STATE OF SOUTH DAKOTA
Nils Boe, Governor

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

Special Report 37

GROUND-WATER SUPPLY FOR THE CITY OF LAKE ANDES, SOUTH DAKOTA

by
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INTRODUCTION

Present Investigation

This report contains the results of a special investigation conducted by the South Dakota Geological Survey from June 9 to July 14, 1965, in and around the city of Lake Andes, Charles Mix County, South Dakota (fig. 1), for the purpose of assisting the city in locating future water supplies. Lake Andes' present water supply is from a well producing about 200 gpm (gallons per minute) from glacial outwash at a depth of 150-200 feet. A standby well, 380 feet deep and capable of pumping about 50 gpm, is producing from what is probably the Codell Sandstone. An adequate quantity is supplied by these wells, but the quality of the water is undesirable.

An investigation of the ground-water possibilities was made at the request of the city officials in a 120 square mile area around the city. The investigation consisted of drilling 39 test holes with the Geological Survey's rotary drill rig, 40 test holes with the Geological Survey's hydraulic auger rig, electric logging the rotary test holes, the collection of 38 water samples for quality analysis, a well inventory, and a review of the geology as mapped by Stevenson and Carlson (1951) and Walker (1963).

As a result of this investigation, two areas were found in which the overall quality of water in the glacial outwash is better than the present city supply, although in both areas treatment would still be required to meet U. S. Public Health Drinking Water Standards. The results of this study also indicate that the water quality of the Codell Sandstone at Lake Andes is inferior to the quality of water from this same formation outside approximately a four mile radius of town.

The field work and preparation of this report were performed under the supervision of Lynn S. Hedges and Cleo M. Christensen, ground-water geologists. The assistance of Dwight Brinkley, Charles Denham, Aldean Fickbohm, Lloyd Helseth, Ronald Helwig, Robert Stach, and Reynold Schuttler is gratefully acknowledged. Water samples were analyzed by Nat Lufkin of the State Geological Survey and personnel of the State Chemical Laboratory in Vermillion.

The cooperation of Russell Stedronsky, Mayor, Ted Krell, and other residents of Lake Andes and the surrounding area is greatly appreciated. The assistance of Maple Young, Charles Oleson, and Pat Leer, well drillers in the area, is gratefully acknowledged.

Location and Extent of Area

The city of Lake Andes is located in Charles Mix County in southeastern South Dakota, and has a population of 1,097 (1960 census). The area is in the Coteau du Missouri division of the Great Plains physiographic province (fig. 1).

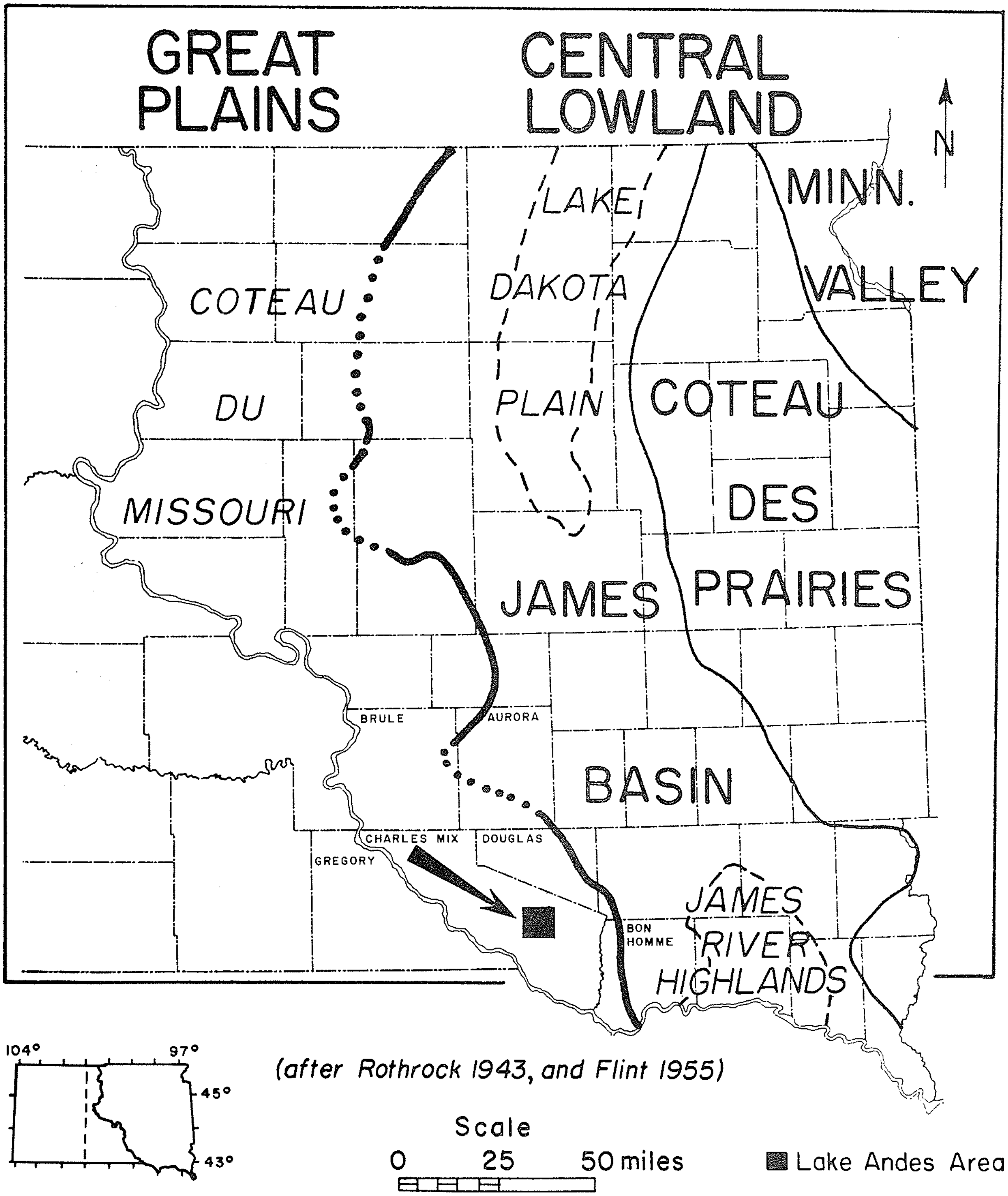


Figure 1. Map showing major physiographic divisions of eastern South Dakota and location of the Lake Andes area.

Climate

The climate is continental temperate with large daily fluctuations in temperature. The average daily temperature is 48.9 degrees F., and the average annual precipitation is 19.0 inches at the U. S. Weather Bureau Station in Pickstown, six miles south of Lake Andes.

Topography and Drainage

The regional topography of the Lake Andes area is largely characterized by hummocky glacial moraine. Locally, however, Lake Andes is in an east-west trending sag in the Coteau du Missouri, which is a surficial expression of a buried bedrock valley (Flint, 1955 and Walker, 1961).

Within the sag area and to the north much of the drainage is internally into small depressions or into Lake Andes. Most of the drainage south of the sag is internally to small depressions or into the Missouri River.

Well-Numbering System

Wells and test holes in this report are numbered in accordance with the U. S. Bureau of Land Management's system of land subdividion. 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, d, are assigned in a 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. Test hole 39 (fig. 2), 96-65-4bccb is located in the NW$\frac{1}{4}$SW$\frac{1}{4}$SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 4, T. 96 N., R. 65 W; the method of designation is shown in figure 3.

GENERAL GEOLOGY

Surficial Deposits

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

Till consists of clay and silt-sized particles mixed randomly with sand, pebbles, and boulders and was deposited directly by the ice. This is the major surficial deposit in the Lake Andes area (fig. 4).

Outwash sediments, which consist chiefly of sand and gravel with minor amounts of silt and clay, were deposited by meltwater streams from the wasting glaciers. Surface outwash sediments (fig. 4) occur in several small isolated areas in the mapped area. Outwash sand and gravel may be buried by glacial till, in which case the outwash is referred to as "buried outwash." Small deposits of stratified sand and gravel occurring in the till are referred to as sand lenses.

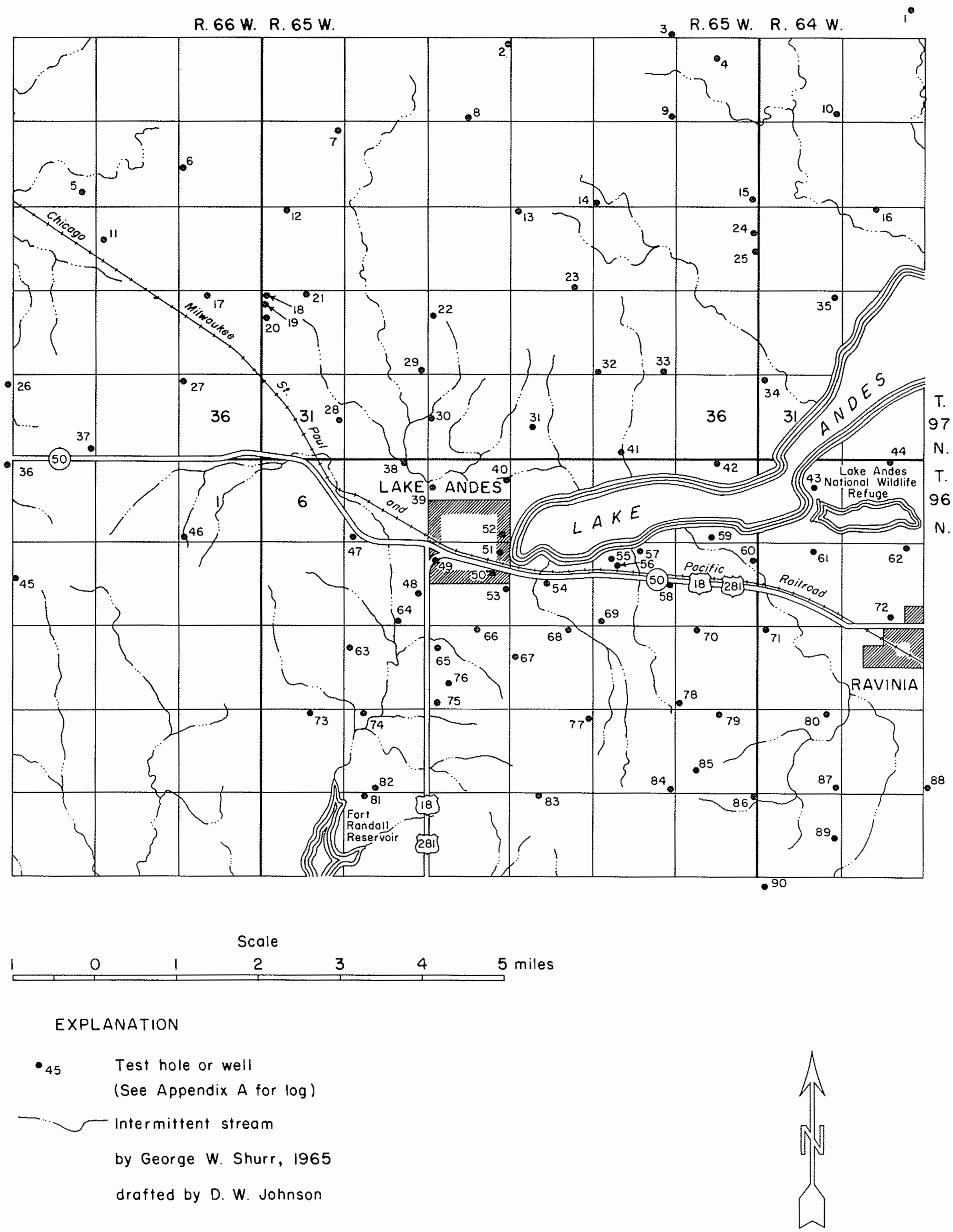


Figure 2. Map showing location of test holes and wells in the Lake Andes area.

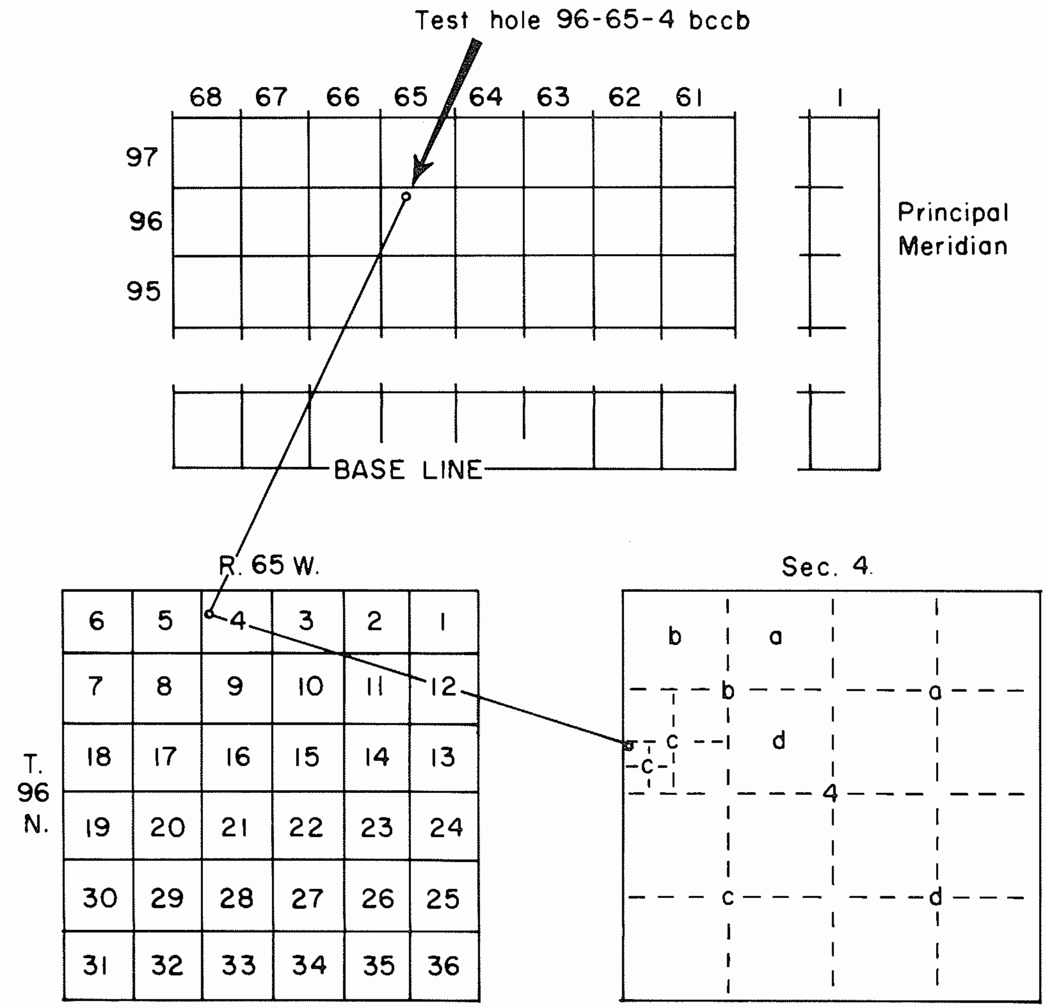


Figure 3. Well—numbering system.

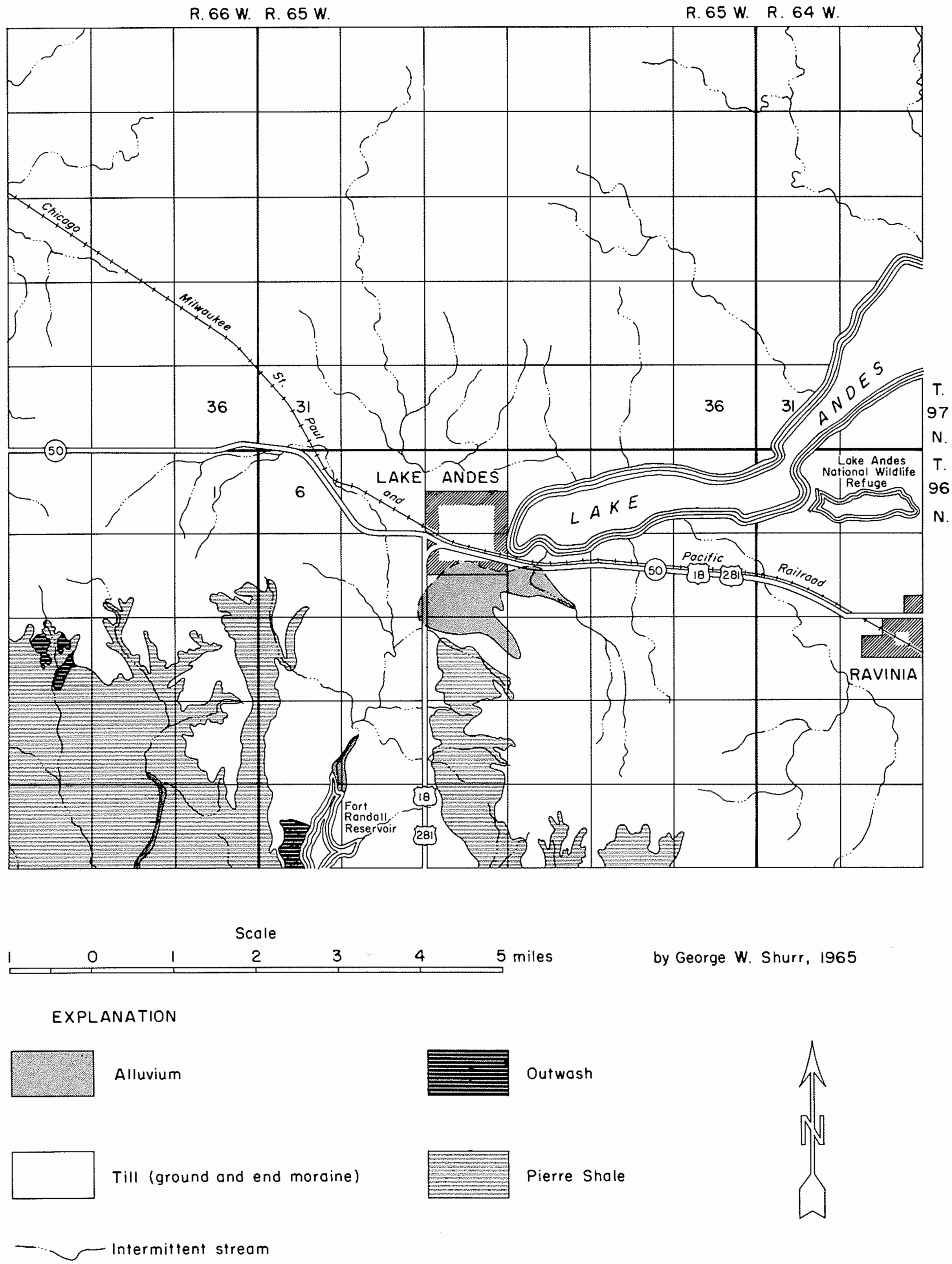


Figure 4. Generalized Geologic Map of the Lake Andes area.

(modified from Stevenson and Carlson, 1951, and Walker, 1963.)

Alluvial material has been deposited along intermittent streams and in closed basins since the retreat of the glaciers. This alluvium, consisting of silt and clay with varying amounts of fine sand, is found in deposits of varying size, the largest being located directly south of the city (fig. 4).

Exposed Bedrock

Pierre Shale, a stratified sedimentary rock of Cretaceous age, is exposed in about 9 square miles south and west of Lake Andes (fig. 4) along the bluffs of the Missouri River. Stevenson and Carlson (1951) differentiate four members of the Pierre and mapped a lower, undifferentiated unit. For this report the entire formation will be referred to as the Pierre Shale.

Subsurface Bedrock

Older Cretaceous rocks underlying the Pierre Shale in descending order are: The Niobrara Marl, Carlile Shale (and Codell Sandstone Member), Greenhorn Limestone, Graneros Shale and the Dakota Group.

Pierre Shale consists of a light- to dark-gray fissile shale with bentonite beds, iron-manganese concretionary zones, and chalk and marl layers; in this area it is over 500 feet thick.

The Niobrara is a light- to medium-gray fossiliferous chalk and marl, which in this area is from 115 to 165 feet thick.

The Carlile Shale is a gray-black sandy shale with the Codell Sandstone Member near the top. The Codell is a fine- to medium-grained sandstone and ranges from about 20 to 60 feet in thickness in this area. The Carlile is 60 to 130 feet thick.

The Greenhorn Limestone consists of a gray chalk and a very dense gray limestone; the entire formation averages approximately 30 feet thick in this area.

The Graneros Shale is a medium- to dark-gray shale which is 110 to 170 feet thick.

The Dakota Group consists predominantly of sandstone with some interbedded shales and a 12 to 50 foot shale bed near the top. In the Lake Andes area the Dakota Group is 200 to 370 feet thick.

Figure 5 shows the bedrock topography and distribution as it would appear if all the overlying glacial drift was removed. The highest bedrock elevation in the mapped area is 1849 feet, about 5 miles west of Lake Andes, while the lowest bedrock surface is 1210 feet about 4 miles east of Lake Andes.

A north-south trending valley is cut into the Pierre Shale. This valley enters the study area in the southwest portion of T. 96 N., R. 65 W., and terminates at the town of Lake Andes. The general elevation of this valley is between 1300 and 1400 feet.

A second valley trends east-west across the study area to the eastern edge where it broadens out in a fan-like manner. This valley is cut mostly into the Niobrara Marl and is generally about 100 feet lower than

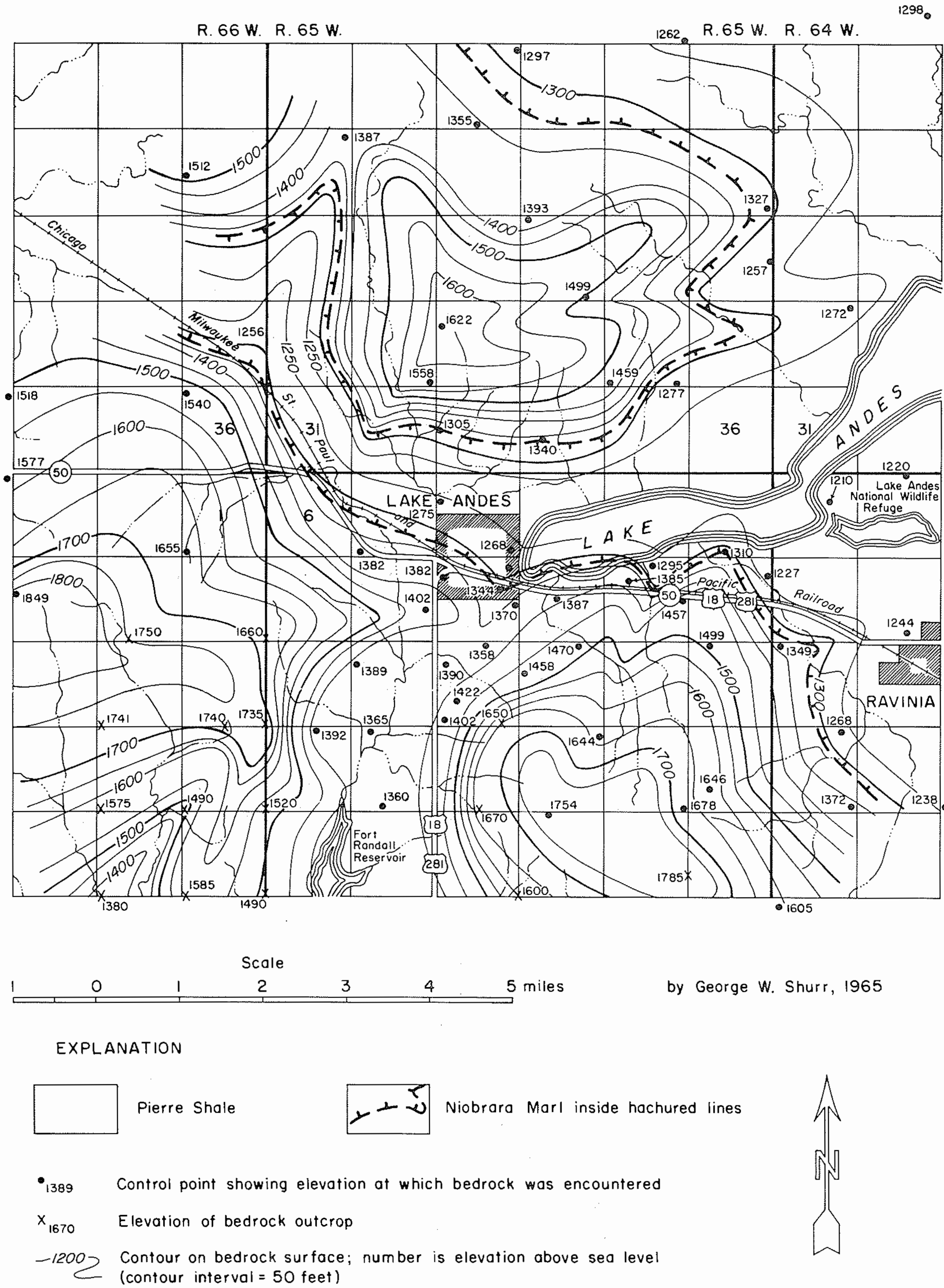


Figure 5. Map showing the configuration and distribution of the buried bedrock surface in the Lake Andes area.

the north-south trending valley. With the data then available, Walker (1961) thought that the east-west trending valley near Lake Andes was cut into the Codell Sandstone Member of the Carlile Shale. Evidence obtained during the course of this study indicates that the Niobrara Marl is the bedrock making up the valley floor. It is possible that the deepest portion of the valley was not penetrated during test drilling operations. If so, the Codell could form the floor in the deepest part of the valley.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Contrary to popular belief, ground water does not occur in "veins" that crisscross 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, (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 is the removal of ground water from an aquifer and is accomplished in four main ways: (1) by evaporation and transpiration by plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water in transient storage, and (4) by pumping.

The amount of water which 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 to 40 percent, whereas sandstones normally have porosities of 15 to 25 percent; the lower porosity of sandstones is due to closer packing and to 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, a geologist is not concerned with finding a "vein" when looking for a good water supply. Because water occurs almost everywhere in the ground, he is searching instead for a sand or gravel or other similarly porous and permeable deposit that lies beneath the water table.

Ground Water in Alluvium

A one-square-mile deposit of alluvium is mapped directly south of town (fig. 4), and small alluvial deposits are found in minor drainage ways scattered throughout the area. Test hole 66 (appendix A) penetrated 112 feet of sandy clay in the alluvium south of Lake Andes. Other test holes in the alluvium (test holes 53, 54, and 67) penetrated lesser amounts of sandy clay. Although the alluvium was found to contain much water, its permeability is low owing to the high clay and silt content and thus would not yield water readily to high-capacity wells required for a municipal supply.

Ground Water in Glacial Deposits

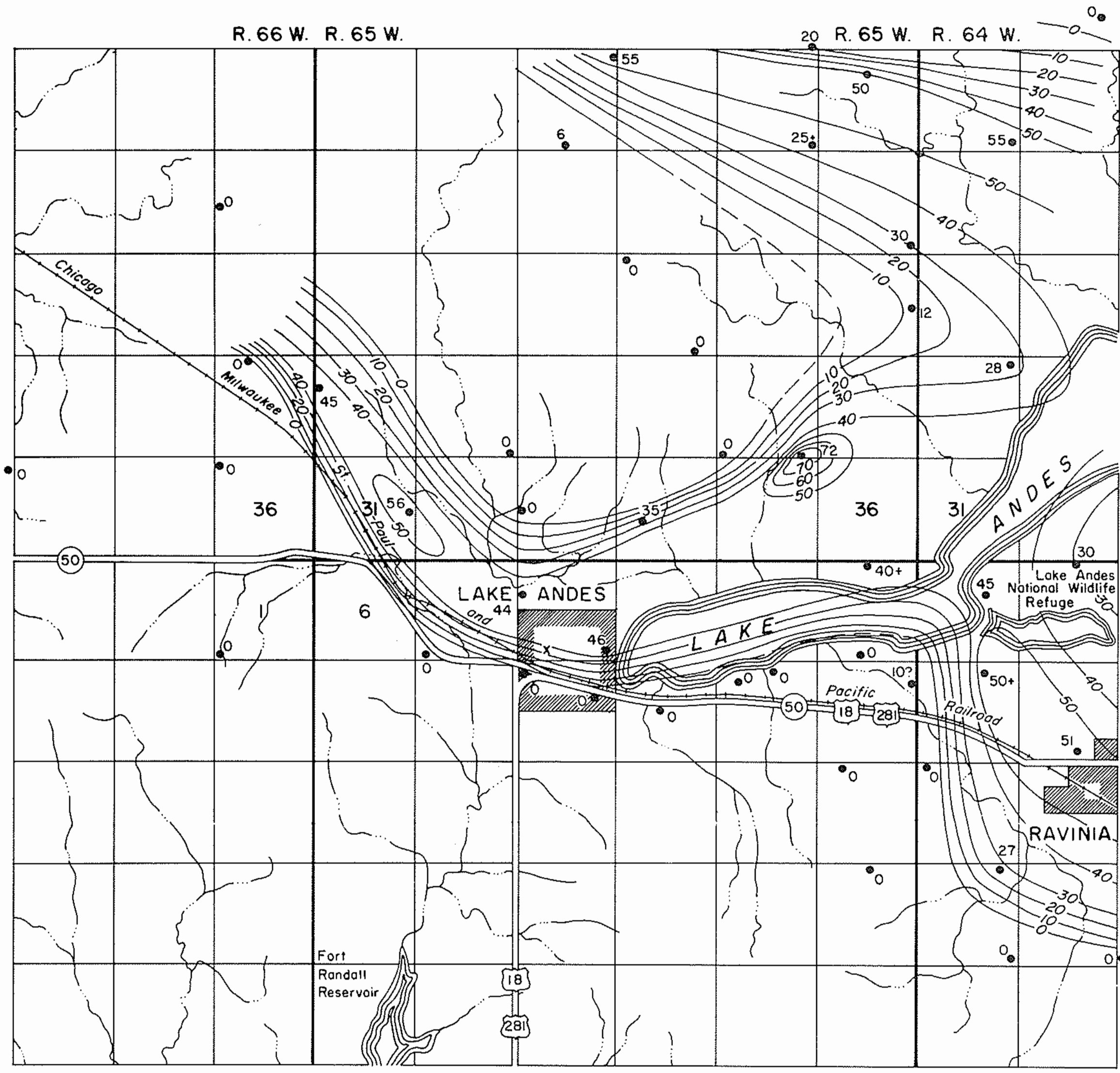
As was stated earlier, glacial deposits can be divided into till and outwash. Till, because of its unsorted nature and the larger amount of clay, usually does not yield water readily. Outwash, on the other hand, is generally a good source of ground water because of its high porosity and high permeability.

The outwash deposits in the Lake Andes area include small deposits of surface outwash, a thin discontinuous upper buried outwash, and a thick continuous lower buried outwash.

A number of test holes penetrated sand and gravel deposits of the upper buried outwash at elevations ranging from about 1370 feet above sea level to over 1500 feet above sea level. Generally, these deposits occur above or marginal to both of the bedrock valleys. The sand and gravel in the upper buried outwash may be more than 25 feet thick (test hole 64, app. A), but generally ranges between 5 and 20 feet thick. Furthermore, these deposits apparently are not continuous, as many test holes failed to penetrate a sand or gravel deposit in the elevation interval expected. The distribution of the sand and gravel deposits over the buried valley suggests that they may have once formed a more or less continuous outwash body. However, the variation of their occurrence in elevation, lithology, and thickness suggests that either the outwash has been mostly removed, or that the isolated sand and gravel bodies are merely lenses enclosed in the till.

The upper buried outwash, where present, supplies limited amounts of water to wells and could locally supply large yields to wells for short periods of time. The limited areal extent and apparent thinness of the upper buried outwash would prohibit high-capacity pumping for extended periods of time.

A lower buried outwash, covering about a 40-square-mile area (fig. 6), occurs near Lake Andes and is confined to the east-west bedrock valley. This outwash is overlain by 150 to 200 feet of glacial drift and is generally penetrated below an elevation of 1350 feet, although the upper surface may exceed 1400 feet along the margin of the bedrock valley. Till or other impermeable deposits usually separate the upper and lower buried outwash, except near the margin of the bedrock valley where the two buried outwashes may locally be in contact.



Scale

1 0 1 2 3 4 5 miles

by George W. Shurr, 1965

EXPLANATION

•45 Test holes and wells showing thickness of saturated sand and gravel; a plus (+) following the number shows the drill did not penetrate the entire thickness of outwash; a question mark (?) indicates that the outwash material in log is questionable.

—40— Lines of equal thickness (contour interval = 10 feet)

x City well

—··— Intermittent stream

Figure 6. Map showing the thickness and distribution of the lower buried outwash in the Lake Andes area.

The greatest thickness of outwash encountered is 72 feet in test hole 33 (fig. 6 and app. A). The outwash thickens rapidly from the sides toward the central part of the valley where it is over 40 feet thick. This aquifer should be capable of sustaining high-capacity wells. The major problems in developing wells from this aquifer would be emplacement of high-capacity wells too near the aquifer boundary, thus causing excessive drawdown or well emplacement in an area where the outwash is locally thin or missing, or too impermeable to yield large volumes of water.

Ground Water in Bedrock

Numerous domestic wells in the Lake Andes area produce water from the Codell Sandstone Member of the Carlile Shale (appendix B). This sandstone underlies the entire area at a depth of 300 to 700 feet, depending on the surface elevation, and is about 300 feet below the town of Lake Andes. The thickness varies widely in the area, but generally is 30 to 50 feet in the immediate vicinity of the town. The town's present standby well probably produces from this aquifer, and both quantity and quality are a problem. It is likely that any additional wells in the Codell in the immediate vicinity of Lake Andes would be similar in quality and quantity to the present city standby well. Therefore, more than one well would be required to obtain an adequate supply for the city.

Domestic wells in the area also produce from the sandstones of the Dakota Group (appendix B) at a depth of 700-950 feet, again depending on the elevation of the land surface. Although no water samples were obtained from the Dakota Group in this study, the data from nearby areas indicate the water quality to be similar to that from the Codell.

Although domestic wells produce from the Niobrara Formation in the Wagner area (Walker, 1961), no wells are known to produce from this formation in the vicinity of Lake Andes.

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, the more minerals a water contains, the poorer its quality.

Table 1 shows the significance of some of the chemical and physical properties of water which should be considered when evaluating its suitability for municipal use. The recommended maximum limits for each chemical constituent as defined by the U. S. Public Health Service has also been included. It should be pointed out that these are recommended limits, and use of water which exceeds these limits, although undesirable, may not necessarily be harmful.

Table 1.--Significance of some chemical and physical properties of water.

Chemical Constituents	Significance	Recommended Limits (ppm)[1]
Calcium (Ca) and Magnesium (Mg)	Cause most of the carbonate hardness and scale-forming properties of water by combining with carbonate and bicarbonate present in the water. Seldom can be tasted except in extreme concentrations.	Ca - None Mg - 125
Sodium (Na)	Large amounts in combination with chloride will give water a salty taste. Large amounts will limit water for irrigation and industrial use.	None
Chloride (Cl)	Large amounts in combination with sodium give water a salty taste. Large quantities will also increase corrosiveness of water.	250
Sulfate (SO_4)	Large amounts of sulfate in combination with other ions give a bitter taste to water and may act as a laxative to those not used to drinking it. Sulfates of calcium and magnesium will form hard scale. U. S. Public Health Service recommends 250 ppm maximum concentration.	500[2]
Iron (Fe) and Manganese (Mn)	In excess will stain fabrics, utensils and fixtures and produce objectionable coloration in the water. Both constituents in excess are particularly objectionable.	Fe - 0.3 Mn - 0.05
Nitrogen (N)	In excess may be injurious when used in infant feeding. The U. S. Public Health Service regards 45 ppm as the safe limit of nitrate (NO_3) or 10 ppm nitrogen (N).	10
Fluoride (F)	Reduces incidence of tooth decay when optimum fluoride content is present in water consumed by children during period of tooth calcification. Excessive fluoride in water may cause mottling of enamel.	0.9-1.7[2,3]
pH	A measure of the hydrogen ion concentration; pH of 7.0 indicates a neutral solution, pH values lower than 7.0 indicates acidity, pH values higher than 7.0 indicate alkalinity. Alkalinity tends to aid encrustation and acidity tends to aid corrosion.	None
Hardness $CaCO_3$	Hardness equivalent to carbonate and bicarbonate is called carbonate hardness. Hardness in excess of this amount is noncarbonate hardness. Hardness in water consumes soap and forms soap curds. Will also cause scale in boilers, water heaters and pipes. Water containing 0-60 ppm hardness considered soft; 61-120 ppm moderately hard; 121-180 ppm hard and more than 180 ppm very hard.	None
Total Solids	Total of all dissolved constituents. U. S. Public Health Service recommends 500 ppm maximum concentration. Water containing more than 1000 ppm dissolved solids may have a noticeable taste; it may also be unsuitable for irrigation and certain industrial uses.	1000[2]

1 (ppm) parts per million
2 Modified for South Dakota by the State Department of Health (written communication, February 5, 1962)
3 Optimum

Table 2 shows the quality of water from the glacial outwash in the Lake Andes area. Inspection of the table shows that the water from the outwash may vary considerably in quality. This is the general rule in glacial deposits and is inherent because of the origin of the deposits and their relation to recharge areas. The composition and lithology of glacial deposits may vary greatly in short distances. Thus, the minerals with which circulating ground water comes in contact and the length of time of contact may also vary greatly.

Even though the water in the glacial outwash varies in quality from place to place, several general statements can be made about the quality. By most standards, all the glacial outwash water is hard; the minimum hardness of the 19 samples was 180 ppm. All but three samples exceeded the U. S. Public Health standards in total solids. Of the 13 tests made for manganese, all but one exceeded the limit and more than half the samples exceeded the limit for iron, and 15 of the 19 samples exceeded the limit for sulfate.

Table 3 shows the quality of water from the Codell Sandstone in the Lake Andes area. In general, the quality of water from the sandstone is much more uniform in quality than is the water from the glacial outwash. The main reasons for more uniform quality of water from the sandstone probably are: (1) the sandstone is a more homogeneous deposit and, (2) it is buried deeper and has more confining beds, thus the chance of mixing from circulating ground water is less than in the glacial deposits. Some of the erratic quality analyses encountered may represent actual differences in quality of water in the formation. Other analyses may represent water from the Codell that has been contaminated by seepage of foreign water through a leaky casing. For instance, water sample 13 (table 3) has a low chloride content and high sulfate content which is in marked contrast to most of the samples. The high sulfate could be a characteristic of the Codell water; however, it might indicate contamination by Niobrara water, or perhaps glacial outwash water. An argument against contamination from glacial outwash water is that water from this source is usually hard, whereas sample 13 shows no relative increase in hardness.

As already indicated, most of the water from the Codell Sandstone contains an abundance of chloride. Although the sodium content was not included in the analyses, it is fairly safe to assume that considerable sodium is also present in the water. High chloride content with the presence of sodium would constitute a salty water. Another characteristic of the Codell water is its relatively low sulfate content. Although five of the samples exceed 500 ppm sulfate, only six of the samples exceed 250 ppm. All but two of the samples are soft or moderately hard water and all samples are high in total solids. The minimum total solids was 1100 ppm (sample 4, table 3) and the greater hardness content and lower chloride content of this sample indicates the possibility of contamination by water from other aquifers. Generally, the total solids content approaches or exceeds 2000 ppm. The iron and manganese content is variable. Apparently the occurrence of these two chemicals has no relationship to each other or to other chemical constituents for which analyses were made.

Table 2--Chemical analyses of water from glacial outwash.

Data Collection Point Number	Location	Well or Test Hole Designation	Depth (feet)	(1) Source	Parts Per Million (ppm) Calcium	Magnesium	Chlorides	Sulfates	Iron	Manganese	pH	Hardness $CaCO_3$	Total Solids	Calculated Quality (3)
0	U. S. Public Health Dept. Recommended Limits				--	125	250	500(2)	0.3	0.05	--	--	1000(2)	500
1	97-66-23bccb	Lawyer	280	L	97	21	118	793	8.0		8.1	320	1675	3100
2	97-66-23dadd	Johannesen	320	L	172	46	205	1620	Trace	1.2	8.1	620	1815	710
3	97-65-13cbbc	Kirchheuel	200	L	132	41	264	550	21.0	None	7.4	500	2108	7417
4	97-65-24cbbc	Newman	235	L	300	15	166	1780	0.5	0.3	8.0	810	2340	945
5	97-64-17bbba	Soulek	110	U	116	25	225	745	0.44	1.0	7.4	390	2105	not calcu.
6	97-65-31dddc	McBride	260	L	225	26	152	1080	6.0		8.0	665	2060	2616
7	97-65-32ddda	Nelson	180	L	177	5	152	1080	0.88	1.0	8.2	460	2040	866
8	96-65-3aabb	Hutchinson	140	L	183	29	122	985	0.80		7.4	575	2240	852
9	96-65-1bbbb	Carda	175	L	152	34	159	937	0.06	1.4	7.2	520	1960	571
10	97-64-31cccc	Sejnoha	160	L	160	27	147	973	1.8	0.7	7.5	510	2095	1166
11	96-65-5dcad	Krokaugger	164	L	112	22	None	288	0.56	0.3	7.5	370	685	386
12(4)	96-65-4ccda	Lake Andes City Well	200	L	211	56	27	730	0.7	2.8	7.6	765	1452	688
13	96-65-10caaa	Raymond	40	U	52	22	960	None	0.16		8.4	220	2520	not calcu.
14	96-64-8cbbb	Dvorak	283	L	144	34	245	936	1.52		7.3	500	1970	1176
15	96-64-18adba	Morrow	200	L	59	8	78	72	Trace	0.4	7.5	180	810	162
16	96-64-19aaba	Soulek	248	L	80	34	132	210	0.08	0.6	8.2	340	920	282
17	96-64-20aaac	Clemens	242	L	152	38	142	840	0.10	1.7	7.3	535	1870	552
18	96-65-19dddc	Soulek	140	U	249	56	15	722	Trace		7.3	900	1222	not calcu.
19	97-64-27aaab	Hawley	180	L	118	45	284	673	Trace	0.9	7.9	481	1810	524

1 Source: U - upper buried outwash; L - lower buried outwash.
2 Modified for South Dakota by the State Department of Health (written communication, February 5, 1962).
3 Calculated quality is based on arbitrary values as explained in text.
4 Sample 12 was analyzed by the State Department of Health in Pierre, the remaining samples were analyzed by the State Geological Survey; the manganese determinations were done by the State Chemical Laboratory in Vermillion.

Table 3--Chemical analyses of water from the Codell Sandstone.

Data Collection Point Number	Location	Well or Test Hole Designation	Depth (feet)	Parts Per Million (ppm) Calcium	Magnesium	Chlorides	Sulfates	Iron	Manganese	pH	Hardness $CaCO_3$	Total Solids	Calculated Quality[2]
0	U. S. Public Health Dept. Recommended Limits			--	50	250	500[1]	0.3	0.05	--	--	1000[1]	500
1	97-66-14aadd	Johannesen	470	23	6	440	696	0.8	None	8.4	80	2270	825
2	97-65-17aadc	Kisley	439	17	4	660	110	0.48		8.2	60	2200	678
3	97-65-23dccd	Bare	374	20	5	786	None	None	None	8.3	72	2340	562
4	97-64-17cdcc	Linnel	325	49	9	294	300	None	0.6	8.0	158	1100	320
5	97-65-30cdbd	Vesely	409	14	4	637	206	Trace	None	8.4	50	2135	519
6	97-65-34cbbb	Carda	410	33	8	1125	19	0.8		8.4	112	2820	1025
7	97-64-32dcad	Nielson	325	11	8	1130	None	0.28	None	7.6	60	2300	787
8	96-66-2bddd	Petocka	608	15	4	856	19	0.12		8.5	54	2165	613
9	96-65-7aadd	Svatos	357	17	4	1220	None	0.6		8.4	60	2815	982
10	96-65-5addd	Pavel	350	14	4	1220	None	Trace	None	8.1	48	2760	774
11[3]	96-65-4cdcd	Lake Andes Standby Well	380	8	5	911	2	2.2	None	8.3	46	2455	1356
12	96-65-10bddb	Soulek	375	19	7	1028	19	0.4		8.3	76	2470	810
13	96-64-7aaaa	Weaver	370	24	10	200	660	0.1	0.2		87	1568	550
14	96-65-16bcaa	Young	390	16	3	930	None	None		8.4	56	2450	627
15	96-65-13babd	Dvorak	480	18	4	836	745	2.40	None	8.3	62	1960	1511
16[3]	96-64-17aadd	Ravina City Well	350	135	35	166	984	1.8	1.5	7.5	488	2050	1166
17	96-66-23bccc	Patocka	577	14	4	785	None	0.2		8.4	50	2440	635
18	96-65-29bacc	Svatos	340	20	5	960	None	0.64		8.3	74	2440	856
19	96-65-23dcbb	Dvorak	666	17	8	638	187	1.3		8.3	76	2080	948
20	96-64-29abba	Mitchell	380	25	6	368	614	None	None	8.3	84	1890	476

1 Modified for South Dakota by the State Department of Health (written communication, February 5, 1962).
2 Calculated quality is based on arbitrary values as explained in text.
3 Samples 11 and 16 were analyzed by the State Department of Health in Pierre; the remaining samples were analyzed by the State Geological Survey; the manganese determinations were done by the State Chemical Laboratory in Vermillion.

Quality Maps

Water quality maps (an idea first used in South Dakota by Bruce, 1963) were drawn to show general areas of similar quality water in both the lower buried outwash and the Codell Sandstone. The aquifers are divided to show areas where the quality is better than Public Health standards, where it is worse than the standards but better than the present city supply, and areas where it is worse than the present city supply.

These maps (figs. 7 and 8) were developed by selecting total solids, total hardness, iron, sulfate, and chloride as the "problem" elements in the area; the remaining elements are less troublesome. A mathematical relationship giving each of these elements equal rank to each other is employed. Obviously a concentration of iron of 9 ppm compared to total solids of 500 ppm seems low. But the iron concentration is 30 times larger than the recommended limit, while the total solids is only one-half the recommended limit. Hence, the need for the equal-ranking relationship.

The relationship is developed by setting the recommended limit for each selected element equal to an arbitrary 100. For example:

Total solids should not exceed 1000 ppm. Therefore, 1000 ppm total solids = 100. Similarly,

500 ppm sulfate = 100
250 ppm chlorides = 100
0.3 ppm iron = 100
500 ppm total hardness = 100

The limits for total hardness of 500 were selected as an arbitrary figure after studying tables 1 and 2. It should be understood that 500 ppm is "very hard" water, compared with other areas.

A ratio, therefore, can be established to determine how the concentrations of the elements in each sample ranks in comparison to the 100 maximum for the Public Health standards.

If we let:

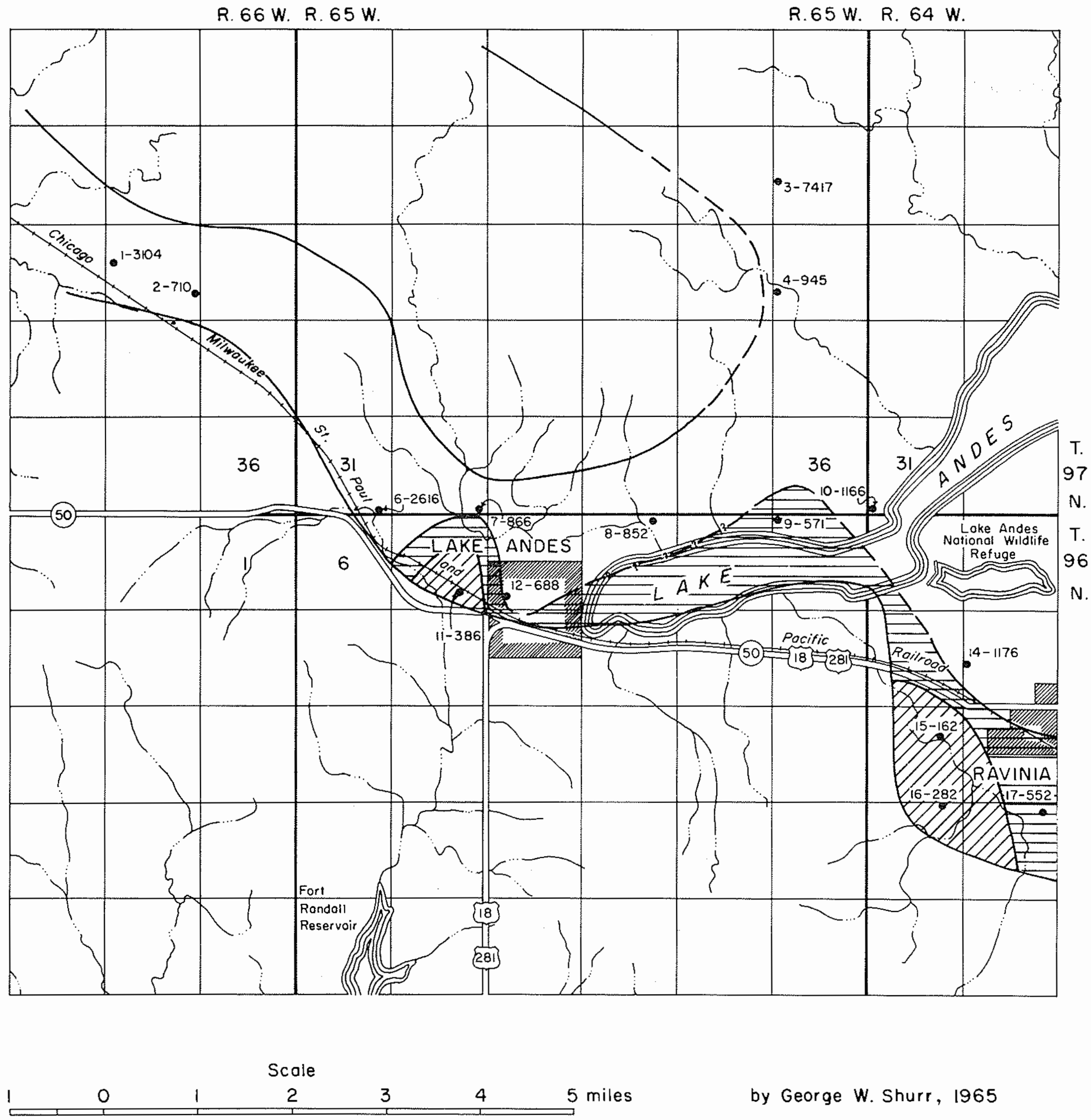
s = concentration of element in sample in ppm
(PH) = maximum concentration in ppm recommended by U. S. Public Health Service
100 = arbitrary number assigned to (PH)
x = quantity of element in each sample

Then:

$$\frac{s}{x} = \frac{(PH)}{100}$$

Solving for x we get

$$x = \frac{100s}{(PH)} \qquad \text{(formula 1)}$$



EXPLANATION

Better than Public Health Standards

Worse than Public Health Standards

As poor as or worse than present city supply

(data taken from column marked "calculated quality" Table 2.)

3-7417 Data point showing location of water sample; first number is analysis number and second number is calculated quality

Samples 5, 13 and 18 from upper buried outwash not shown; sample 19 from lower buried outwash also not shown

Figure 7. Map showing water quality in the lower buried outwash comparing the city's present supply with calculated U. S. Public Health Standards.

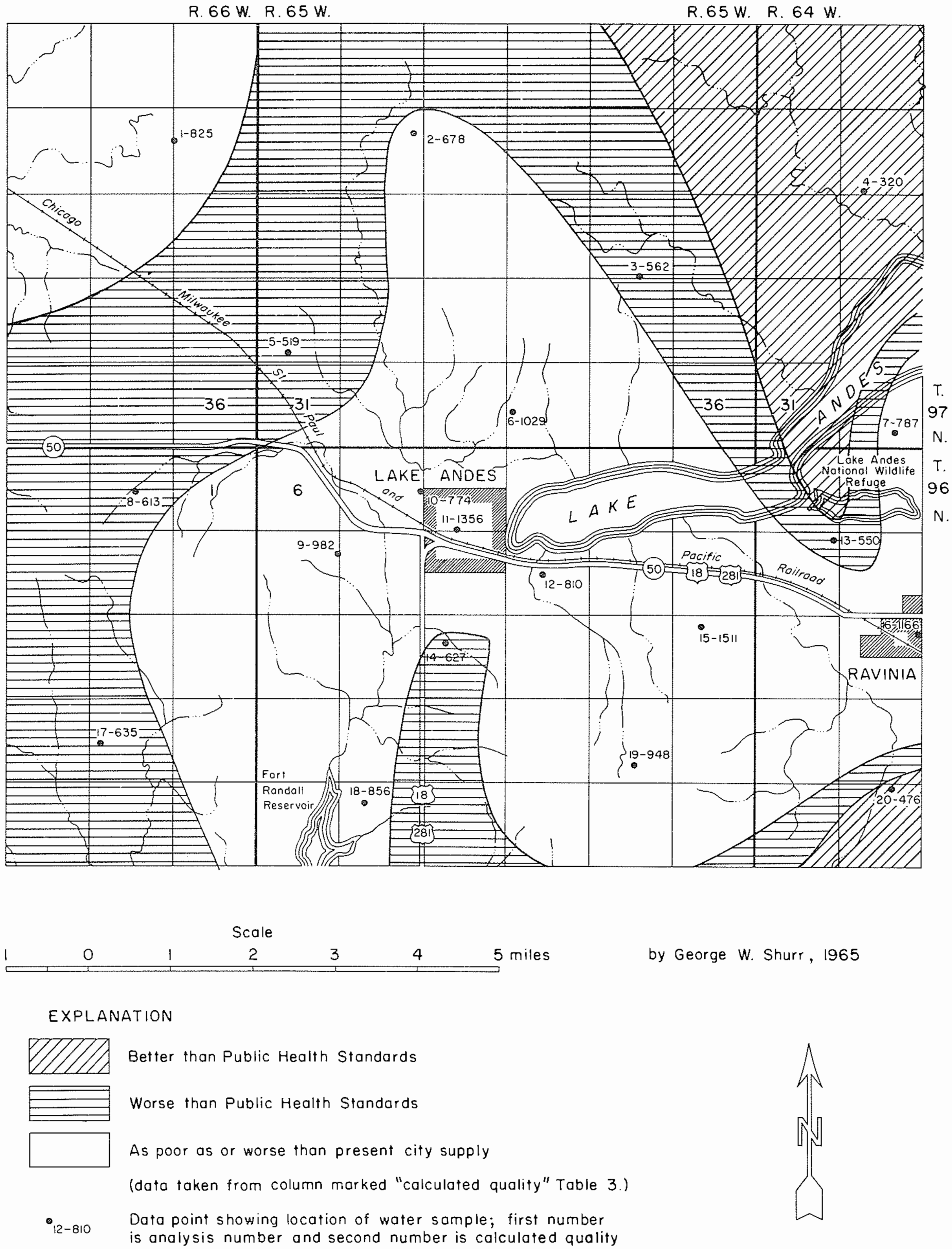


Figure 8. Map showing water quality in the Codell Sandstone comparing the city's present supply with calculated U. S. Public Health Standards.

By applying this formula to each element and adding the results we get a maximum of 500 recommended by the U. S. Public Health standards. The totals for each sample figured with this formula are found in the column marked Calculated Quality in tables 2 and 3.

Using sample 12 (city's present supply) from table 2 as an example, we have:

Total Solids	1452 ppm
Sulfates	730 ppm
Chlorides	27 ppm
Iron	0.7 ppm
Total Hardness	765 ppm

Applying formula 1 to total solids:

$$x = \frac{100\ (1452)}{1000}$$

$$x = 145.2$$

Similarly for sulfates:

$$x = \frac{100\ (730)}{500}$$

$$x = 146$$

Similar application of formula 1 yields:

Chlorides	x = 11
Iron	x = 233
Total Hardness	x = 153
TOTAL	688

This total is the figure given for sample 12 of the outwash water and all other samples were figured in this manner.

A general rule should now be noted--the lower the figure, the better the water quality.

Figure 7 shows the water quality for the lower buried outwash and figure 8 shows the water quality for the Codell Sandstone. The figures indicate only general areas because not enough data is available to present detailed maps. Even though a particular sample calculates less than the U. S. Public Health Standards, each chemical constituent used in the calculation may not be less than the recommended limit. For instance, water sample 11 (table 2) calculates 386 by the method previously described. By the standards adopted for this calculation anything less than 500 would be better than the recommended limits. Yet, according to our established criteria, water sample 11 exceeds the limits by nearly a factor of two for iron.

The resultant low figure of 386 for calculated quality is the result of the other four chemical constituents being present in lesser amounts than the recommended limits. Conceivably then, all but one of the chemical constituents could be present in amounts exceeding the recommended limits and still result in a calculation below the recommended limits.

In spite of the obvious caution that must be exercised when using these maps, they afford a useful basis for general water quality comparison.

Figure 7 shows the calculated quality of water in the buried outwash based on the five chemical constituents: iron, sulfate, hardness, total solids and chlorides. Examination of this map shows two areas where the water quality is better than the U. S. Public Health Standards. The area just west of town is represented by one water sample (no. 11, table 2). This sample is a considerable improvement over the present water supply (no. 12, table 2) in all respects, even though the iron and manganese exceed the recommended limits.

The second area, southwest of Ravinia, is represented by water samples 15 and 16 (table 2). The water from this area is of a better quality than the first area west of Lake Andes and is better than the recommended Public Health limits in all constituents except manganese.

Figure 8 shows the calculated quality of water in the Codell Sandstone based on the five chemical constituents. (It should be emphasized that although figure 8 shows the calculated quality of water from the Codell Sandstone, the comparison used in figure 8 is with water from the lower buried outwash which is the present city supply.) Examination of this map shows that in general the water quality gets progressively better in all directions away from the town with the best quality of water occurring northeast of town (sample 4) and southeast of town (sample 20). In these two areas the water (from the Codell Sandstone) is within the limits set by the U. S. Public Health Standards. In the city of Lake Andes and within a radius of about three miles (except water sample 14) the water from the Codell is inferior in quality to the present city supply from the lower buried outwash.

Sample 10 (figure 8) from the northwest corner of Lake Andes is of particular interest. This sample shows no sulfates or manganese and only a trace of iron. Chloride is the only chemical constituent present in excess of the recommended limits (excepting total solids which is a direct reflection of the chloride content). Removal of the sodium chloride (ordinary salt) would probably result in excellent quality water.

In both figures 7 and 8 it is obvious that the iron content is most influential in causing a wide divergence in calculated quality. To see what influence this would have on areal distribution of the water quality maps, the calculations were made and the results plotted neglecting the iron content. The results showed the general patterns unchanged from figures 7 and 8 and thus the calculations and plotted figures have not been put into this report.

CONCLUSIONS AND RECOMMENDATIONS

Four aquifers in the Lake Andes area were investigated as possible sources of water of better quality than the city is presently using. Each aquifer is distinctly different in the quality and quantity of water it would produce.

The alluvium south of the city and the upper outwash deposits cannot supply the quantity of water demanded by a town the size of Lake Andes and therefore quality determinations were not made for these aquifers. However, the two remaining aquifers, the lower buried outwash and the Codell Sandstone, are suggested as most favorable for future investigations. Neither of the latter two aquifers investigated during this study contains water which would be of acceptable quality for use by the town without some treatment. At all locations tested, each aquifer has at least one chemical constituent which is in excess of the U. S. Public Health Standards recommended limits. Furthermore, the excess is great enough that partial or complete removal of the undesired chemical would be necessary to make the water acceptable for domestic use. The city has three alternatives from which to choose in order to obtain water of better quality than that now being used:

(1) Treat the city's present supply of water from the lower buried outwash for removal of iron, manganese, hardness and perhaps sulfates. An additional quantity of water from this same source could probably be easily obtained if the city so desires. The major restrictions would be to space any additional wells in the lower buried outwash at a sufficient distance from the present well to avoid pumping interference.

(2) Further investigate the lower buried outwash in those areas suggested in figure 7 that show the best quality water. The area one-quarter mile west of town would probably produce water of better quality than the present city supply; however, the water would still exceed the recommended limits in iron and manganese and would require treatment. The area bordering the southwest corner of Ravinia is high only in manganese. The distance from the city would be the critical factor in the possible future development of this supply.

(3) Develop a water supply from the Codell Sandstone aquifer from which the city standby well now produces. There would be many considerations to bear in mind before developing a water supply from this aquifer. All samples of water from the Codell within a four-mile radius of the city have one or more chemicals in excessive amounts and treatment would probably be required. Samples 5 and 10 (table 3 and fig. 8) are high only in total solids and chlorides. Partial or complete removal of chlorides would also reduce the total solid content considerably. Other factors to consider in possible future development of the Codell Sandstone are the greater depth of wells and limited production. Wells in the Codell are 300 to 400 feet deep as opposed to 200 to 300 feet in the lower buried glacial outwash. One or perhaps two wells in the glacial outwash would provide sufficient quantity of water, whereas several wells would be required in the Codell.

If the city decides to make additional tests for ground water in the future, it is recommended that they test first in the SE$\frac{1}{4}$ of sec. 5, T. 96 N., R. 65 W. near or between Codell water sample 10 and lower buried outwash water sample 11 (figs. 7 and 8). A test or test holes in this area would penetrate both the outwash and the Codell and water from both formations could be tested for quality. Because water sample 11 from the lower buried outwash is near the margin of the aquifer, it should be determined if an adequate thickness of sand and gravel is available in the area, and if the margin of the aquifer is an adequate distance from proposed well sites to eliminate boundary conditions during extensive pumping.

A consulting engineering firm licensed in South Dakota should be hired to plan and direct future testing programs, and to conduct an economic survey of the various possibilities the city may pursue in future development of a water supply. A commercial well drilling company licensed by the State of South Dakota should be hired to conduct any future test drilling or installation of wells. 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.

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APPENDIX A

Logs of Test Holes and Wells in the Lake Andes Area

(for location see figure 2)

Test Hole No. 1
Water Resources Commission Test Hole
Location: 97-64-5da
Surface elevation: 1490 feet

0- 3	topsoil
3- 14	clay, brown
14- 19	sand and gravel
19-179	clay, blue, some sand and gravel
179-197	extremely hard layer of hardpan or boulders
197-210	chalk, Niobrara

* * * *

Test Hole No. 2
SDGS Rotary Test Hole
Location: 97-65-9aaaa
Surface elevation: 1632 feet

0- 40	clay, brown
40- 79	clay, gray
79-140	clay, silty and sandy
140-280	clay, gray
280-335	gravel, clayey
335-350	chalk, Niobrara

* * * *

Test Hole No. 3
SDGS Rotary Test Hole
Location: 97-65-2dddd
Surface elevation: 1561 feet

0- 28	clay, brown
28- 40	clay, gray
40- 60	clay, gray, sandy, gravel stringers
60-240	clay, gray
240-255	clay, gray, gravel stringers
255-265	clay, gray
265-285	gravel, with clay in it
285-299	clay, gray
299-310	chalk, Niobrara

* * * *

Test Hole No. 4
W. Paulis Farm Well
Location: 97-65-12bada
Surface elevation: 1560 feet

0-250	no sample
250-300	gravel
300-450	no sample
450-	sandstone, Codell

* * * *

Test Hole No. 5
Andy Horst Farm Well
Location: 97-66-15ddbd
Surface elevation: 1575 feet

0-250	clay, with sand stringers
250-	gravel

* * * *

Test Hole No. 6
SDGS Rotary Test Hole
Location: 97-66-13cbbc
Surface elevation: 1630 feet

0- 42	clay, buff to brown
42-118	clay, gray
118-125	shale, Pierre

* * * *

Test Hole No. 7
SDGS Rotary Test Hole
Location: 97-65-18aaad
Surface elevation: 1612 feet

0- 28	clay, buff to brown
28- 45	clay, gray
45- 47	clay, sandy
47-225	clay, gray
225-230	marl, Pierre

* * * *

Test Hole No. 8
SDGS Rotary Test Hole
Location: 97-65-9cddd
Surface elevation: 1632 feet
(continued on next page)

Test Hole No. 8--continued

0- 33	clay, brown
33-180	clay, gray, silty and sandy stringers
180-230	clay, gray
230-234	gravel
234-242	clay, gray, silty
242-244	gravel
244-277	clay, gray
277-300	marl, Niobrara

* * * *

Test Hole No. 9
SDGS Rotary Test Hole
Location: 97-65-11dddd
Surface elevation: 1570 feet

0- 3	topsoil, black
3- 41	clay, buff to brown
41-170	clay, gray, very thin gravel stringers beyond 65'
170-230	clay, gray
230-232	gravel
232-245	clay and gravel stringers interbedded
245-255	gravel, abandoned hole

* * * *

Test Hole No. 10
SDGS Rotary Test Hole
Location: 97-64-7dddd
Surface elevation: 1530 feet

0- 27	clay, brown
27- 30	sand, medium
30-121	clay, gray
121-131	gravel, clay stringers
131-149	clay, gray, gravel stringers
149-160	gravel, coarse
160-170	clay, gray, gravel stringers
170-200	clay, gray, sands and gravels
200-215	clay, gray, gravel stringers
215-270	gravel, fairly coarse
270-286	clay, gray, gravel stringers; hit rock, abandoned hole

* * * *

Test Hole No. 11
E. Lawyer Farm Well
Location: 97-66-23bccb
Surface elevation: 1562 feet

300- ?	top of gravel

* * * *

Test Hole No. 12
SDGS Auger Test Hole
Location: 97-65-19babb
Surface elevation: 1642 feet

0- 2	topsoil
2- 9	clay, dark brown, few pebbles
9- 54	clay, moist, brown
54- 84	clay, saturated, brown
84-140	clay, gray, 20% medium sand

* * * *

Test Hole No. 13
SDGS Rotary Test Hole
Location: 97-65-22bbbb
Surface elevation: 1636 feet

0- 30	clay, buff to brown
30- 90	clay, gray, 10% sand and gravel
90-185	clay, gray
185-200	clay, gray, very thin gravel stringers
200-218	clay, gray, silty and sandy
218-243	clay, gray
243-260	marl, Pierre

* * * *

Test Hole No. 14
SDGS Rotary Test Hole
Location: 97-65-14cccc
Surface elevation: 1590 feet

0- 12	clay, brown
12- 15	gravel
15- 30	clay, brown
30-242	hit rock, abandoned hole

* * * *

Test Hole No. 15
Water Resources Commission Test Hole
Location: 97-65-13dd
Surface elevation: 1520 feet

0- 3	topsoil
3- 27	clay, brown
27- 85	clay, "blue"
85-100	sand, coarse gravel
100-145	sandy, gray, clay, and sand streaks
145-175	gravel, coarse, sand, some clay
175-193	clay, sandy, gray
193-200	chalk, Niobrara

* * * *

Test Hole No. 16
SDGS Auger Test Hole
Location: 97-64-20baba
Surface elevation: 1485 feet

0- 2	topsoil
2- 29	clay, brown, moist, many pebbles
29- 39	clay, gray, moist, many pebbles
39-104	clay, gray, saturated, 20% coarse sand

* * * *

Test Hole No. 17
SDGS Auger Test Hole
Location: 97-66-25baba
Surface elevation: 1579 feet

0- 1	topsoil
1- 39	clay, brown, moist, few pebbles
39- 54	clay, brown, saturated, trace of sand
54- 69	clay, brown, 10% medium sand
69- 74	clay, gray, 10% medium sand
74-104	clay, gray, 20% medium-coarse sand
104-125	clay, gray, 20% medium sand, water flows

* * * *

Test Hole No. 18
SDGS Rotary Test Hole
Location: 97-65-30bbbb
Surface elevation: 1578 feet
(continued on next page)

Test Hole No. 18--continued

0- 30	clay, brown
30-100	clay, gray, silty
100-110	sand and gravel
110-120	clay, gray, very silty and sandy
120-140	gravel
140-165	clay, gray, silty
165-200	clay, gray
	tried to pump, but only got mud: abandoned hole due to caving

* * * *

Test Hole No. 19
SDGS Rotary Test Hole
Location: 97-65-30bbbc
Surface elevation: 1575 feet

0-30	clay, brown
30-95	clay, gray
	hit rock, abandoned hole

* * * *

Test Hole No. 20
SDGS Rotary Test Hole
Location: 97-65-30bcbb
Surface elevation: 1570 feet

0- 22	clay, brown, sand and gravel stringers
22- 35	clay, brown
35-250	clay, gray
250-295	gravel, coarse
295-300	clay, gray
300-302	gravel
302-314	clay, gray, silt stringers
314-320	chalk, Niobrara

* * * *

Test Hole No. 21
SDGS Auger Test Hole
Location: 97-65-30baab
Surface elevation: 1571 feet

0- 2	topsoil
2- 29	clay, brown, moist, some pebbles
29- 39	clay, gray, very moist
39-100	clay, gray, saturated, 20% medium sand

* * * *

Test Hole No. 22
SDGS Rotary Test Hole
Location: 97-65-28bbcc
Surface elevation: 1655 feet

0-17	clay, brown, very few sand stringers
17-22	clay, black
22-33	clay, light brown
33-60	clay, gray, sticky, shale (?)

* * * *

Test Hole No. 23
SDGS Rotary Test Hole
Location: 97-65-22ddcd
Surface elevation: 1617 feet

0- 45	clay, brown
45-140	clay, gray
140-175	clay, gray, silty
175-185	shale, Pierre

* * * *

Test Hole No. 24
SDGS Rotary Test Hole
Location: 97-65-24adad
Surface elevation: 1617 feet

0- 30	clay, buff to brown
30- 63	clay, gray
63- 65	sand and gravel
65- 70	clay, gray
70- 90	clay, gray, silty
90-106	clay, gray
106-120	boulders, abandoned hole

* * * *

Test Hole No. 25
SDGS Rotary Test Hole
Location: 97-65-24daaa
Surface elevation: 1515 feet

0- 25	clay, brown, silt stringers
25-120	clay, gray
120-160	clay, gray, sand and silt stringers
160-213	clay, gray, gravel stringers
213-225	gravel

(continued on next page)

Test Hole No. 25--continued

225-258	clay, gray, gravel stringers
258-270	chalk, Niobrara

* * * *

Test Hole No. 26
SDGS Rotary Test Hole
Location: 97-66-33aaaa
Surface elevation: 1650 feet

0- 21	clay, brown
21-132	clay, gray, silty
132-155	shale, Pierre

* * * *

Test Hole No. 27
SDGS Rotary Test Hole
Location: 97-66-36bbbb
Surface elevation: 1625 feet

0-31	clay, buff to brown
31-68	clay, gray
68-75	gravel
75-85	clay, gray, sand stringers
85-90	shale, Pierre

* * * *

Test Hole No. 28
SDGS Rotary Test Hole
Location: 97-65-31daaa
Surface elevation: 1527 feet

0- 6	clay, gray
6- 12	clay, brown
12- 28	clay, brown, sandy
28- 38	clay, gray
38- 40	gravel, sandy
40-222	clay, gray; silty stringers; very fine sand stringers
222-226	gravel
226-228	clay
228-280	gravel, coarse
	abandoned due to caving

* * * *

Test Hole No. 29
SDGS Auger Test Hole
Location: 97-65-29dddd
Surface elevation: 1580 feet

0-19	clay, light brown, moist, many large pebbles
19-22	clay, dark brown, moist, some pebbles
22	shale, Pierre

* * * *

Test Hole No. 30
SDGS Rotary Test Hole
Location: 97-65-33bccc
Surface elevation: 1498 feet

0- 12	topsoil, black
12- 21	clay, yellow
21- 40	clay, gray
40-160	clay, gray, very silty and sandy
160-193	clay, gray
193-220	chalk (?)

* * * *

Test Hole No. 31
Water Resources Commission Test Hole
Location: 97-65-34c
Surface elevation: 1475 feet

0- 3	topsoil
3- 17	clay, brown
17- 53	clay, blue
53- 59	sand and coarse gravel
59-100	clay, sandy; sand streaks 90-100
100-104	sand, coarse, some clay
104-135	sand, clayey
135-160	chalk, Niobrara

* * * *

Test Hole No. 32
SDGS Rotary Test Hole
Location: 97-65-26cccc
Surface elevation: 1546 feet
(continued on next page)

Test Hole No. 32--continued

0- 3	topsoil, black
3-30	clay, yellow
30-34	clay, brown, sandy
34-42	clay, brown
42-87	clay, gray
87-95	shale, Pierre

* * * *

Test Hole No. 33
SDGS Rotary Test Hole
Location: 97-65-26dddc
Surface elevation: 1507 feet

0- 35	clay, buff to brown, sandy
35- 61	clay, gray
61- 76	gravel, sandy
76-158	clay, gray, silty and sandy stringers
158-178	gravel
178-200	sand, very fine, with gravel stringers
200-230	gravel, very coarse
230-240	chalk, Niobrara

* * * *

Test Hole No. 34
SDGS Auger Test Hole
Location: 97-64-31bbbb
Surface elevation: 1482 feet

0- 2	topsoil
2- 9	clay, brown, dry, few pebbles
9- 29	clay, brown, moist, few pebbles
29- 59	clay, gray, moist, few pebbles
59- 79	clay, gray, saturated, pebbles
79- 99	clay, gray, 10% medium sand
99-139	clay, gray, 30% medium-coarse sand

* * * *

Test Hole No. 35
SDGS Rotary Test Hole
Location: 97-64-30aaaa
Surface elevation: 1475 feet
(continued on next page)

Test Hole No. 35--continued

0- 2	topsoil, black
2- 22	clay, buff to brown
22- 25	gravel
25-175	clay, gray
175-203	gravel, coarse
203-260	shale (?)

* * * *

Test Hole No. 36
SDGS Rotary Test Hole
Location: 96-66-4aaab
Surface elevation: 1745 feet

0- 23	clay, buff to brown
23- 61	clay, gray
61- 75	gravel, clay stringers
75- 85	clay, gray
85- 90	clay, silty and sandy
90-125	clay, gray
125-162	gravel, clay stringers
162-168	clay, gray
168-200	shale, Pierre

* * * *

Test Hole No. 37
SDGS Auger Test Hole
Location: 97-66-34dddd
Surface elevation: 1800 feet

0- 2	topsoil
2- 44	clay, moist, brown, some pebbles
44- 79	clay, dark brown, saturated
79- 89	clay, gray, with 25% medium sand
89-129	clay, gray, 50% medium sand
129-140	clay, gray, 10% fine sand

* * * *

Test Hole No. 38
SDGS Auger Test Hole
Location: 96-65-5aaab
Surface elevation: 1460 feet
(continued on next page)

Test Hole No. 38--continued

0- 2	topsoil
2- 14	clay, brown, moist, some pebbles
14- 34	clay, brown, saturated, water flowed at 19 feet
34- 39	clay, brown, 30% medium sand
39- 49	clay, brown, 60% medium-coarse sand
49- 59	clay, gray, 20% fine sand
59- 84	clay, gray, 40% medium-coarse sand
84-139	clay, gray, 60% medium-coarse sand

* * * *

Test Hole No. 39
SDGS Rotary Test Hole
Location: 96-65-4bccb
Surface elevation: 1465 feet

0- 12	topsoil, brown-gray clay
12- 21	clay, sandy
21- 31	clay, gray
31- 40	clay, gray, some sandy stringers and coal
40- 63	clay, gray, with fine sand
63- 70	gravel
70- 97	clay, gray, sand stringers; some very poorly-sorted gravel
97-113	clay, gray, very silty
113-118	clay, gray, very hard
118-146	clay, gray, silty
146-190	gravel
190-210	chalk, Niobrara

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Test Hole No. 40
SDGS Auger Test Hole
Location: 96-65-4aadd
Surface elevation: 1460 feet

0- 24	clay, moist, brown
24- 39	clay, gray
39-104	clay, gray, saturated
104-110	clay, gray

* * * *

Test Hole No. 41
SDGS Auger Test Hole
Location: 97-65-35cdcd
Surface elevation: 1470 feet

0- 34	clay, moist, brown, few pebbles
34- 44	clay, dark brown
44- 69	clay, gray, moist
69- 80	clay, saturated, 15% fine sand
80-100	clay, 25% medium sand

* * * *

Test Hole No. 42
Krell Irrigation Well
Location: 96-65-1abbd
Surface elevation: 1455 feet

0- 20	clay, yellow
20-145	clay, "blue," sandy
145-185	sand and gravel, water bearing

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Test Hole No. 43
Bureau of Sport Fishing and Wildlife Refuge Well
Location: 96-64-6ac
Surface elevation: 1440 feet

1- 2	topsoil
2- 30	clay, yellow, sandy
30- 40	clay, "blue," sandy
40- 60	gravel
60-120	clay, "blue," sandy
120-135	clay, gray
135-180	sand and gravel
180-190	clay, "blue," with sand and gravel
190-230	clay, gray, with gravel
230-250	shale, gray
250-272	shale, brown
272-279	caprock
279-300	shale, "blue"
300-338	clay, sandy
338-470	shale, with sand streaks
470-520	clay, "blue"
520-630	shale, gray
630-639	sand, shale breaks
639-650	shale

(continued on next page)

Test Hole No. 43--continued

650-710	shale, sand breaks
710-719	sandrock
719-728	shale, sand streaks
728-743	sand, shale breaks
743-760	sand
760-770	sand, shale breaks
770-790	sand

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Test Hole No. 44
SDGS Rotary Test Hole
Location: 96-64-5abbb
Surface elevation: 1458 feet

0- 3	topsoil
3- 45	clay, buff to brown, sandy
45- 90	clay, gray
90- 95	clay, gravel stringers
95-165	clay, gray, silty and sandy
165-195	gravel
195-238	clay, gray, silty
238-250	chalk, Niobrara

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Test Hole No. 45
SDGS Auger Test Hole
Location: 96-66-10bccb
Surface elevation: 1885 feet

0-29	clay, moist, brown, many pebbles
29-36	clay, moist, dark brown, some pebbles
36-	shale, Pierre

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Test Hole No. 46
SDGS Auger Test Hole
Location: 96-66-1cccc
Surface elevation: 1785 feet

0- 2	topsoil
2-19	clay, dark brown, moist, few large pebbles
19-44	clay, light brown, saturated
44-69	clay, gray, 20% fine-medium sand

(continued on next page)

Test Hole No. 46--continued

69-104	clay, gray, 20% medium-coarse sand
104-130	clay, gray, 20% sand
130-	shale, Pierre

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Test Hole No. 47
SDGS Rotary Test Hole
Location: 96-65-5cdcd
Surface elevation: 1475 feet

0-15	clay, buff to brown
15-20	clay, gray
20-43	sand and gravel
43-73	clay, gray
73-93	gravel
93-95	marl, Pierre

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Test Hole No. 48
SDGS Auger Test Hole
Location: 96-65-8dada
Surface elevation: 1468 feet

0-39	clay, moist, brown
39-59	clay, saturated, light brown
59-64	clay, brown, 25% medium sand
64-66	clay, gray, 15% medium sand
66-	shale, Pierre

* * * *

Test Hole No. 49
SDGS Rotary Test Hole
Location: 96-65-9bcbb
Surface elevation: 1468 feet

0-25	clay, brown, slightly sandy
25-86	clay, gray, very few sand stringers
86-95	marl, Pierre

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Test Hole No. 50
SDGS Auger Test Hole
Location: 96-65-9adcc
Surface elevation: 1453 feet

0- 4	topsoil
4- 27	clay, light brown, some pebbles
27- 40	clay, saturated
40- 99	clay, gray, large pebbles
99-109	clay, 20% sand
109-	shale, Pierre

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Test Hole No. 51
SDGS Auger Test Hole
Location: 96-65-9aaca
Surface elevation: 1445 feet

0- 9	clay, dry, brown, many pebbles
9- 29	clay, moist, brown
29- 74	clay, gray, saturated
74- 94	clay, gray, 10% medium sand
94-129	clay, gray, 40% medium sand
129-140	no change

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Test Hole No. 52
SDGS Rotary Test Hole
Location: 96-65-4dddb
Surface elevation: 1450 feet

0- 40	clay, brown
40- 55	clay, gray
55- 65	clay, gray, gravel stringers
65- 90	clay, gray
90- 92	gravel
92- 95	gravel stringers
95-120	clay, gray
120-126	clay, gray, gravel stringers
126-172	gravel
172-182	clay, gray, gravel stringers
182-185	chalk, Niobrara

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Test Hole No. 53
SDGS Auger Test Hole
Location: 96-65-9daaa
Surface elevation: 1448 feet

0- 4	clay, moist, brown, pebbles (few)
4- 9	clay, 70% medium-grained sand
9-14	clay, brown, 50% medium sand, saturated
14-24	clay, with 25% medium sand
24-44	clay, 25% fine sand
44-78	clay, gray
78-	shale, Pierre

* * * *

Test Hole No. 54
SDGS Auger Test Hole
Location: 96-65-10bdda
Surface elevation: 1450 feet

0- 2	topsoil
2-19	clay, brown, some pebbles
19-49	clay, saturated, gray
49-59	clay, 15% sand
59-63	clay, gray
63-	shale, Pierre

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Test Hole No. 55
SDGS Auger Test Hole
Location: 96-65-11bbdd
Surface elevation: 1455 feet

0- 2	topsoil
2- 39	clay, brown, few pebbles, moist
39- 54	clay, gray
54- 79	clay, saturated, 15% medium sand
79- 99	clay, 10% fine sand
99-140	clay, gray, 10% medium-coarse sand

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Test Hole No. 56
SDGS Rotary Test Hole
Location: 96-65-11bcab
Surface elevation: 1460 feet
(continued on next page)

Test Hole No. 56--continued

0-30	clay, yellow, sandy and gravelly
30-75	clay, gray, silty
75-92	clay, black; shale (?)
92-95	white soft material

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Test Hole No. 57
SDGS Rotary Test Hole
Location: 96-65-11abcb
Surface elevation: 1455 feet

0- 30	clay, brown
30- 74	clay, gray
74- 75	sand and gravel
75-160	clay, gray, silty and sandy
160-170	chalk, Niobrara

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Test Hole No. 58
SDGS Auger Test Hole
Location: 96-65-11daaa
Surface elevation: 1482 feet

0- 2	topsoil
2-14	clay, moist, brown, many pebbles
14-25	clay, brown, saturated
25-	shale, Pierre

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Test Hole No. 59
SDGS Auger Test Hole
Location: 96-65-1cddd
Surface elevation: 1450 feet

0- 2	topsoil
2- 24	clay, moist, brown, few pebbles
24- 39	clay, yellow, saturated, 15% coarse sand
39- 64	clay, gray, 15% medium sand
64-140	clay, gray, 10% medium sand
140-	shale, Pierre

* * * *

Test Hole No. 60
SDGS Rotary Test Hole
Location: 96-65-12aadd
Surface elevation: 1457 feet

0- 8	clay, buff
8- 18	gravel
18- 35	clay, brown
35-180	clay, gray, silty and sand; gravel stringers 120-130, 130-180
180-190	gravel?
190-220	clay, gray, very silty
220-230	clay, very hard
230-240	chalk, Niobrara

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Test Hole No. 61
State Game, Fish and Parks Commission Well
Location: 96-64-7abbd
Surface elevation: 1455 feet

0- 20	sand and gravel, clayey
20- 30	sand and chalk fragments
30- 70	sand
70- 90	sand, coarse, gray, with gravel
90-170	sand, fine, gray, with gravel
170-200	gravel, fine
200-240	gravel, coarse
240-270	sand, fine
270-340	"grit conglomerate" with sand
340-360	sand, cemented
360-380	sandstone, (Codell?)
380-960	shales, sandstone, limestone, and chalk
960-	quartzite (Sioux)

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Test Hole No. 62
SDGS Auger Test Hole
Location: 96-64-8aabb
Surface elevation: 1460 feet

0- 2	topsoil
2-14	clay, brown, moist, few pebbles
14-19	clay, brown, saturated, few pebbles
19-49	clay, brown, 30% medium-coarse sand
49-99	clay, gray, 30% medium-coarse sand

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Test Hole No. 63
SDGS Auger Test Hole
Location: 96-65-17bbcc
Surface elevation: 1457 feet

0-24	clay, moist, brown, few pebbles
24-49	clay, brown, saturated
49-68	clay, gray to brown
68-	shale, Pierre

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Test Hole No. 64
SDGS Rotary Test Hole
Location: 96-65-8dcdc
Surface elevation: 1453 feet

0-20	till, brown, with sand and gravel stringers
20-30	till, brown
30-55	till, gray
55-60	gravel and sand (rocks at 60')
60-80	gravel, very coarse, with fine sand stringers abandoned due to caving

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Test Hole No. 65
SDGS Auger Test Hole
Location: 96-65-16bcbb
Surface elevation: 1470 feet

0- 2	topsoil
2-34	clay, moist, brown, few pebbles
34-44	clay, gray-brown, moist
44-80	clay, gray, moist
80-	shale, Pierre

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Test Hole No. 66
SDGS Auger Test Hole
Location: 96-65-16abba
Surface elevation: 1470 feet

0- 3	topsoil
3- 39	clay, moist, brown, some pebbles
39- 54	clay, 20% medium coarse sand
54- 69	clay, 35% medium sand

(continued on next page)

Test Hole No. 66--continued

69- 89	clay, 50% medium sand
89-112	clay, 25% fine sand
112-	shale, Pierre

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Test Hole No. 67
SDGS Auger Test Hole
Location: 96-65-15bcbc
Surface elevation: 1522 feet

0- 2	topsoil
2-14	clay, moist, brown, some pebbles
14-44	clay, light brown
44-59	clay, brown
59-64	clay, saturated, gray
64-	shale, Pierre

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Test Hole No. 68
SDGS Auger Test Hole
Location: 96-65-15abaa
Surface elevation: 1515 feet

0- 2	topsoil
2-19	clay, dark brown, many pebbles
19-24	clay, gray, fewer pebbles
24-45	clay, gray, moist
45-	shale (?)

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Test Hole No. 69
SDGS Auger Test Hole
Location: 96-65-11cccc
Surface elevation: 1595 feet

0- 4	clay, brown, few pebbles
4-65	clay, moist, brown, pebbles
65-	clay, (no change), no water

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Test Hole No. 70
SDGS Auger Test Hole
Location: 96-65-13babb
Surface elevation: 1587 feet

0- 1	topsoil
1-54	clay, moist, brown, few pebbles
54-74	clay, saturated, 20% medium sand
74-88	clay, gray, 10% fine sand
88-	shale, Pierre

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Test Hole No. 71
SDGS Rotary Test Hole
Location: 96-64-18bbbb
Surface elevation: 1502 feet

0- 4	topsoil, black
4- 45	clay, brown
45- 55	clay, brown, very sandy and gravelly
55- 64	clay, brown, silty
64-153	clay, gray
153-170	shale, Pierre

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Test Hole No. 72
SDGS Rotary Test Hole
Location: 96-64-8dccc
Surface elevation: 1498 feet

0- 30	clay, brown
30- 35	clay, brown
35- 50	clay, brown
50-148	clay, gray
148-160	clay, gray, gravel stringers
160-203	clay, gray
203-254	gravel, coarse
254-260	chalk, Niobrara

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Test Hole No. 73
SDGS Auger Test Hole
Location: 96-65-19abba
Surface elevation: 1480 feet
(continued on next page)

Test Hole No. 73--continued

0- 2	topsoil
2-44	clay, moist, brown, few pebbles
44-59	clay, light brown, saturated
59-77	clay, gray
77-88	clay, with some gravel-size pebbles
88-	shale, Pierre

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Test Hole No. 74
SDGS Rotary Test Hole
Location: 96-65-20bbba
Surface elevation: 1425 feet

0- 10	clay, brown, sand
10- 28	clay, brown
28- 40	clay, gray
40- 51	clay, gray, with sand stringers
51- 60	sand and some gravel
60- 75	marl, Pierre
75-110	shale, Pierre

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Test Hole No. 75
SDGS Auger Test Hole
Location: 96-65-16cccc
Surface elevation: 1481 feet

0- 2	topsoil
2-24	clay, moist, brown, few pebbles
24-34	clay, brown, saturated
34-49	clay, with 20% medium coarse sand
49-54	clay, 25% fine-medium sand
54-59	clay, 50% medium sand
59-64	clay, gray
64-79	clay, gray
79-	shale, Pierre

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Test Hole No. 76
Corps of Engineers Test Hole
Location: 96-65-16c
Surface elevation: 1480.5 feet
(continued on next page)

Test Hole No. 76--continued

0- 58	clay, brown
58-105	Pierre Shale, undifferentiated
105-123	Pierre, Gregory Member, marl
123-157	Pierre, Sharon Springs Member, dark shale
157-224	Niobrara Chalk, Smoky Hill Member
224-297	Niobrara Chalk, Fort Hayes Member
297-317	Carlile Shale
317-375	Codell Sandstone
375-386	Carlile Shale

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Test Hole No. 77
SDGS Auger Test Hole
Location: 96-65-22aada
Surface elevation: 1730 feet

0- 1	topsoil
1-49	clay, moist, brown, some pebbles
49-59	clay, brown, saturated
59-74	clay, 10% medium sand
74-86	clay, gray
86-	shale, Pierre

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Test Hole No. 78
SDGS Auger Test Hole
Location: 96-65-13cccc
Surface elevation: 1660 feet

0- 1	topsoil, moist, brown-black
1- 24	clay, brown, few pebbles
24- 69	clay, gray, few pebbles
69-124	clay, gray, saturated, 10% fine sand

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Test Hole No. 79
SDGS Auger Test Hole
Location: 96-65-24abbb
Surface elevation: 1640 feet

0- 9	clay, brown, moist, few pebbles
9-29	sand pocket, 70% medium sand, saturated
29-64	clay, dark gray, 20% sand

(continued on next page)

Test Hole No. 79--continued

64- 99	clay, 10% fine sand
99-140	clay, gray, 20% fine sand
140-	no change

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Test Hole No. 80
SDGS Rotary Test Hole
Location: 96-64-19aaba
Surface elevation: 1518 feet

0- 30	clay, brown, sandy, taking water
30- 90	clay, gray, sandy, taking water
90-110	clay, gray, sandy and silt
110-203	clay, gray
203-230	gravel
230-235	clay, gray
235-250	clay, dark gray
250-260	chalk, Niobrara

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Test Hole No. 81
SDGS Auger Test Hole
Location: 96-65-29bbaa
Surface elevation: 1434 feet

0- 2	topsoil
2- 4	clay, brown, dry, some pebbles
4-14	clay, brown, moist, some pebbles
14-34	clay, brown, dry, some pebbles

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Test Hole No. 82
SDGS Auger Test Hole
Location: 96-65-20cdcd
Surface elevation: 1438 feet

0- 2	topsoil
2-39	clay, light brown, moist, many pebbles
39-49	clay, gray-brown, saturated
49-54	clay, gray, 10% medium sand
54-77	clay, gray, 10% sand
77	shale

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Test Hole No. 83
SDGS Auger Test Hole
Location: 96-65-27babb
Surface elevation: 1856 feet

0- 1	topsoil
1- 49	clay, brown, moist, some pebbles
49- 64	clay, brown, saturated, 10% medium sand
64-102	clay, gray, 10% medium sand
102-	shale, Pierre

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Test Hole No. 84
SDGS Auger Test Hole
Location: 96-65-23dddd
Surface elevation: 1785 feet

0- 2	topsoil
2- 19	clay, moist, light brown, some pebbles
19- 64	clay, dark brown, few pebbles
64- 99	clay, gray
99-107	clay, gray
107-	shale, Pierre

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Test Hole No. 85
Tom Bouza Farm Well
Location: 96-65-24cacc
Surface elevation: 1742 feet

0- 2	topsoil
2- 45	clay, yellow
45- 58	clay, blue
58- 60	sand
60- 95	clay, blue
95- 96	sand
96-101	shale, Pierre

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Test Hole No. 86
SDGS Auger Test Hole
Location: 96-65-25aaaa
Surface elevation: 1645 feet

0- 1	topsoil
1- 29	clay, moist, brown, many pebbles
29-105	clay, gray

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Test Hole No. 87
SDGS Rotary Test Hole
Location: 96-64-19dddc
Surface elevation: 1552 feet

0- 45	clay, brown
45-180	clay, gray, silty
180-185	shale, Pierre

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Test Hole No. 88
SDGS Rotary Test Hole
Location: 96-64-21cccc
Surface elevation: 1535 feet

0- 30	clay, buff to brown
30- 85	clay, gray
85- 95	clay, very silty and sandy stringers
95-155	clay, gray
155-165	clay, sandy and gravel stringers
165-280	clay, gray
280-285	clay, gray, silty and sandy
285-297	clay, gray
297-300	chalk, Niobrara

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Test Hole No. 89
SDGS Auger Test Hole
Location: 96-64-30daaa
Surface elevation: 1585 feet

0- 2	topsoil
2- 14	clay, moist, brown, some pebbles
14- 39	clay, saturated, brown
39- 49	clay, brown, 10% medium sand
49-104	clay, gray, 20% medium sand
104-140	clay, 10% fine sand, water flowing

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Test Hole No. 90
SDGS Auger Test Hole
Location: 96-64-31bbbc
Surface elevation: 1672 feet
(continued on next page)

Test Hole No. 90--continued

0- 1	topsoil
1-39	clay, brown, moist, few pebbles
39-59	clay, gray, moist
59-67	clay, gray, saturated, trace of sand
67-	shale, Pierre

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APPENDIX B

Records of Wells in the Lake Andes Area

Type of well: D, drilled; A, augered; Du, dug; B, bored
Character of material: o, outwash; ss, sandstone; s, sand
Use of water: D, domestic; S, stock; I, irrigation

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Character of Material	Use of Water
96-64-1c	M. Nesgaard		189	Glacial	o	D,S
96-64-2ab	E. Cuka	D	215	Glacial	o	D,S
96-64-3dc	R. Scott		183	Glacial	o	D,S
96-64-5ab	Novok		310	Codell		D,S
96-64-7aaaa	B. Weaver	D	370	Codell		D,S
96-64-8cbbb	Louis Dvorak	D	283	Glacial	o	S
96-64-8cddc	Doil Reinschmidt	D	240	Glacial	o	D,S
96-64-8dddd	Pat Leer	D	230	Glacial	o	D
96-64-10c	E. Weaver		200	Glacial	o	D,S
96-64-12ba	E. Havranek		189	Glacial	o	D,S
96-64-12dd	L. Andersh		208	Glacial	o	D,S
96-64-13bb	Buus		250	Codell ?		D,S
96-64-15cd	Kokesh	D	205	Glacial	o	D,S
96-64-15ba	E. Barkley	D	215	Glacial	o	S
96-64-16dd	Ed Clemens	D	185	Glacial	o	S
96-64-18adba	A. C. Morrow	D	200	Glacial	o	D,S
96-64-19aaba	Tom Soulek	D	248	Glacial	o	D
96-64-19bacc	Rudy Honomichl	D	450	Codell	ss	D,S

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geo-logic Source	Character of Material	Use of Water
96-64-20aaac	Ed Clemens	D	242	Glacial	o	D,S
96-64-24cb	Lebeda	D	242	Glacial	o	
96-64-29abba	Jim Mitchell	D	380	Codell	ss	D,S
96-64-30aaab	Walter Olsen	D	428	Codell	ss	D,S
96-64-35bb	G. Davis		240	Glacial	o	D,S
96-65-1bbbb	William Carda	D	175	Glacial	o	D,S
96-65-3aabb	Mrs. G. Hutchinson	D	140	Glacial	o	D,S
96-65-3ccca	Mrs. Emma Moneka	D	362	Codell	ss	D
96-65-3cccb	Henry Wilson	D	400	Codell	ss	D,S
96-65-5addd	Rudy Pavel	D	350	Codell	ss	D,S
96-65-5dcad	Ray Krokaugger	D	164	Glacial	o	D
96-65-7aadd	Albert Svatos	D	357	Codell	ss	D,S
96-65-7ddda	Emil Svatos	D	920	Dakota	ss	D,S
96-65-9bddd	William O'conner	D	385	Codell	ss	D,S
96-65-10bdbb	Ed Buxton	A	20	Glacial	o	D,S
96-65-10bddb	Tom Soulek	D	375	Codell	ss	D,S
96-65-10caaa	Vince Raymond	Du	40	Glacial	o	D,S
96-65-12dcbb	John Birger	D	400	Glacial	o	D,S
96-65-13abbd	James Birger		400	Codell	ss	D,S
96-65-13babd	James Dvorak	D	480	Codell	ss	D,S
96-65-14acaa	Carl Blair	D	480	Codell	ss	D,S
96-65-14bccc	Herman Flying Hawk	D	700	?	ss	

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geo-logic Source	Character of Material	Use of Water
96-65-16bcaa	Maple Young	D	390	Codell	ss	D
96-65-19dadc	Jim Soulek	D	140-45	Glacial	o	D,S
96-65-21ccaa	Herman Monek	D	920	Dakota	ss	S
96-65-23dcbb$_1$	James Dvorak	D	180	Glacial	o	S
96-65-23dcbb$_2$	James Dvorak	D	666	Codell	ss	D
96-65-24abaa	Ed Bouza	D	538	Codell	ss	D,S
96-65-24adcc	L. Pesicka	Du	28-30	Glacial	s	D,S
96-65-24cacc$_1$	Tom Bouza	D	101	Glacial	s	
96-65-24cacc$_2$	Tom Bouza	D	600	Codell	ss	D,S
96-65-27bdaa	Charlie Koupal	D	710	Codell	ss	D
96-65-26dddd	Eagle Horned	D	520	Codell	ss	D,S
96-65-29bacc	George A. Svatos	D	340	Codell	ss	D
96-65-29bbdd	George A. Svatos	D	840	Dakota	ss	S
96-65-33dbbd	Vern Bures	D	300	Codell	ss	S
96-65-35cacc	John Clarie	A	28	Glacial	s	D,S
96-65-35ccaa	H. L. Gasper	Du	40	Glacial	s	
96-65-36abbb	Albert Fuchs	Du	30	Glacial	o	S
96-66-2bddd	James Patocka	D	608	Codell	ss	S
96-66-2dbcb	William Soulek		635	Codell	ss	S
96-66-4abaa	Cleon Rolston	D	600	Codell	ss	S
96-66-10addc	Knute Aarhus	Du	85	Glacial	s	S

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geo-logic Source	Character of Material	Use of Water
96-66-14bbdd	Alvin Archambeau	D	630	Codell	ss	S
96-66-23bccc	John Patocka	D	577	Codell	ss	S
97-64-1d	C. Farke	D	193	Glacial	o	D,S
97-64-3d	A. Schroeder	D	240	Glacial	o	D,S
97-64-5a	Fryda	D	330	Codell		D,S
97-64-6ad	J. Uhlbrich	D	400	Codell		
97-64-9bb	D. Youngstrum		338	Codell		D,S
97-64-9d	Youngstrum	D	400	Codell		D,S
97-64-10c$_1$	D. McFarland	D	185	Glacial	o	D,S
97-64-10c$_2$	D. McFarland	D	206	Glacial	o	I
97-64-10d	R. Kietzman		190	Glacial	o	D,S
97-64-11d	R. Soulek		180	Glacial	o	D,S
97-64-12a	C. Fryda	D	180	Glacial	o	D,S
97-64-13d	E. Meyer	D	180	Glacial	o	D,S
97-64-15c	W. Banks	D	185	Glacial	o	D
97-64-17bbba	Jerry Soulek	D	110	Glacial	o	D
97-64-17ccbd	Gilbert Meyer	D	600	?	ss	D,S
97-64-17c	D. Linnell		180	Glacial	o	D,S
97-64-17cdcc	D. Linnell	D	325	Codell		
97-64-18aada	Fred Hughes	D	180	Glacial	o	D,S
97-64-19bbaa	Ralph Engel	D	135	Glacial	o	D,S

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geo-logic Source	Character of Material	Use of Water
97-64-21d	G. VonCollen		320	Codell		
97-64-24a$_1$	H. Johnson		165	Glacial	o	D,S
97-64-24a$_2$	P. Kreeger		180	Glacial	o	D,S
97-64-25d	G. VonCollen		160	Glacial	o	D,S
97-64-26d	A. Johnson		180	Glacial	o	D,S
97-64-27aaab	D. Hawley		180	Glacial	o	D,S
97-64-31cccc	Vincent Sejnoha	D	160	Glacial	o	D
97-64-32dcad	George Nielsen	D	325	Codell	ss	S
97-65-1abbd	Ed Krell	B	178	Glacial	o	I
97-65-8aada	Fyle Nelson	D	473	Codell	ss	D,S
97-65-8abbd	Dale Svatos	A	37	Glacial	o	D
97-65-8ccab	Dorothy Stluka	D	420	Codell	ss	D,S
97-65-9bbdd	Oscar Thompson	D	500	Codell	ss	D,S
97-65-11cccc	George Rezak	D	410	Codell	ss	D,S
97-65-12dcbd	Sam Steele	D	425	Codell	ss	D,S
97-65-13aaca$_1$	John Rezek	D	360	Codell	ss	S
97-65-13aaca$_2$	John Rezek	D	200	Glacial	o	S
97-65-13cbbc	Ed Kirchhevel	D	200	Glacial	o	D,S
97-65-15addd	Albert Jones	D	420	Codell	ss	D,S
97-65-17aadc	Tony Kisley	D	439	Codell	ss	D,S
97-65-17daca	Joe Kisley	A	92	Glacial	s	S

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geo-logic Source	Character of Material	Use of Water
97-65-18ccdd	Ralph M. Brooks	D	400	Codell	ss	D,S
97-65-20cdbb	Frank Petrik	D	420	Codell	ss	D,S
97-65-20cdba	J. H. Jensen	B	55	Glacial	s	S
97-65-21aaaa	Leo Kirasch	D	350	Glacial	o	S
97-65-21cbbb	Tony Kisley	D	480	Codell	ss	D,S
97-65-23dccd	Alvin Bare	D	374	Codell	ss	D,S
97-65-24acad	Ival Evans	D	295	Codell?	ss	D,S
97-65-24cbcc	Dale Newman	D	235	Glacial	o	D,S
97-65-24dcab	Mrs. Marie Baldwin	D	310	Codell	ss	D
97-65-26c	W. Jones	D	394	Codell		
97-65-27aaaa	George Hakl	D	380	Codell	ss	D,S
97-65-29bbcc	Joe Carda	D	424	Codell	ss	D,S
97-65-29adda	Marlin Walker	D	450	Codell?	ss	D,S
97-65-30cdbd	Robert R. Vesely	D	409	Codell	ss	D,S
97-65-30dbdc	Richard Vesely	D	400	Codell?	ss	D,S
97-65-31aaac	Frank F. Dvorak	D	390	Codell	ss	D,S
97-65-31cdab	Ken McBride	D	252	Glacial	o	S
97-65-31dddc	M. McBride	D	260	Glacial	o	S
97-65-32bbcc	William C. Sprick	D	391	Codell	ss	D,S
97-65-32ddda	Arnold Nelson	D	180	Glacial	o	D,S
97-65-33bccc	William Cihak	D	270	Codell	ss	

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geo-logic Source	Character of Material	Use of Water
97-65-33ccdd$_1$	Herbert Engel		30	Glacial	o	S
97-65-33ccdd$_2$	Herbert Engel		35	Glacial	o	S
97-65-34cbbb	E. Carda		410	Codell		
97-65-35bbcc	Joe Melmer	D	470	Codell	ss	D,S
97-66-10bcaa	Louise Dufek	D	498	Codell	ss	D,S
97-66-10cbcb	Joe Dolejsi	D	400	Codell	ss	D,S
97-66-11dcdd	James Rezek	A	60	Glacial	o	S
97-66-14aadd	Johanneson	D	470	Codell	ss	D,S
97-66-23bccb	Elmer Lawyer	D	280	Glacial	o	D,S
97-66-23dadd	Sevrt Johanneson	D	320	Glacial?	o?	D,S
97-66-34aaaa	Bob Myers	D	460	Codell?	ss	D,S
97-66-34bccc	Harlan Herkwan	D	400	Codell	ss	D,S