 63
Location: 97-76-4bab
Depth to water: 5 feet

0- 4	topsoil
4-10	sand, medium, gray
10-24	clay, sandy

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Test Hole No. 64
Location: 97-76-3bab
Depth to water: 10 feet

0- 2	topsoil
2- 4	sand, medium, brown
4-15	sand, fine, tan
15-29	clay, tan