STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

MISCELLANEOUS INVESTIGATIONS 5

WATER SUPPLY FOR THE CITY OF WAKPALA, SOUTH DAKOTA

by
Lynn S. Hedges

Science Center
University of South Dakota
Vermillion, South Dakota
May, 1962

CONTENTS

ILLUSTRATIONS

TABLES

APPENDIXES

INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota Geological Survey during the summer of 1961 for the municipality of Wakpala, Corson County, South Dakota (fig. 1), for the purpose of locating future water supplies. The city now receives its water from one shallow dug well near the center of town (fig. 2). This well has a jet pump and a hand pump. The jet pump furnishes water to the school and one other building in the town. The remainder of the residents obtain their water from the hand pump at the well. The well is 35 feet deep and 12 feet in diameter; it has a reservoir capacity of approximately 18,000 gallons, which becomes inadequate during the latter part of the summer. There is also discussion of installing a sewage system for the city, which would require more water than the present well could produce. Consequently, the State Geological Survey was asked to help the city locate additional water supplies.

A survey of the shallow ground water possibilities was conducted in and around Wakpala in July, 1961. Included in this survey was a review of the geology as mapped by the South Dakota State Geological Survey (Baldwin and Glass, 1949), the drilling of 16 test holes, and collection of four water samples for analysis. Also used in the present study was information from six test holes (Appendix B) and two water analyses which was part of a preliminary investigation of Indian lands by the U. S. Geological Survey in the summer of 1960.

The field work and preparation of this report were performed under the supervision of Merlin J. Tipton, geologist in charge of ground water studies for the State Geological Survey, with the assistance of Mike Clancy and Steve Pottratz. Thanks are due to the residents of Wakpala for their cooperation, and especially to Township Board Chairman Alvin Rieger, and John Schlomer, Wakpala School Custodian.

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

Location and Extent of Area

The city of Wakpala is located in north-central South Dakota in Corson County, on the west bank of Oak Creek, a tributary of the Missouri River. The Missouri River and Oak Creek are both in the Missouri Plateau Section of the Great Plains physiographic province (fig. 1).

Climate

The climate is continental temperate, with large daily fluctuations in temperature. No information on temperature and precipitation is

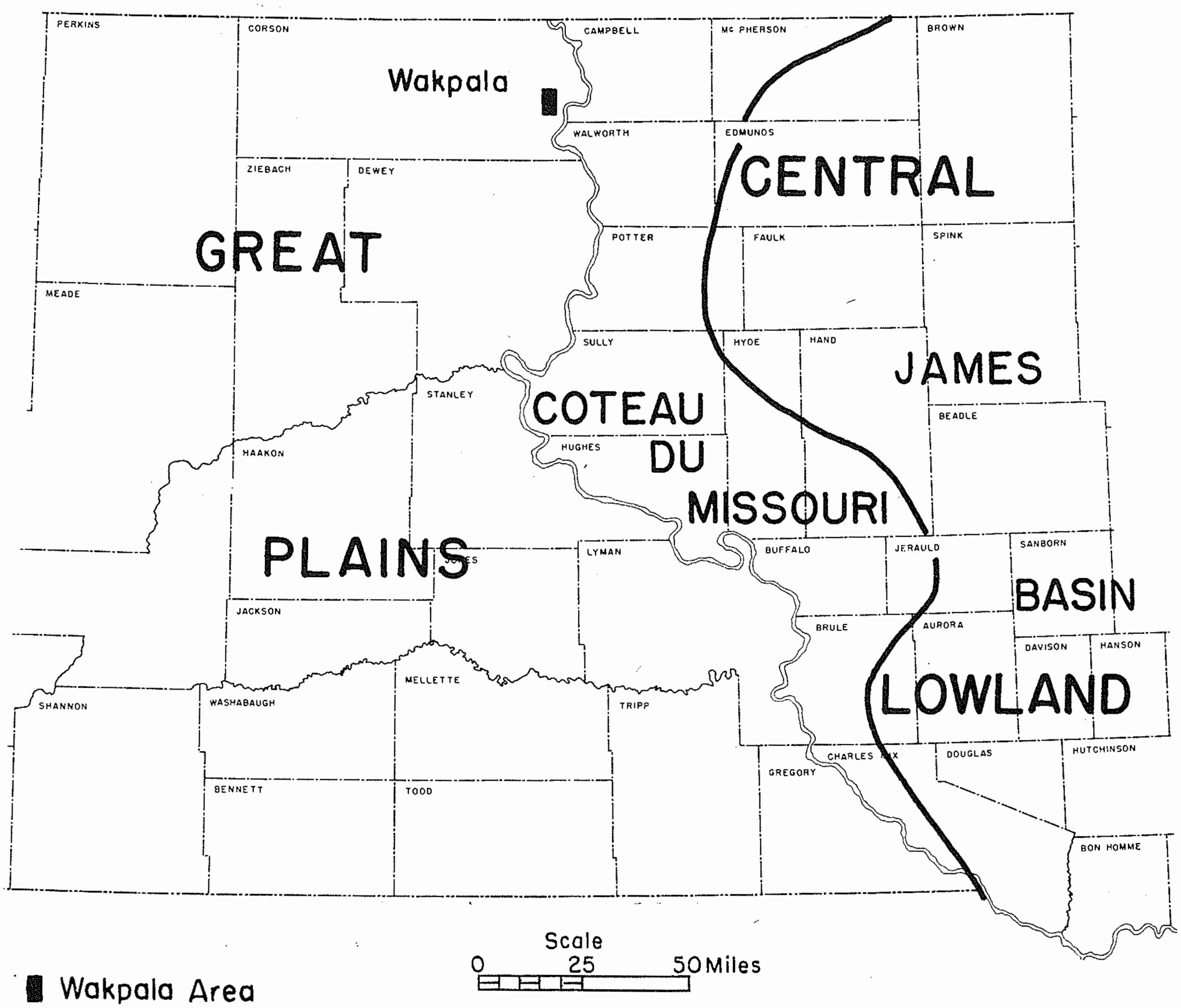

Figure I. Index Map Showing Major Physiographic Divisions of Central South Dakota, and the Wakpala Area. (modified from Rothrock, 1943)

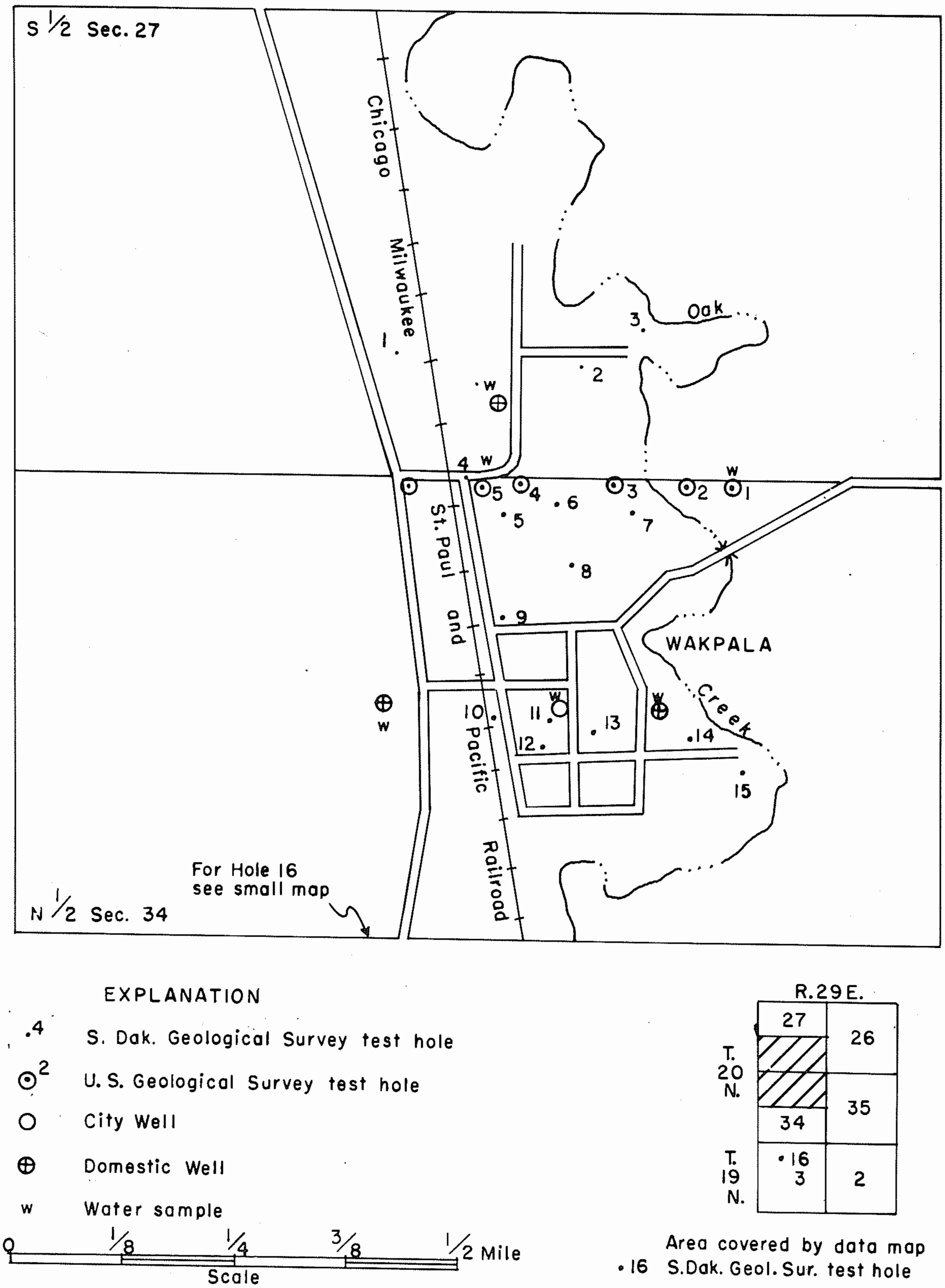

Figure 2. Data Map of the Wakpala Area

by
Lynn Hedges

available for Wakpala; however, at the U. S. Weather Bureau Station at Mobridge, the average yearly temperature is 45.1°F., and the average annual precipitation is 15.83 inches.

Topography and Drainage

The municipality of Wakpala is located on the floodplain of Oak Creek which is a narrow flat having a maximum relief of 15 feet. Immediately north and south of the city are abandoned meanders of Oak Creek which leave "scars" on the floodplain 10-15 feet deep. East of the floodplain, shale bluffs rise sharply to a height of 120 feet, whereas west of the floodplain the bluffs rise to the same height but with a more gentle slope.

Oak Creek, which drains the area intermittently, enters the Missouri River about seven miles southeast of Wakpala.

Well-Numbering System

Wells in this report are numbered in accordance with the U. S. Bureau of Land Management's system of land subdivision. The first numeral of a well designation indicates the township, the second the range, and the third the section in which the well is situated. Lowercase letters after the section number indicate the well location within the section. The letters a, b, c, and d are assigned in counterclockwise direction, beginning in the northeast corner of each tract. The first letter denotes the 160-acre tract, the second the 40-acre tract, the third the 10-acre tract, and the fourth the $2\frac{1}{2}$-acre tract. To distinguish between two or more wells situated within the same tract, consecutive numbers beginning with 1 are added as a suffix to each well designation. Test Hole 11, 20-29-34acba is the one located in the NE$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 34, T. 20 N., R. 29 E.; the method of designation is shown in Figure 3.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits in the Wakpala area are mostly the result of Recent stream deposition by Oak Creek. These stream deposits are called alluvium (Qal, fig. 4) and contain clay, silt, sand and gravel.

Glacial sediments were deposited in the area during early Pleistocene time, as evidenced by scattered erratics and by eastern-derived terrace deposits (Baldwin and Glass, 1949).

The alluvium in the Wakpala area consists mainly of silt-size detrital particles of shale, some reworked glacial material, and sands and gravels of western origin.

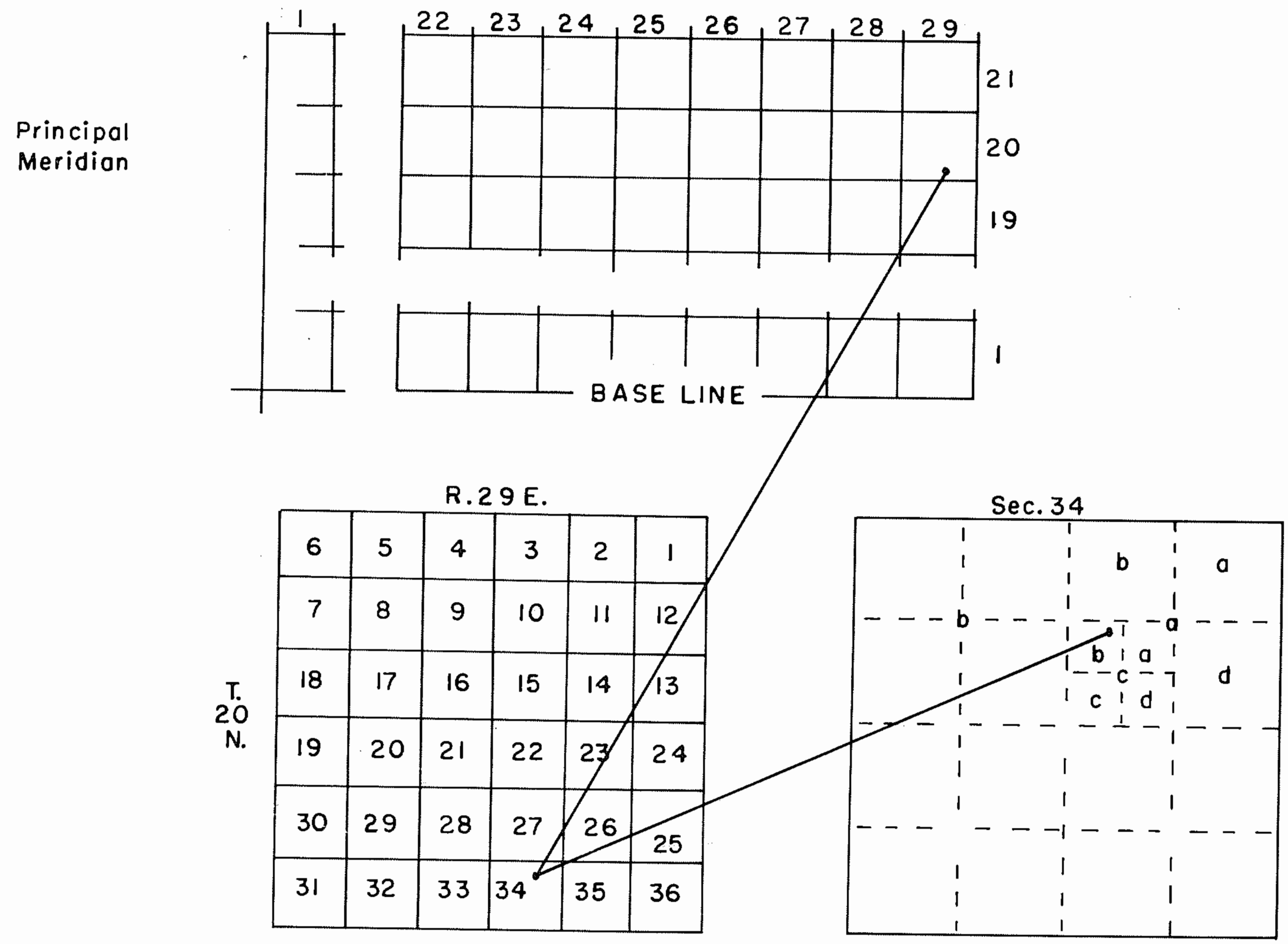

Figure 3. Well-Numbering System.

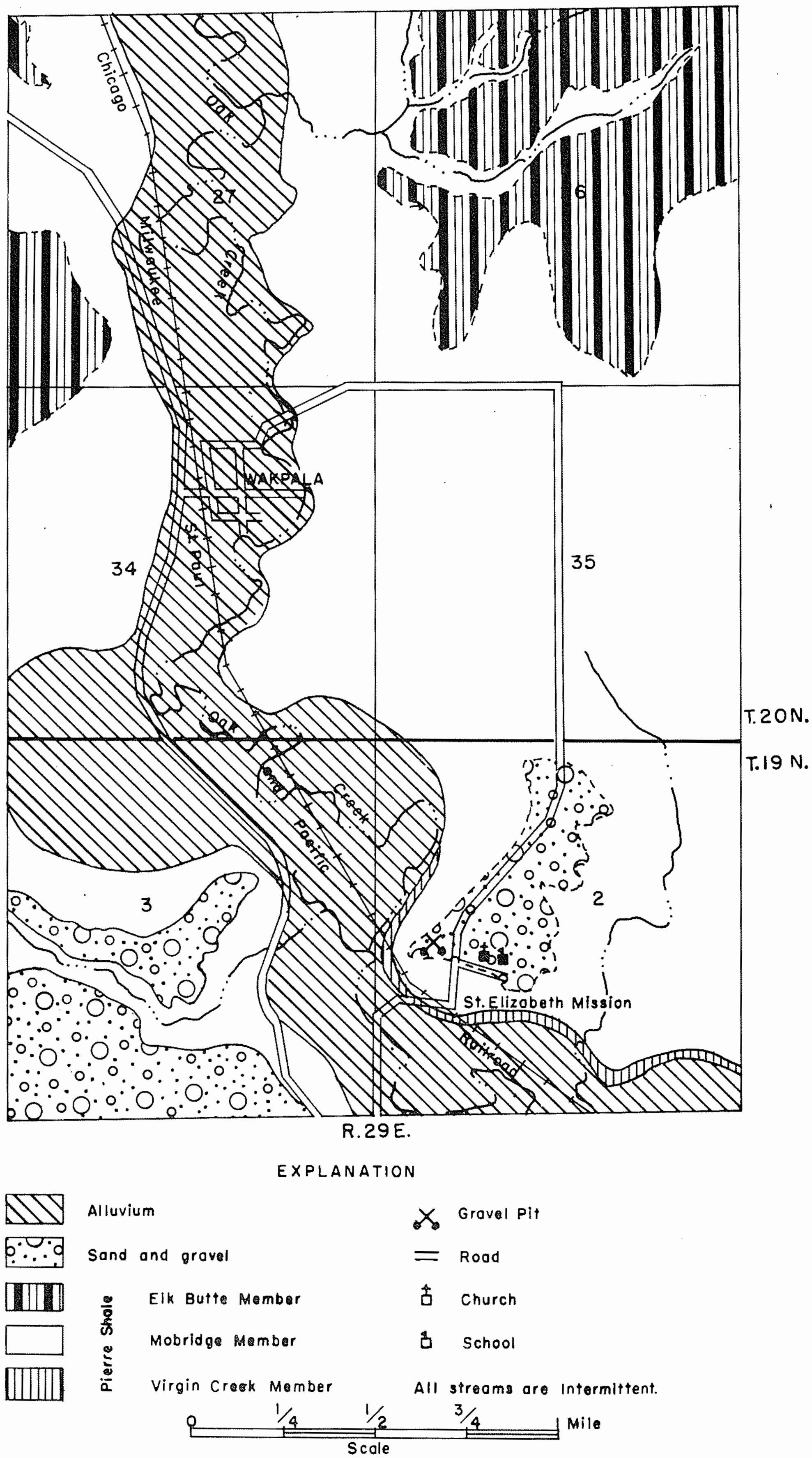

Figure 4. Geologic Map of the Wakpala Area.
(after Baldwin and Glass 1949)

Exposed Bedrock

The only bedrock exposed in the area studied is the Pierre Shale, of Cretaceous age. Three members are present; the uppermost is the Elk Butte, a flaky weathering, gray clay. The Mobridge Member lies conformably below the Elk Butte and is calcareous to non-calcareous gray to buff clay. It is marly in the upper part, and contains many clay ironstone concretions which enclose an abundant fauna of baculites. The lower member exposed in this area is the Virgin Creek, a dark gray clayey shale.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Despite the common belief that ground water occurs in "veins" which criss-cross the country in a disconnected maze, it can be shown that water occurs almost everywhere in the ground, at depths below the surface which vary from a few feet to several tens of feet. The top of this zone of water saturation is known as the water table, and in the Wakpala area it is at a depth of 12-27 feet except where the Pierre Shale is at or near the surface; in those places the water table is usually much deeper.

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 evaporates, escapes to the ocean by streams, or percolates downward to the ground water table. In general, ground water moves laterally down the hydraulic gradient, and is said to be in transient storage.

Recharge is the addition of water to an aquifer (water-bearing material), and is accomplished in three ways: (1) by downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, and (3) by lateral underflow of water in transient storage.

Discharge, or the removal of ground water from an aquifer, is accomplished in four main ways: (1) by evaporation and transpiration by plants, (2) by seepage upward or laterally into surface bodies of water such as springs, (3) by lateral underflow of water in transient storage, and (4) by pumping.

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

The rate at which water will drain or pass through a material is a function of the permeability of the substance. Water will pass through a material with interconnected pores, but will not pass through a material with unconnected pores even if the latter material has a higher porosity. Therefore, permeability and porosity are not synonymous terms. As an example, clay has high porosity but will yield little water because it has low permeability.

The ratio of the volume of water that will drain from a material by gravity, to the volume of the material, is called specific yield. Values for specific yields vary from zero for plastic clays to nearly the total value of the porosity for coarse sands and gravels.

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

Ground Water in the Alluvium

In the Wakpala area, the thickest alluvial deposit recorded by drilling is 31 feet in State Geological Survey Test Hole 12 (fig. 2 and Appendix A). The average thickness of the alluvium is about 23 feet, of which 6 feet is saturated. In State Geological Survey Test Hole 4, as much as 14 feet of saturated alluvium was recorded. This thickness normally would be adequate to supply water to a well if the alluvial sediments were sand and gravel. Unfortunately, in this area, the alluvium consists mostly of silt- and clay-size particles and has low permeability and yields water very slowly.

The U. S. Geological Survey test holes show as much as 10 feet of sand and gravel (Test Hole 5, Appendix B). The South Dakota Geological Survey drilled a test hole in the same locality (Test Hole 4) but found only fine sand, silt and clay with an occasional pebble. Consultation with the U. S. Geological Survey revealed that different drilling methods were used, which accounted for the difference in the logs. A study of the samples from State Geological Survey Test Hole 4 showed that silt-size particles constitute the greater percentage of the deposit.

Ground Water in Bedrock

The bedrock exposed at the surface in the Wakpala area is the Pierre Shale, which is about 800 feet thick. Its low permeability and poor quality of the water eliminates it as a possible source of ground water.

Ground Water in Terrace Sands and Gravels

The terrace deposits in Figure 4 generally are not more than 20 feet thick, with little or no saturation. Locally, the terrace deposits furnish an adequate supply for farm wells but are not important as a possible city supply.

Chemical Quality of Ground Water

Ground water always contains minerals in various quantities. These minerals are derived: (1) from the atmosphere as the 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.

The quality of water from the alluvial deposits in the Wakpala area is extremely variable: compare in Table 1 Sample B (city well) and Sample D (domestic well). This wide range of quality is probably due to the source of recharge of the ground water, or possibly to variation in the composition of the alluvium. The exact nature of the factors affecting the quality of the ground water in the Wakpala area could not be determined because water samples could not be pumped from the test holes. Two factors, however, are believed to be very important in determining the quality of ground water in this area: (1) nearness of the well to Oak Creek and (2) distance of the well from the shale bluffs. In general, the closer to Oak Creek and the farther from the shale bluff the well is located, the better the quality of the water.

CONCLUSIONS AND RECOMMENDATIONS

The results of the shallow ground water survey for the city of Wakpala show that there are no good areas to recommend for construction of additional shallow wells in the area studied. A well similar in construction to the present city well in the area of Test Hole 4 (fig. 2), or Test Hole 2 (fig. 2) would probably produce as much water as the present city well but the quality of the water would be similar to that of Samples D and E (table 1), and this is poorer than the city well (Sample A).

The only other possibility for obtaining ground water would be to drill a deep well into the artesian aquifers. From logs of two wells 24 and 30 miles southeast of Wakpala, it is estimated that the top of the Dakota Group is at a depth of 1500 feet in the Wakpala area. The 2000-foot well at the St. Elizabeth Indian Mission near Wakpala is supposedly in the Dakota Group. This well flows an estimated five gallons of warm water per minute, produces gas and is high in mineral content. Any well from an artesian aquifer would probably be higher in mineral content than the present city well.

If the city decides to construct a new well it is recommended that a commercial drilling company licensed in South Dakota be contracted to do the test drilling. A consulting engineering firm licensed in South Dakota should also be engaged to conduct pump tests and to design the water system. The city officials should also consult the State Water Resources Commission with regard to obtaining a water right and a permit to drill a city well, and State Department of Health with regard to the biological and chemical suitability of the water.

Table 1.--Chemical Analyses of Water Samples in the Wakpala Area

(for location see fig. 2)

Sample	Parts Per Million										Hardness $CaCO_3$	Total Solids
	Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate	Fluoride	pH		
A	--	--	--	250	500*	0.3	0.05	10*	0.9-1.7**	--	---	1000*
B	127		11	32	340	0.2					360	
B_1	132	180	15	31	384	Tr.	none	Tr.	0.6		390	1070
C	95		66	28	292	none					500	
D	220		775	540	2430	0.2					3650	
E	348		73	40	1360	0.2					1160	
E_1	367	455	8	34	1918	0.7	1.7	Tr.	0.8		948	3410
F	172	165	57	20	528	0.22		none	0.8	7.3	663	1260
G	363	470	96	74	1780	0.03		none	1.0	7.4	1300	3030

A. Drinking Water Standards, U. S. Department of Public Health (1961)
B. Wakpala city well
C. Henry Three-Legs, 20-29-34abdc
D. 20-29-34badc
E. 20-29-27dcbc
F. 20-29-34aabb
G. 20-29-34baaa

Samples B, C, D, and E analyzed by State Geological Survey field test kit.
Samples B_1 and E_1 analyzed by State Chemical Laboratory at Vermillion.
Samples F and G analyzed by U. S. Geological Survey, Department of the Interior.

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

** Optimum

REFERENCES CITED

Baldwin, Brewster, and Glass, M. G., 1949, Geology of the Wakpala quadrangle: S. Dak. Geol. Survey, quad. map series.

Rothrock, E. P., 1943, A geology of South Dakota, Pt. 1: The surface: S. Dak. Geol. Survey, Bull. 13, p. 88.

U. S. Public Health Service, 1961, Drinking water standards: Am. Water Works Assoc. Jour., v. 53, no. 8, p. 935-945.

APPENDIX A

Logs of State Geological Survey Test Holes in the Wakpala Area

Test Hole No. 1
Location: 20-29-27bdac
Surface elevation: 1637 feet
Depth to water: 19 feet

0-14	silt and clay, brown
14-19	same, with some fine sand
19-24	sand, fine, saturated
24-29	shale

* * * * * *

Test Hole No. 2
Location: 20-29-27ddca
Surface elevation: 1637 feet
Depth to water: 20 feet

0- 4	silt and clay
4- 9	clay, gray and hard
9-19	clay, light brown
19-24	silt and clay, brown, saturated
24-29	same, shale

* * * * * *

Test Hole No. 3
Location: 20-29-27dcac
Surface elevation: 1637 feet
Depth to water: 19 feet

0- 9	silt and clay, brown
9-19	clay, pebbly, brown
19-24	same with some sand, shale

* * * * * *

Test Hole No. 4
Location: 20-29-34baaa
Surface elevation: 1637 feet
Depth to water: 12 feet

0- 4	silt, brown
4- 9	silt and clay
9-14	silt and clay, brown, saturated
14-26	sand, very fine, clay, silt
26-29	shale

* * * * * *

Test Hole No. 5
Location: 20-29-34abbb
Surface elevation: not measured
Depth to water: dry

0- 9	silt, brown
9-19	clay, brown, silty
19-24	shale

* * * * * *

Test Hole No. 6
Location: 20-29-27dccd
Surface elevation: not measured
Depth to water: 27 feet

0-14	silt and clay, brown
14-19	clay, brown
19-24	silt and clay, brown, pebbly, saturated
24-27	silt and clay
27-29	shale

* * * * * *

Test Hole No. 7
Location: 20-29-34abab
Surface elevation: not measured
Depth to water: 17 feet

0- 9	silt and clay
9-14	clay, brown
14-21	silt and clay, saturated
21-24	shale

* * * * * *

Test Hole No. 8
Location: 20-29-34abbd
Surface elevation: not measured
Depth to water: dry

0- 4	silt and clay
4- 9	clay, brown, moist
9-15	clay, blue
15-19	shale

* * * * * *

Test Hole No. 9
Location: 20-29-34abdb
Surface elevation: 1634 feet
Depth to water: 22 feet
(continued on next page)

Test Hole No. 9--continued

0- 9	silt and clay, brown
9-14	clay, silty, dark
14-19	same, moist
19-26	same, saturated
26-29	shale

* * * * * *

Test Hole No. 10
Location: 20-29-34bdaa
Surface elevation: 1634 feet
Depth to water: 23 feet

0-19	clay, silty, brown
19-24	shale

* * * * * *

Test Hole No. 11
Location: 20-29-34acba
Surface elevation: 1633 feet
Depth to water: 19 feet

0-14	silt and clay, brown
14-19	same, few pebbles, saturated
19-27	same, some fine sand
27-29	shale

* * * * * *

Test Hole No. 12
Location: 20-29-34acba
Surface elevation: 1632 feet
Depth to water: 27 feet

0- 4	silt and clay, hard
4-14	clay, brown, moist
14-24	same, with some fine sand
24-29	silt, water at 27 feet
29-31	silt and clay, brown
31-39	shale

* * * * * *

Test Hole No. 13
Location: 20-29-34acab
Surface elevation: not measured
Depth to water: 18 feet

0- 4	silt, clayey, brown
4- 9	same, only gray
9-27	same, only brown, saturated at 18 feet
27-28	shale

* * * * * *

Test Hole No. 14
Location: 20-29-34acaa
Surface elevation: 1632 feet
Depth to water: 16 feet

0- 9	silt, clayey, brown
9-14	silt and clay, brown, moist
14-24	clay, brown, some fine sand
24-29	shale

* * * * * *

Test Hole No. 15
Location: 20-29-34adbc
Surface elevation: 1630 feet
Depth to water: 17 feet

0- 4	silt, brown and clay
4- 9	silt, brown and clay, chunks of iron concretions
9-14	clay, brown and damp
14-19	clay, blue, saturated
19-20	clay, brown
20-24	shale

* * * * * *

Test Hole No. 16
Location: 19-29-3adbd
Surface elevation: not measured
Depth to water: 13 feet

0- 4	silt and clay, dark
4- 9	silt and clay, brown
9-21	same, saturated at 13 feet, shale at 21 feet

* * * * * *

APPENDIX B

Logs of U. S. Geological Survey Test Holes in the Wakpala Area

Test Hole No. 1
Location: 20-29-34aabb
Depth to water: 14.6 feet
Pump estimated 5 gpm

0- 1	topsoil
1-15	clay, brown to reddish, oxidized
15-25	sand, very fine to fine, saturated
25-27	shale

* * * * * *

Test Hole No. 2
Location: 20-29-34abaa (on east bank of Oak Creek)
Depth to water: 17 feet

0- 1	topsoil
1-15	clay, brown, oxidized
15-20	sand and gravel, saturated
20-22	shale

* * * * * *

Test Hole No. 3
Location: 20-29-34abab
Depth to water: 17 feet

0- 1	topsoil
1-13	clay, brown, oxidized
13-20	sand, very fine, and saturated gravel
20-27	shale

* * * * * *

Test Hole No. 4
Location: 20-29-34abbb
Depth to water: not measured

0- 1	topsoil
1- 7	clay, brown, oxidized
7-17	sand, fine, and saturated gravel
17-25	shale

* * * * * *

Test Hole No. 5
Location: 20-29-34baaa
Depth to water: 17.4 feet
Pump estimated 3 gpm

0- 1	topsoil
1-12	clay, brown, oxidized
12-22	sand, fine, and saturated gravel
22-27	shale

* * * * * *

Test Hole No. 6
Location: 20-29-34baab
Depth to water: dry

0- 1	topsoil
1-26	clay, brown, oxidized
26-27	shale

* * * * * *