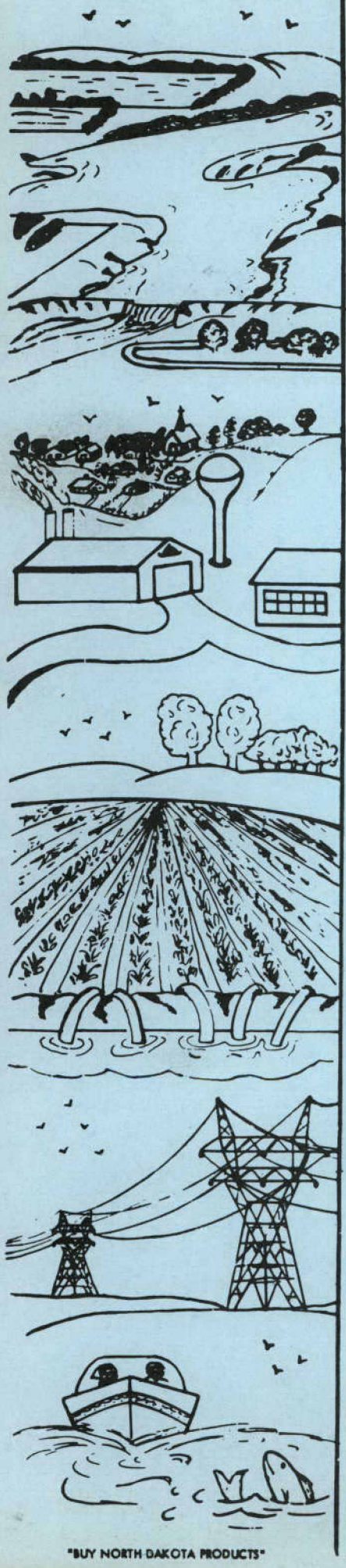


GROUND WATER IN THE ST. JOHN AREA ROLETTE COUNTY, NORTH DAKOTA

N.D.S.W.C. PROJECT NO. 798

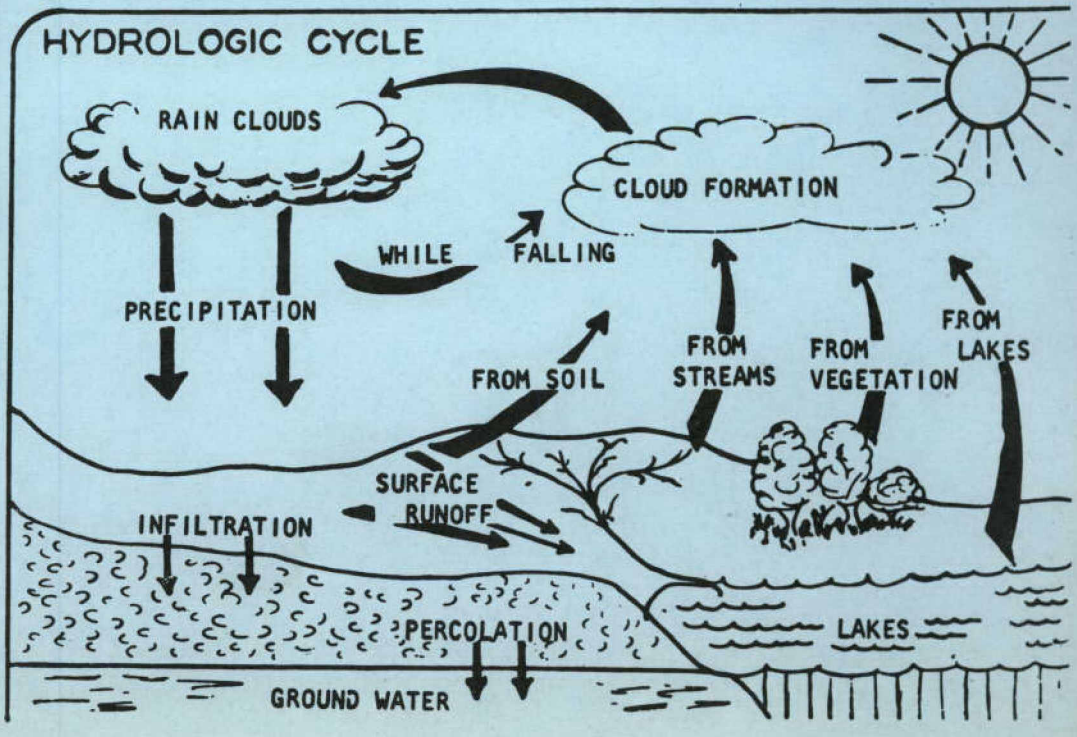
NORTH DAKOTA GROUND-WATER STUDY NO. 67

By

Larry L. Froelich, Geologist

Published by:
North Dakota State Water Commission
1301 State Capitol
Bismarck, North Dakota

- 1967 -



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INTRODUCTION

Purpose and Scope

At the request of the Village of St. John, the North Dakota State Water Commission, in June 1966, conducted a ground-water study of the St. John area. The purpose of the study was to locate a suitable municipal water supply for the Village.

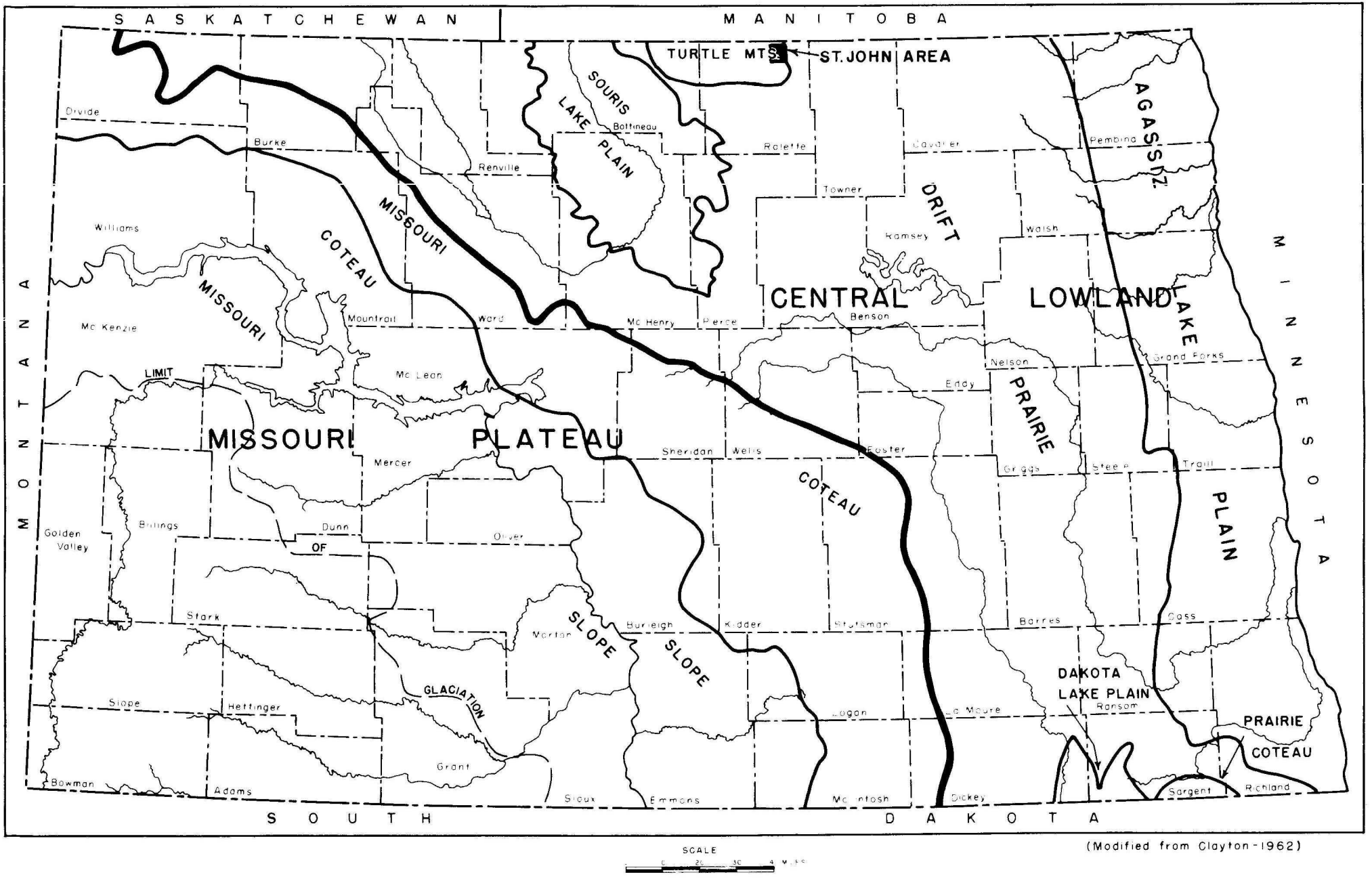
The ground-water study consisted of a selected well inventory, test drilling and observation well installation, chemical analyses of water samples for quality determination, a compilation of available existing data and preparation of this report.

The study was conducted by personnel of the State Water Commission under the supervision of the writer. Test drilling was done by Lewis Knutson and Hugh Jacobson using the State-owned hydraulic rotary drilling rig. Sample description and drilling supervision was performed by Clifford Beeks, Geologist. Chemical analyses were performed by Donald Delzer, Chemist.

Location and General Features

The St. John area, as described in this report, consists of 16 square miles in Township 163 North, Range 70 West in northeastern Rolette County. It is located in the Turtle Mountains and Drift Prairie Districts of the Central Lowland Physiographic Province of North Dakota as shown in Figure 1.

The Turtle Mountains physiographic district in the St. John area is characterized by rugged, heavily-forested topography interspersed with



(Modified from Clayton-1962)

FIGURE 1--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC PROVINCES AND LOCATION OF THE ST. JOHN AREA

numerous lakes and undrained depressions. Elevations range from 1970 feet to 2100 feet above mean sea level. Drainage is essentially non-integrated. Grasses in some of the depressions are mowed for hay during the summer and fall and occasional small tracts of land have been cleared for farmland.

The Drift Prairie is a level to undulating plain with local relief from 50 to 75 feet. Lakes, sloughs and potholes are common and usually connected with or drained by moderately well-integrated intermittant streams. The soil is very fertile and the land is extensively cultivated. Shrubs and trees are confined to drainage courses and lake shores.

The population of St. John in 1960 was 420. It is located 2 miles west of State Highway 30 and approximately $3\frac{1}{2}$ miles south of the United States-Canadian Boundary. It is served by a branch line of the Great Northern Railway. The average temperature in 1965 at Rolla, 6 miles southeast of St. John, was 36° F. (U. S. Department of Commerce, 1966). No departure from the average annual temperature was listed by the Weather Bureau. The lowest monthly average temperature was - .9° F. in January with July recording an average of 66.1° F. Total precipitation for 1965 was 21.61 inches. February received the least amount recording .02 inches while July was high with 6.73 inches. Average annual precipitation is about 17 inches.

Present Water Supply

Water supplies in St. John are presently limited to privately-owned wells and one city-owned public supply well from which water is carried to residences without a water system. The wells range in depth from less than 10 feet to approximately 200 feet. The quality of the water is generally poor.

Previous Investigations

A general study of Rolette County geology and ground-water resources was made by Simpson (1929, pp. 214-217, 296-297) in which he discusses the water-bearing strata of the county and includes a compilation of several water wells. Abbott and Voedisch (1938, pp. 74-75) included two chemical analyses from water wells in St. John in their study of municipal ground-water supplies.

Brookhart and Powell (1961, pp. 6-34) assembled data for a reconnaissance report on the ground-water and geology in the Rolla-St. John area. Test hole logs and other pertinent data are included in this report. Schmid (1964) discusses glacial geology, hydrology and water quality in his report on the Rolla area. Much of his narrative is applicable to the St. John area as well.

Well-numbering System

The well-numbering system used in this report and illustrated in Figure 2, is based on the location of the well or test hole in the Federal system of rectangular surveys of public lands. The first number denotes the township north and the second number denotes the range west, both referred to the fifth principal meridian and base line. The third number denotes the section in which the well is located. The letters a,b,c and d designate respectively the northeast, northwest, southwest and southeast quarter sections, quarter-quarter sections and quarter-quarter-quarter sections (10-acre tracts). Consecutive terminal numbers are added if more than one well is located in a 10-acre tract. Thus well 163-70-15daa would be located in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, SE$\frac{1}{4}$, Section 15, Township 163 North, Range 70 West.

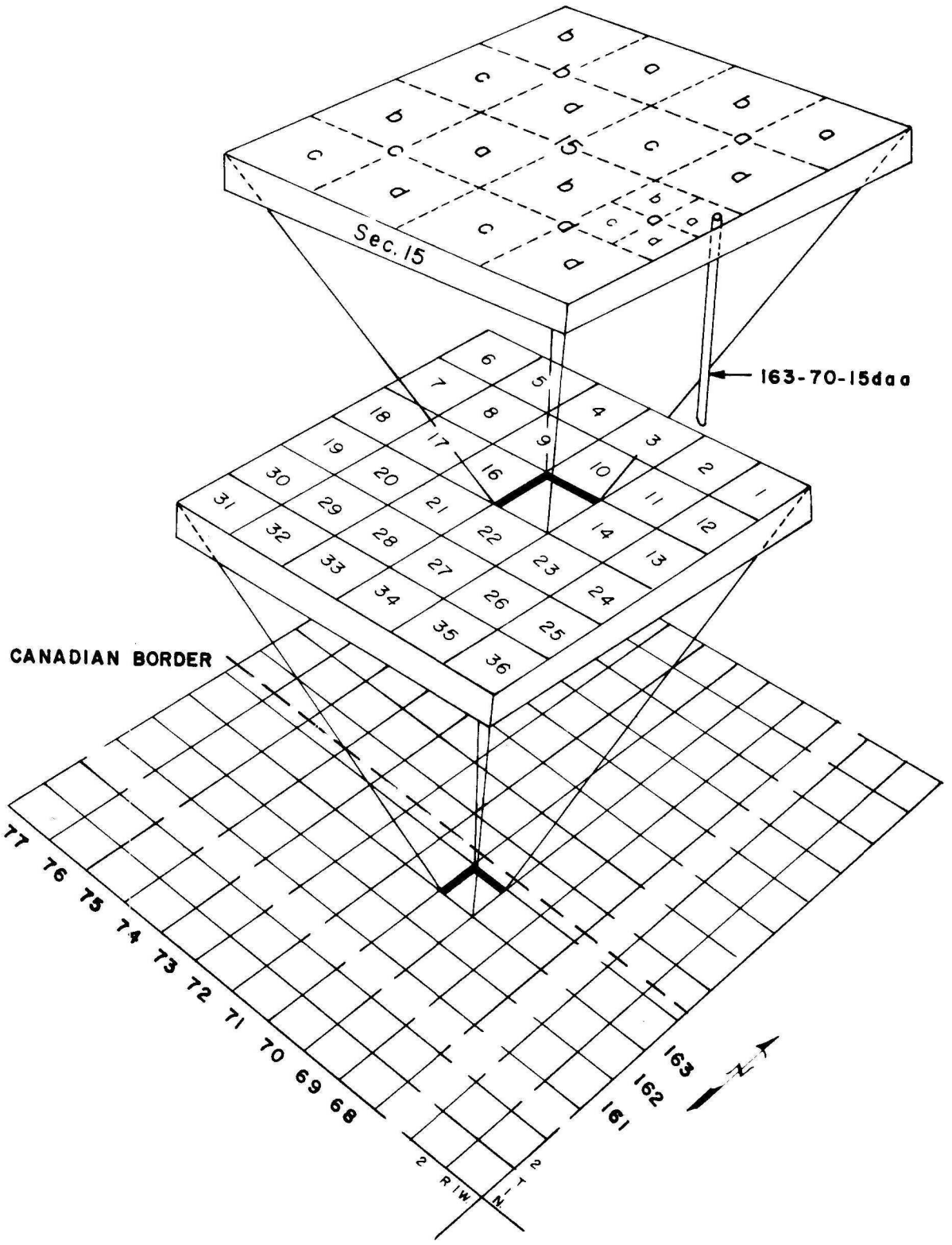


FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

GEOLOGY AND GROUND WATER OCCURRENCE

Contrary to the popular belief that ground water occurs in 'veins' or underground rivers and lakes, scientific investigations have proven that nearly everywhere, at varying depths, porous material composing the earth's crust is saturated with water. It is the geologic structure and composition of the material that determines whether water can be withdrawn in sufficient quantity for an intended purpose from a well penetrating the material. Because the occurrence of ground water is dependent upon geologic relationships, the geology and hydrology of any given area must be examined simultaneously to determine ground-water availability.

Bedrock

Surficial deposits in the St. John area consist of material, glacial drift, that accumulated during Pleistocene glaciation. The drift is underlain by more than 3,000 feet of consolidated sedimentary rocks collectively termed bedrock.

The bedrock formation immediately underlying the glacial drift in the St. John area is described as undifferentiated in this report. Schmid (1964, p. 7) also classified the bedrock sediments above the Pierre Shale in the Rolla area as undifferentiated, but suggested they may be correlative with the Paleocene Tongue River and Cannonball Formations and/or the Cretaceous Fox Hills Formation.

Test holes, completely penetrating the glacial drift, encountered sequences of shale, clay, silt and sand. This material, for the most part, was either grayish or greenish in color, noncalcareous, and more consolidated than the overlying drift. No significant sand sections were encountered nor was any shale noted that could be definitely ascribed to the Pierre Shale.

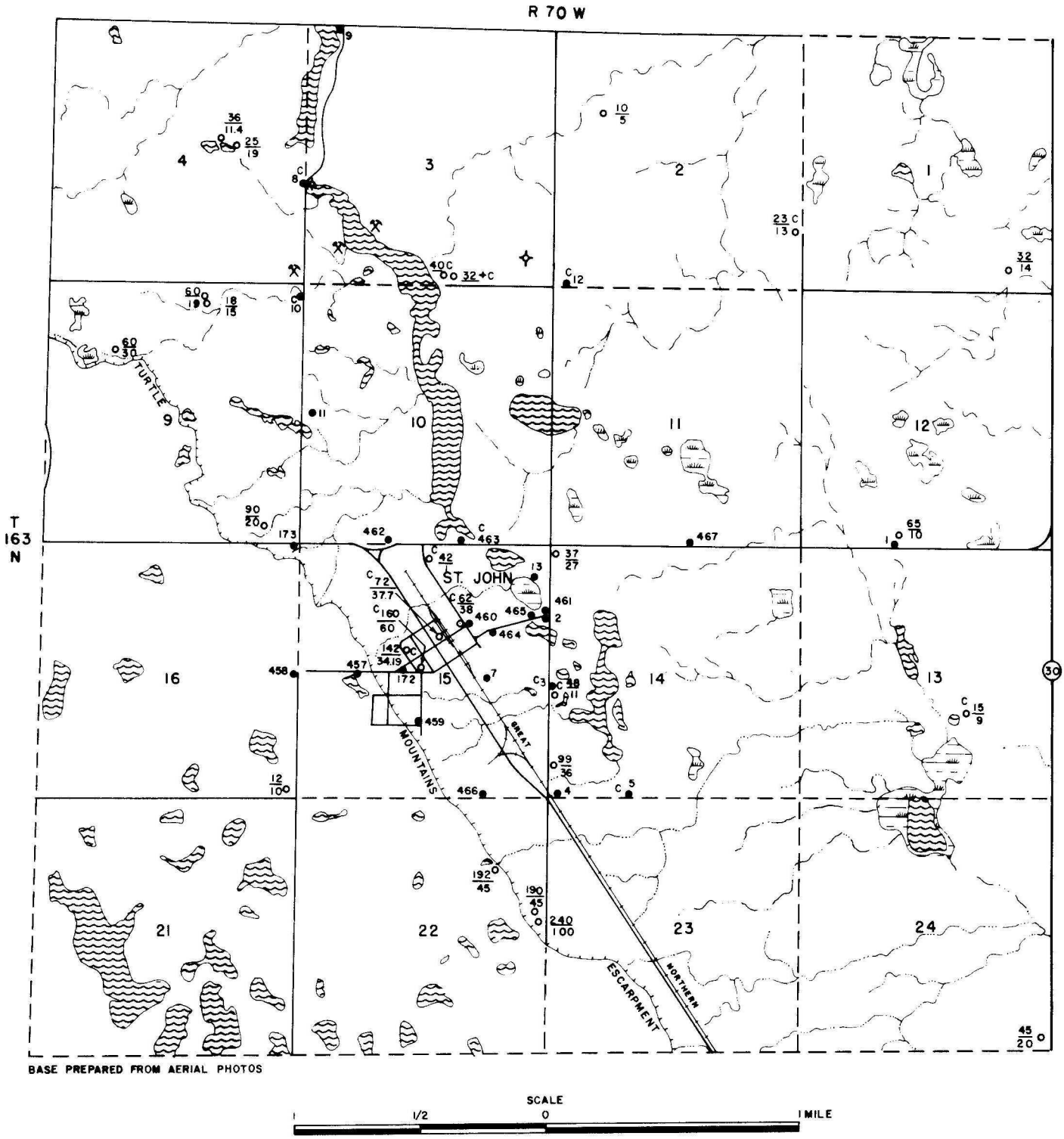


FIGURE 3--MAP OF THE ST. JOHN AREA SHOWING LOCATIONS OF SELECTED WELLS AND TEST HOLES

There are no known wells producing water from the undifferentiated bedrock section or from the Pierre Shale in the St. John area. Published literature and verbal reports by local residents indicate there is no history of deep bedrock wells encountering significant bedrock aquifers in the immediate area of St. John.

Glacial Drift

The glacial drift in the St. John area consists predominently of till. Till is a heterogeneous mixture of clay, silt, sand, gravel and boulders transported into the area and deposited directly by the ice with little or no sorting by running water. Essentially all till in the St. John area was derived from bedrock formations in Canada. There is little, if any, differentiation between the till in the Turtle Mountains and that in the Drift Prairie other than the topographic expression.

Minor constituents of the glacial drift are sorted sands and gravels deposited by meltwater streams and clays and silts deposited in bodies of standing water. Meltwater streams are generally confined to definite channels; however, during glaciation and the subsequent deterioration and melting of the ice, conditions are so variable that just about anything can happen, and it usually does. Sand and gravel can be deposited in lenses or pockets, in long narrow sinuous channels or in blanket-like features with large areal extent. It is often very difficult to determine the origin and depositional characteristics of a sand and gravel deposit on the basis of one, and sometimes several, test holes.

All the known water wells in the St. John area are developed in sand or gravel associated with glacial till. The wells range in depth from less than 10 feet to 240 feet. Nearly all well owners reported adequate water for ordinary domestic or stock use. All are low-capacity wells (less than 10 gallons per minute).

Of the 13 test holes drilled in connection with this survey, only five encountered sufficient thicknesses of saturated sand and gravel to be considered a potential source for a municipal water supply. Of these, only Test Hole 8 (163-70-4daa) and Test Hole 12 (163-70-2ccc) produced water chemically acceptable for a municipal supply.

Test Hole 8 was drilled adjacent to the dam creating the reservoir in Section 3 (See Figure 3). Sand and gravel were encountered from 31 to 96 feet. This material was extremely interbedded and contained lenses of silt and silty clay in the interval from 59 to 96 feet. It probably represents an alluvial deposit created by a meltwater stream flowing between the Turtle Mountains Escarpment and the glacier as the ice was receding. The water level in the observation well installed in the test hole was 6.79 feet below land surface on November 11, 1966.

Test Hole 12 encountered decidedly better sorted sand and gravel than Test Hole 8. The main aquifer was found in the depth interval from 28 to 53 feet. This material was probably deposited as outwash by several streams emerging from the ice front, depositing the sand and gravel and transporting the finer silt and clay to areas further south. Indications are this deposit may be continuous for $\frac{1}{2}$ mile or more in all directions from the site of the test hole. Much drilling fluid was lost while drilling this test hole indicating, by some authorities, a highly permeable material.

The water level in the observation well installed in the test hole was 5.39 feet below land surface on November 11, 1966.

WATER QUALITY

Ground water is derived primarily from rain and snowmelt. The amount and character of minerals dissolved by ground water depends upon the physical

and chemical composition of the rocks it contacts, the duration of contact, temperature, pressure, and gases and minerals already in solution.

The quality of water for a public supply is commonly evaluated in relation to standards of the United States Public Health Service for drinking water. Table 1 lists, in part, standards adopted by the Health Service.

TABLE 1 -- DRINKING WATER STANDARDS OF THE UNITED STATES PUBLIC HEALTH SERVICE

Iron (Fe)	.3 ppm(parts per million)
Magnesium (Mg)	125 ppm
Sulfate (SO_4)	250 ppm
Chloride (Cl)	250 ppm
Flouride (F)	1.5 ppm
Nitrate (NO_3)	45 ppm
Total dissolved solids	500 ppm

Table 2 lists sixteen chemical analyses of ground water and one of a water sample taken from the reservoir north of St. John. In general the quality of water is much better in the northern part of the St. John area than the southern part. With the exception of the Gustafson well (163-70-2dda) all wells sampled contained very hard water with excessive concentrations of sulfates and total dissolved solids. Nearly all contained excessive iron also.

Excessive iron is undesirable in a water supply because of the taste it imparts, its corrosion of plumbing fixtures and stains it leaves on laundry. Hardness is undesirable because of the increased soap consumption and formation of scale in cooking utensils, hot water heaters, boilers, etc. The effects of hardness are usually the same whether caused by carbonate or noncarbonate hardness. Iron and hardness can be economically removed by

TABLE 2 -- CHEMICAL ANALYSES

(analytical results in parts per million except as indicated)

Location	Depth of well (feet)	Aquifer	Date of Collection	(SiO_2)	(Fe)	(Ca)	(Mg)	(Na)	(K)	(HCO_3)	(CO_3)	(SO_4)	(Cl)	(F)	(NO_3)	(B)	Total dissolved Solids	Total Hardness as $CaCO_3$	Total Hardness noncarbonate	% Sodium	SAR	Specific conductance	pH
163-70-2ccc	40	Gravel	6-30-66	26	.5	148	57	73	7.1	459	0	368	6.3	.2	.2	.78	935	605	229	21	1.3	1,300	7.7
163-70-2dda	23	-	6-23-66	26	.1	74	41	6.3	2.0	380	0	21	8.0	.2	13	.43	394	353	42	4	.1	652	7.7
163-70-3cbb	Surface Water	-	9-28-66	30	.7	73	71	45	15	275	0	334	10	.3	1.9	.17	757	473	248	17	.9	1,030	8.0
163-70-3dcc$_1$	40	Sand	6-21-66	24	.06	145	96	23	5.1	440	0	296	26	.4	155	.74	988	757	397	6	.4	1,310	7.5
163-70-3dcc$_2$	32+	Sand	9-28-66	24	.11	225	199	31	5.5	696	0	370	132	.4	425	.07	1,740	1380	810	4.6	.4	2,460	8.0
163-70-4daa	75	Sand	6-28-66	27	1.5	157	57	119	7.2	477	0	447	21	.3	0	.9	1,080	626	235	29	2.1	1,510	7.7
163-70-9aaa	70	Gravel	6-30-66	26	4.8	242	94	111	11	431	0	863	9.9	.2	0	1.1	1,690	991	638	19	1.5	1,950	7.5
163-70-10dcd	247	-	2-27-52	-	4.8	172	98	255	-	261	-	1,000	26	-	130	-	1,820	832	618	41	-	-	7.9 1/
163-70-13dbd	15	Gravel	6-22-66	20	.18	210	115	80	7.7	439	0	698	53	.4	17	.82	1,510	998	639	15	1.1	1,830	7.6
163-70-14cbb	75	Gravel	6-22-66	25	.32	319	133	144	14	494	0	1,220	19	.2	0	1.1	2,120	1,340	939	19	1.7	2,470	7.5
163-70-14cbb	48	Sand	6-21-66	23	9.7	346	110	171	11	494	0	1,190	18	.1	0	1.2	2,120	1,320	912	22	2.1	2,470	7.4
163-70-14cdc	63	Gravel	6-24-66	26	4.0	381	122	113	13	466	0	1,280	16	.2	0	1.0	2,190	1,450	1,070	14	1.3	2,470	7.6
163-70-15abb	12	-	3-29-51	-	.4	276	288	152	-	718	-	1,480	29	.4	34	-	1,880	2,980	1,290	16	-	-	7.7 1/
163-70-15aca	62	-	10-4-51	-	7.7	484	182	127	-	540	-	1,710	18	-	-	-	3,070	1,960	1,520	13	-	-	8.2 1/
163-70-15acb	72	-	10-4-51	-	7.8	122	126	154	-	125	-	987	16	-	4.3	-	1,540	820	718	29	-	-	8.0 1/
163-70-15bdd$_1$	142	-	10-4-51	-	3.2	254	95	-	-	354	-	688	4	-	2.1	-	1,400	102	-	0	-	-	7.9 1/
163-70-15bdd$_3$	160	-	-	-	1.2	290	110	154	-	490	-	1,050	11	-	2.1	-	2,110	1,180	774	23	-	-	7.6 1/

1/ Brookhart and Powell, 1961

water treatment.

Present methods of removing sulfates and lowering dissolved solids are complicated and expensive. Sulfates are a major quality problem in the St. John area. Where the sulfate concentration exceeds 600 ppm, the water is generally reported as unfit for drinking by the well owners. The U. S. Public Health Service will allow water with up to 1000 ppm total dissolved solids to be used on common carriers if better water is not available. The human body can become accustomed to water containing up to 2000 ppm dissolved solids or more, but it is not recommended for a municipal supply.

By far the best quality of water in the St. John area, as indicated by the chemical analyses, is that found in the Gustafson well (163-70-2dda). The analysis of this water did show 13 ppm nitrates, however. Nitrates in ground water indicate contamination by sewage effluent or fertilizers. Concentrations over 45 ppm can cause or contribute to a condition in infants known as methemoglobinemia ("blue babies"). Excessive concentrations could be fatal to both humans and animals.

RECOMMENDATION

Past history of water wells and test holes in the St. John area indicate no significant bedrock aquifers within economical reach of a municipal water supply well. Sand and gravel deposits associated with glacial till supply all water wells in the area. These deposits, although generally capable of supplying adequate water for small demands, are highly variable in thickness and extent as indicated by test holes.

Quality of water is a serious problem in the St. John area, especially in the southern part. Only the Gustafson well contained water to meet the standards of the U. S. Public Health Service. Water from this well contains

some nitrates, but nitrates are highly variable within short distances as indicated by the Tinglestad wells (163-70-3dcc$_1$ and 2, (Table 3). Additional test drilling may locate similar water without nitrates in the immediate area of the Gustafson well.

Test Holes 8 and 12 encountered aquifers apparently capable of supplying the quantity of water needed for a municipal water supply. Chemical analyses indicate water from either of these locations would require softening and iron removal to be a satisfactory municipal water. Additional test drilling in the vicinity of these two test holes would help determine hydrologic characteristics of the aquifers, and perhaps better quality water could be located.

TABLE 3 -- RECORDS OF WELLS AND TEST HOLES

Depth to water: Measured water levels in feet and tenths or hundredths; reported water levels in feet.

Depth of well: Measured depths in feet and tenths; reported depths in feet.

Type of well: Dr, drilled; Du, dug; Bo, Bored

Use: D, domestic; U, unused; PS, public supply; S, stock; T, test hole; OT, oil test hole; O, observation well

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use	Aquifer	Remarks
163-70-1ddc	Herman Garceau	32	-	Dr	-	14	6- -49	S	-	Hard, unfit for drinking
163-70-2bca	O. Mathiason	10	-	Du	1919	5	7- -49	D,S	-	Medium hard, adequate
163-70-2ccc	Test Hole 12	40	1¼	Dr	6-29-66	5.39	10-11-66	O	Gravel	Chem. analysis, See log
163-70-2dda	LaVerne Gustafson	23	36	Du	1930	13	6- -49	D	-	Chem. analysis, adequate
163-70-3bbb	Test Hole 9	84	4 3/4	Dr	6-28-66	-	-	T	-	See log
163-70-3dcc$_1$	Melvin Tingelstad	32+	-	Dr	-	-	-	D	-	Chem. analysis
163-70-3dcc$_2$	Melvin Tingelstad	40	-	Dr	1920	-	-	S	-	Chem. analysis
163-70-3dd	S.D. Johnston-Melvin Tingelstad #1	2,825	8 5/8	Dr	5- -54	-	-	OT	-	See log
163-70-4ac	W. Lassonde	36	24	Dr	1908	11.4	7-18-51	-	-	Hard, adequate
163-70-4acd	-	25	-	Du	1941	19	7- -51	D,S	Sand	Hard, adequate
163-70-4daa	Test Hole 8	75	1¼	Dr	6-27-66	6.79	10-11-66	O	Sand	Chem. analysis, See log
163-70-9aaa	Test Hole 10	70	1¼	Dr	6-28-66	15.58	-	O	Gravel	Chem. analysis, See log

TABLE 3 -- RECORDS OF WELLS AND TEST HOLES (Cont.)

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use	Aquifer	Remarks
163-70-9abb$_1$	John Billgren	18	18	Du	1936	15	7- -51	D	Sand	Hard, adequate, good
163-70-9abb$_2$	John Billgren	60	4	Dr	1940	19	7- -51	S	Gravel	Hard, adequate
163-70-9bca	Ed Johnson	60	4	Dr	1929	30	7- -51	D,S	-	Medium Hard, adequate
163-70-9ddd	Jack Carries	90	-	Dr	-	20	6- -49	S	-	Hard, adequate, iron
163-70-10bcc	Test Hole 11	231	4 3/4	Dr	6-29-66	-	-	T	-	See log
163-70-10cdd	USGS Test Hole 462	232	5	Dr	8-28-51	-	-	T	-	See log
163-70-10dcd	USGS Test Hole 463	247	5	Dr	8-31-51	-	-	T	Gravel	Chem. analysis, See log
163-70-11dcc	USGS Test Hole 467	162	5	Dr	9-15-51	-	-	T	-	See log
163-70-12cd$_1$	E. Mathiason	65	-	Dr	-	10	6- -49	D,S	-	Hard, rusty, unfit for drinking
163-70-12cd$_2$	Test Hole 1	115½	4 3/4	Dr	6-21-66	-	-	T	-	See log
163-70-13dbd	Emile Foussard	15'	-	Du	1957	9	6-22-66	D	Sand	Chem. analysis
163-70-14bbb	Amie Des Roches	37	-	Du	1937	27	6- -49	D,S	-	Hard, adequate, rusty
163-70-14cbb$_1$	Amie Des Roches	48'	-	Bo	-	16	6-21-66	S	Sand	Chem. analysis
163-70-14cbb$_2$	Test Hole 3	75'	1¼	Dr	6-22-66	-	-	O, destroyed	Sand	Chem. analysis, See log
163-70-14ccb	W. Des Roches	99	-	Du	1928	36	6- -49	-	Gravel	-
163-70-14ccc	Test Hole 4	199½	4 3/4	Dr	6-23-66	-	-	T	-	See log
163-70-14cdc	Test Hole 5	63	1 1/4	Dr	6-23-66	11.16	10-11-66	O	Gravel	Chem. analysis, See log

TABLE 3 -- RECORDS OF WELLS AND TEST HOLES (Cont.)

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use	Aquifer	Remarks
163-70-15aa	Test Hole 13	136½	4 3/4	Dr	6-30-66	-	-	T		See log
163-70-15abb	C. Guedesse	12	42	Du	1945	1	4-22-49	D,S	Gravel	Chem. analysis
163-70-15aca$_1$	USGS Test Hole 460	280	5	Dr	8-17-51	-	-	T	-	See log
163-70-15aca$_2$	Mrs. P. Le Beau	62	-	Dr	-	38	7- -51	D	Gravel	Chem. analysis
163-70-15acb	City of St. John	72	4	Du	1935	37.7	7-11-51	PS	-	Chem. analysis
163-70-15ada$_1$	Test Hole 2	241½	4 3/4	Dr	6-21-66	-	-	T	-	See log
163-70-15ada$_2$	USGS Test Hole 465	140	5	Dr	9-11-51	-	-	T	-	See log
163-70-15ada$_3$	USGS Test Hole 461	203	5	Dr	8-22-51	-	-	T	-	See log
163-70-15adb	USGS Test Hole 464	200	5	Dr	9-10-51	-	-	T	-	See log
163-70-15bdd$_1$	Mrs. R. Byrnes	142	6	Dr	-	34.19	7-11-51	D	Sand	Chem. analysis
163-70-15bdd$_2$	USGS Test Hole 172	300	5	Dr	8-1-49	-	-	T	-	See log
163-70-15bdd$_3$	St. John School	160	4	Dr	1933	60	4- -49	D	-	Chem. analysis
163-70-15cab	USGS Test Hole 457	205	5	Dr	8-8-51	-	-	T	-	See log
163-70-15cad	USGS Test Hole 459	180	5	Dr	8-16-51	-	-	T	-	See log
163-70-15dba	Test Hole 7	210	4 3/4	Dr	6-27-66	-	-	T	-	See log
163-70-15dcd	USGS Test Hole 466	230	5	Dr	9-12-51	-	-	T	-	See log
163-70-16aaa	USGS Test Hole 173	305	5	Dr	8-4-49	-	-	T	-	See log
163-70-16daa	USGS Test Hole 458	280	5	Dr	8-13-51	-	-	T	-	See log
163-70-16ddd	Harmon Dillon	12	-	Du	1951	10	7- -51	D	-	Hard, inadequate
163-70-22adb	Harvey James	192	4	Dr	1941	45	7- -50	D,S	Gravel	Hard, rusty
163-70-22daa$_1$	A. Belgarde	190	4	Dr	-	45	7- -51	U	-	Hard, rusty
163-70-22daa$_2$	A. Belgarde	240	-	Dr	-	100	6- -49	D,S	-	Hard, rusty
163-70-24ddd	John Coghlen	45	30	Du	1929	20	6- -49	D,S	-	Hard, adequate

TABLE 4 -- LOGS OF TEST HOLES

163-70-2ccc
Test Hole 12

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Loam, sandy and silty, dusky brown, loose	1	1
	Gravel, fine to coarse, sandy, subangular and subrounded, mostly shale and limestone, rusty	3	4
	Clay, very silty with much sand and gravel, dusky yellow, oxidized; rough drilling (Till)	6	10
	Sand, fine and medium, clayey with gravel, olive gray; rough drilling(Till).	2	12
	Gravel, fine and medium with coarse sand, subangular to subrounded, mostly shale and limestone; drills fast	8	20
	Clay, silty to gravelly, olive gray; rough drilling because of large rocks, (Till)	8	28
	Gravel, fine and medium, well-sorted, subangular and subrounded; taking large amounts of water	12	40
	Gravel, as above, very sandy with occasional silt and very fine sandy clay lenses, moderately sorted; mixed 3 bags of drilling mud at 52 feet	13	53
	Clay, silty with some sand and gravel, olive gray to dark greenish gray; moderately rough drilling (Till)	5	58
	Sand, medium with lenses of fine sand and silt, gray; drills fast and easy.	16	74
	Clay, silty with sand grains and pebbles, moderately olive brown, cohesive, partially oxidized moderately smooth drilling (Till)	$20\frac{1}{2}$	$94\frac{1}{2}$

Electric Log to 50 Feet
Observation Well

163-70-3bbb
Test Hole 9

Glacial Drift:			
	Gravel, fine and medium, sandy, poorly sorted, rusty	2	2
	Clay, silty to very sandy with pebbles, dusky yellow, oxidized (Till)	10	12
	Till, as above, very gravelly, iron-stained	4	16

163-70-3bbb
Test Hole 9 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Clay, silty to sandy with pebbles and cobbles, olive gray (Till)	4	20
	Boulder, limestone	1	21
Undifferentiated:			
	Clay, silty, dusky yellow, soft, non-calcareous	10	31
	Sand, fine, silty, dusky yellow, soft	11	42
	Sand, fine, silt and silty clay, all interbedded, dusky yellow to moderately olive brown to dark greenish gray, soft; noncalcareous; drills easy but fairly tight	42	84

Electric Log

163-70-3dd
S.D. Johnston-Melvin Tingelstad #1
North Dakota Geological Survey Circular Number 127

Undifferentiated:			
	Samples missing	346	346
	Shale, medium gray, massive, compact, earthy, micro-micaceous	119	465
	Samples missing	153	618
	Shale, medium gray, massive, compact, resinous, micro-micaceous	178	796
	Samples missing	669	1465

Partial log - total depth 2,825 feet
Electric and gamma ray logs from 330 to 2,821 feet
Formation tops determined from samples and electric log
Not all tops determined

163-70-4daa
Test Hole 8

Glacial Drift:			
	Clay, silty, dusky yellow, soft, cohesive, moderately plastic, oxidized(Till) . . .	10	10
	Clay, silty with sand and gravel, olive gray, unoxidized (Till)	4	14
	Gravel, sandy, moderately sorted, sub-angular to subrounded; large percentage of shale pebbles	6	20
	Clay, silty with sand, gravel and boulders, olive gray, cohesive; rough drilling (Till)	5	25

163-70-4daa
Test Hole 8 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Gravel, silty to sandy, poorly sorted, subangular to subrounded, many shale pebbles and lignite fragments	6	31
	Sand, medium to coarse with lenses of fine to medium gravel, moderately sorted, subangular to subrounded; drills fast. .	19	50
	Sand, coarse with fine gravel, moderately well-sorted, subangular and subrounded. .	9	59
	Sand, fine to coarse with occasional lenses of silt and silty clay, interbedded; easy drilling	37	96
	Clay, silty to sandy, olive gray, interbedded lenses; easy drilling	5	101
	Gravel, fine to coarse, poorly sorted, subangular to subrounded, rough drilling .	3	104
	Clay, silty with pebbles and cobbles, olive gray, moderately soft, cohesive; drills tight and rough	6	110
	Clay, silty, olive gray, cohesive, plastic	16	126

Electric Log to 82 Feet
Observation Well

163-70-9aaa
Test Hole 10

Glacial Drift:			
	Silt, clayey, dusky brown, soft	1	1
	Clay, silty with occasional sand and gravel, dusky yellow, cohesive, oxidized (Till)	15	16
	Clay, silty with sand grains and pebbles, olive gray, moderately soft, cohesive (Till)	5	21
	Clay, silty with occasional sand, gravel and cobbles, dusky yellow to moderate olive brown, cohesive, oxidized (Till)	10	31
	Clay, silty to sandy with pebbles and occasional cobbles and boulders, olive gray, moderately soft, cohesive(Till). .	20	51
	Gravel, fine and medium, subangular and subrounded, moderately well-sorted. .	10	61
	Gravel, fine to coarse with lenses of sand, silt and silty clay, interbedded, poorly sorted, 'dirty'; mixed 3 bags of drilling mud at 65 feet and 3 bags at 70'	13	74

163-70-9aaa
Test Hole 10 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Clay, silty with sand grains, pebbles, cobbles, and boulders, olive gray, moderately soft, cohesive; rough drilling (Till)	10	84

Electric Log
Observation Well

163-70-10bcc
Test Hole 11

Glacial Drift:			
	Silt, clayey, dusky brown	1	1
	Clay, silty with sand grains and pebbles, dusky yellow, calcareous, oxidized (Till)	18	19
	Clay, silty with sand grains and pebbles, olive gray, soft, cohesive (Till)	24	43
	Sand, coarse with fine gravel, moderately well-sorted, subangular to subrounded, mostly limestone and shale particles	11	54
	Clay, silty, varigated-predominently pale olive and moderate yellow, cohesive, tight, calcareous, oxidized (Till)	6	60
	Clay, silty and sandy, dusky yellow to moderate olive brown, cohesive, oxidized (Till)	13	73
	Clay, silty to sandy with pebbles, cobbles, and occasional lenses of sand and gravel, olive gray, moderately soft, cohesive; drills good (Till)	54	127
	Clay, silty with sand grains and pebbles, dusky yellow to moderate olive brown, moderately soft, cohesive, tight, oxidized (Till)	11	138
	Clay, silty with sand grains and pebbles, olive gray, moderately soft to slightly hard, very cohesive and tight (Till). .	21	159
	Clay, silty to sandy with pebbles, cobbles, and lenses of sand and gravel, olive gray, moderately soft, cohesive; moderately rough drilling (Till)	43	202
	Gravel, sandy, layered, moderately well sorted, subangular to subrounded; drills rough	10	212

163-70-10bcc
Test Hole 11 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Undifferentiated:	Clay, silty, light olive gray to olive gray, brittle, slightly calcareous, tight	19	231

Electric Log

163-70-10cdd
U.S.G.S. Test Hole 462

Glacial Drift:	Topsoil, black	1	1
	Clay, sandy to gravelly, light brown (Till)	24	25
	Clay, sandy to gravelly, gray(Till). .	21	46
	Clay, sandy to gravelly, light brown (Till)	28	74
	Clay, sandy to gravelly, gray(Till). .	62	136
	Gravel, fine to medium, clayey	2	138
	Clay, very coarse sand and fine gravel, gray (Till)	80	218
	Clay, sandy with fine gravel, gray brown	14	232

No Electric Log

163-70-10dcd
U.S.G.S. Test Hole 463

Glacial Drift:	Topsoil, black	2	2
	Clay, sandy with fine to medium gravel, light brown (Till)	16	18
	Clay, sandy with fine to medium gravel, gray (Till)	49	67
	Gravel, fine to medium with medium to very coarse sand	8	75
	Gravel, medium	15	90
	Gravel, coarse	10	100
	Clay, sandy with fine to medium gravel, gray (Till)	20	120
	Clay, sandy with fine to medium shale gravel, gray (Till)	105	225
Undifferentiated:	Shale, gray	22	247

No Electric Log

163-70-11dcc
U.S.G.S. Test Hole 467

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, black	2	2
	Sand, coarse with fine gravel, light brown	2	4
	Clay, sandy with fine to medium gravel, light brown (Till)	12	16
	Clay, sandy with fine to medium gravel, gray (Till)	36	52
	Clay, sandy with medium gravel, light brown (Till)	25	77
	Sand, coarse with fine gravel, light brown	3	80
	Clay, sandy with fine to medium gravel, gray (Till)	40	120
	Clay, very coarse sand and fine to medium gravel (Till)	42	162

No Electric Log

163-70-12cd
Test Hole 1

Glacial Drift:			
	Clay, silty, dusky brown	2	2
	Clay, silty with lenses of sand and gravel, dusky yellow, oxidized(Till). .	18	20
	Clay, sandy with pebbles and gravel, olive gray, moderately cohesive(Till) .	6	26
	Clay, silty with sand grains and pebbles, dusky yellow to light olive gray, cohesive (Till)	12	38
	Clay, silty with sand, pebbles, cobbles and occasional boulders, olive gray, moderately soft, cohesive; rough drilling (Till)	34	72
	Sand, fine to coarse with gravel, poorly sorted, subangular to subrounded .	4	76
	Clay, silty with numerous sand and gravel lenses, olive gray; moderately rough drilling (Till)	14	90
Undifferentiated:			
	Shale, silty to sandy with beds of silt and loose very fine to fine sand, light olive gray to greenish gray, loose to slightly hard, friable to brittle; drills tight	$25\frac{1}{2}$	$115\frac{1}{2}$

Electric Log

163-70-14cbb
Test Hole 3

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Silt, clayey, dusky brown, slightly cohesive	2	2
	Clay, silty with sand grains, pebbles and occasional cobbles, dusky yellow to moderate olive brown, soft, moderately cohesive, oxidized (Till)	15	17
	Clay, silty with sand grains, pebbles, and occasional cobbles and sand lenses, olive gray, moderately soft (Till) . .	24	41
	Gravel, fine to medium with some coarse sand, moderately well-sorted, subangular to subrounded, moderately rough drilling	3	44
	Clay, silty, olive gray, soft, smooth. .	2	46
	Gravel, coarse, poorly sorted, rough drilling	3	49
	Clay, silty to sandy with pebbles and cobbles, olive gray, moderately soft, cohesive, tight (Till)	15	64
	Gravel, fine to coarse with beds of medium to very coarse sand, poorly sorted, interbedded; rough drilling, taking water; used 2 bags of drilling mud at 72 feet	16	80
	Clay, silty with sand, pebbles and occasional cobbles or boulders, olive gray, cohesive, tight (Till)	25	105

Electric Log to 77 Feet
Observation Well

163-70-14ccc
Test Hole 4

Glacial Drift:			
	Silt, clayey to pebbly, dusky brown. .	1	1
	Clay, silty with sand grains, pebbles and occasional cobbles, dusky yellow, soft, moderately cohesive, oxidized (Till)	14	15
	Till, as above, moderate olive brown	14	29
	Clay, silty with sand grains, pebbles, cobbles and occasional boulders, olive gray, moderately soft (Till)	32	61
	Clay, silty to sandy with numerous sand and gravel lenses, moderate olive brown to olive gray; very rough drilling (Till)	15	76

163-70-14ccc
Test Hole 4 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Gravel, fine to coarse, poorly sorted; rough drilling	6	82
	Clay, silty to sandy with gravel, olive gray, moderately soft, tight(Till) . .	7	89
	Gravel, fine to very coarse, sandy with possible clay layers, poorly sorted, 'dirty'; rough drilling	11	100
	Clay, silty to sandy with lenses of gravel, olive gray; rough drilling (Till)	13	113
	Clay, silty to sandy with pebbles and occasional cobbles or boulders, olive gray, moderately soft to slightly hard, tight (Till)	13	126
	Till, as above, with layers of fine to coarse; rough drilling gravel	18	144
	Clay, silty with sand grains and pebbles, olive gray, tight (Till)	7	151
	Clay, silty, olive gray, soft, plastic, tight	11	162
	Clay, silty to sandy with lenses of sand and gravel, olive gray; moderately rough drilling (Till)	16	178
Undifferentiated:	Silt and very fine to fine sand, olive gray to dark greenish gray, slightly brittle, moncalcareous, tight.	21½	199½

Electric Log

163-70-14cdc
Test Hole 5

Glacial Drift:	Silt, clayey, dusky brown, slightly cohesive	2	2
	Clay, silty with sand grains and pebbles, dusky yellow to moderate olive brown, iron-stained, oxidized(Till). .	16	18
	Clay, silty with sand grains and pebbles, olive gray, soft to moderately soft, tight	18	36
	Gravel, fine to coarse, clayey to sandy, poorly sorted, angular to subrounded, rough drilling	6	42
	Silt, clayey, light olive gray to sand, fine, olive gray to clay interbedded with silt and fine sand, soft; easy drilling .	13	55

163-70-14cdc
Test Hole 5 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Gravel, fine to coarse, sandy, poorly sorted, subangular to subrounded; drills rough	10	65
	Clay, silty with sand grains, pebbles, and occasional cobbles, olive gray, tight (Till)	29½	94½

Electric Log to 69 Feet
Observation Well

163-70-15aaa
Test Hole 13

Glacial Drift:	Silt, clayey, dusky brown	1	1
	Clay, silty and sandy, yellowish gray to dusky yellow, oxidized (Till). . .	10	11
	Clay, silty with sand grains, pebbles, and occasional cobbles, olive gray, moderately soft, cohesive (Till). . .	14	25
	Till, as above, with lenses of fine to medium sand	11	36
	Clay, silty to sandy with pebbles, cobbles, and occasional sand and gravel, olive gray, moderately soft; variable drilling (Till)	63	99
	Gravel, fine to very coarse, sandy, poorly sorted, subangular to subrounded, very shaley; rough drilling	4	103
	Clay, silty with sand grains, pebbles and occasional cobbles or boulders, olive gray, moderately soft to slightly hard, tight (Till)	16	119
Undifferentiated:	Silt, clayey to sandy, light olive gray to olive gray, moderately brittle, noncalcareous, tight	17½	136½

Electric Log

163-70-15aca
U.S.G.S. Test Hole 460

	Roadfill	2	2
Glacial Drift:	Clay, sandy with fine gravel, light brown (Till)	8	10

163-70-15aca
U.S.G.S. Test Hole 460 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Sand, fine to very coarse, silty and clayey, light brown	17	27
	Sand, very coarse, clayey to fine gravel, gray, many shale particles.	13	40
	Clay, very sandy with fine to medium gravel, gray (Till)	14	54
	Clay, sandy with fine to medium gravel, gray brown (Till)	10	64
	Clay, sandy with fine to medium gravel, gray (Till)	52	116
	Clay, sandy with fine to medium gravel, gray brown (Till)	21	137
	Clay, sandy with fine to medium gravel, gray (Till)	41	178
	Clay, very sandy with fine gravel, gray (Till)	87	265
Undifferentiated:			
	Shale, gray	15	280

No Electric Log

163-70-15ada$_1$
Test Hole 2

Glacial Drift:			
	Silt, clayey, dusky brown	1	1
	Clay, silty with sand grains and pebbles, dusky yellow, slightly calcareous, oxidized; drills easy(Till).	16	17
	Clay, silty with sand grains and pebbles, olive gray, moderately soft (Till)	14	31
	Clay, sandy with pebbles and cobbles and lenses of fine to coarse sand and fine to coarse gravel, poorly sorted	20	51
	Boulder, granite	1	52
	Clay, silty to sandy, olive gray, soft, slightly gritty, moderately plastic	9	61
	Sand, fine, well-sorted, olive gray	5	66
	Silt, clayey, smooth and plastic with occasional sand grains and pebbles to sandy, moderately plastic with occasional pebbles, olive gray, soft (Till)	18	84
	Clay, sandy with pebbles, occasional cobbles and streaks of sand and gravel, olive gray, soft to moderately soft; easy drilling (Till)	20	104
	Clay, silty with sand grains and pebbles, olive gray, moderately soft, tight(Till).	19	123

163-70-15ada$_1$
Test Hole 2 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Clay, sandy to gravelly, olive gray, moderately soft, moderately rough drilling (Till)	13	136
Undifferentiated:	Sand, very fine to fine with interbedded thin siltstone and shale layers, sand is light greenish gray, moderately friable. Silt and shale vary from light olive gray to olive gray; drills tight	14	150
	Sand, silt and shale, as above, interbedded in layers generally from two to four feet thick, varigated green and gray tones with occasional streaks of brownish black carbonaceous material, micaceous, noncalcareous; tight drilling	91½	241½

Electric Log

163-70-15ada$_2$
U.S.G.S. Test Hole 465

Glacial Drift:	Topsoil, black	1	1
	Clay, very sandy with fine gravel, light gray (Till)	3	4
	Clay, sandy with fine to medium gravel, light brown (Till)	9	13
	Clay, sandy with fine to medium gravel, gray (Till)	22	35
	Clay, very sandy with fine to medium gravel, gray (Till)	27	62
	Sand, medium to very coarse, clayey to gravelly, gray	8	70
	Sand, very coarse with fine gravel . . .	12	82
	Sand, very coarse, clayey to gravelly, gray	11	93
	Gravel, fine with very coarse sand . . .	7	100
	Clay, very sandy with fine gravel, gray	5	105
	Gravel, fine to coarse	16	121
	Clay, very sandy with fine to medium gravel, gray	19	140

No Electric Log

163-70-15ada$_3$
U.S.G.S. Test Hole 461

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, black	1	1
	Sand, very fine to coarse, clayey, light brown	19	20
	Sand, medium to coarse, clayey and silty, gray	25	45
	Sand, medium to very coarse, clayey to fine gravel, gray	17	62
	Clay, sandy with fine gravel, gray (Till)	52	114
	Gravel, fine with coarse sand and clay	12	126
	Clay, sandy with fine gravel, gray (Till)	34	160
	Clay, very sandy with fine to medium gravel, gray	28	188
Undifferentiated:			
	Shale, gray	15	203

No Electric Log

163-70-15adb
U.S.G.S. Test Hole 464

Glacial Drift:			
	Topsoil, black	1	1
	Clay, sandy with fine to medium gravel, light brown (Till)	21	22
	Clay, sandy with fine to medium gravel, gray (Till)	56	78
	Clay, sandy with fine to medium gravel, gray brown (Till)	10	88
	Clay, sandy with fine to medium gravel, gray (Till)	17	105
	Clay, sandy with fine to medium gravel, light brown (Till)	17	122
	Clay, sandy with fine to medium gravel, gray (Till)	56	178
Undifferentiated:			
	Shale, gray	22	200

No Electric Log

163-70-15bdd
U.S.G.S. Test Hole 172

Glacial Drift:			
	Topsoil, black	2	2
	Clay, sandy with fine gravel, light brown (Till)	19	21

163-70-15bdd
U.S.G.S. Test Hole 172 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Clay, sandy with fine to medium gravel, gray (Till)	45	66
	Sand, very coarse, clayey to fine gravel, gray	11	77
	Clay, sandy with fine to medium gravel, gray (Till)	49	126
	Clay, sandy with fine to medium gravel, light brown (Till)	23	149
	Clay, sandy with fine to medium gravel, gray (Till)	41	190
Undifferentiated:	Clay, very coarse sand and fine gravel, gray; could be either till or bedrock	110	300

163-70-15cab
U.S.G.S. Test Hole 457

Glacial Drift:	Clay, sandy with fine gravel, light brown (Till)	23	23
	Clay, sandy with fine to medium gravel, gray (Till)	12	35
	Sand, very coarse, clayey to fine gravel, gray	2	37
	Clay, sandy with fine to medium gravel, gray (Till)	56	93
	Clay, sandy with fine to medium gravel, light brown (Till)	12	105
	Clay, sandy with fine to medium gravel, gray (Till)	52	157
	Sand, medium to very coarse, clayey to fine gravel, gray	4	161
	Clay, sandy with fine to medium gravel, gray (Till)	22	183
	Sand, medium to very coarse, clayey to fine gravel, gray	2	185
Undifferentiated:	Clay, sandy with fine gravel and abundant shale fragments, gray brown; could be either bedrock or till	20	205

No Electric Log

163-70-15cad
U.S.G.S. Test Hole 459

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, black	1	1
	Clay, sandy with fine to medium gravel, light brown (Till)	15	16
	Clay, sandy with fine to medium gravel, gray (Till)	51	67
	Clay, sandy with fine to medium gravel, light brown (Till)	17	84
	Clay, sandy with fine to medium gravel, gray (Till)	54	138
	Clay, very sandy with fine gravel, light brown (Till)	18	156
	Clay, sandy with fine to medium gravel, gray (Till)	15	171
Undifferentiated:			
	Shale, gray	9	180

No Electric Log

163-70-15dba
Test Hole 7

Glacial Drift:			
	Silt, clayey, dusky brown	1	1
	Clay, silty with sand grains and pebbles, dusky yellow to moderate olive brown, soft, moderately cohesive, oxidized (Till)	31	32
	Clay, silty with sand grains, pebbles and occasional cobbles or boulders, olive gray, soft (Till)	15	47
	Gravel, fine and medium with lenses of sand and silty clay, interbedded, sub-angular to subrounded	9	56
	Clay, silty to sandy with pebbles, moderate olive brown to grayish olive, moderately soft, tight, oxidized(Till).	19	75
	Gravel, fine and medium, sandy	2	77
	Clay, silty to sandy with pebbles and occasional lenses of sand and gravel, olive gray, moderately soft, tight (Till)	53	130
	Till, as above, with numerous lenses of gravel; moderately rough drilling . .	48	178
	Sand, medium to coarse, some gravel, highly lignitic, moderately well-sorted, silty streaks; easy drilling	10	188

163-70-15dba
Test Hole 7 (Cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Undifferentiated:	Shale, silty to sandy, light greenish gray to light olive gray, moderately brittle, noncalcareous, tight	22	210

Electric Log

163-70-15dcd
U.S.G.S. Test Hole 466

Glacial Drift:	Topsoil, black	2	2
	Clay, sandy with fine to medium gravel, light brown (Till)	27	29
	Clay, sandy with fine to medium gravel, gray (Till)	93	122
	Clay, sandy with fine gravel, gray brown (Till)	11	133
	Clay, sandy with fine gravel, light gray (Till)	1	134
	Clay, sandy with fine gravel, gray brown (Till)	24	158
	Clay, sandy with fine to medium gravel, gray, (Till)	58	216
Undifferentiated:	Shale, gray		

No Electric Log

163-70-16aaa
U.S.G.S. Test Hole 173

Glacial Drift:	Topsoil, black	2	2
	Clay, sandy with fine to medium gravel, light brown (Till)	33	35
	Clay, sandy with fine to medium gravel, gray (Till)	159	194
	Clay, sandy with fine to medium gravel, light gray (Till)	16	210
Undifferentiated:	Clay, sandy and fine gravel, gray; could be till or bedrock	80	290
	Shale, gray	15	305

No Electric Log

163-70-16daa
U.S.G.S. Test Hole 458

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, black	1	1
	Clay, sandy and fine gravel, light brown (Till)	26	27
	Clay, sandy with fine to medium gravel, gray (Till)	100	127
	Clay, sandy with fine to medium gravel, light brown (Till)	31	158
	Clay, sandy with fine to medium gravel, gray (Till)	103	261
Undifferentiated:			
	Clay, very sandy with fine gravel and abundant shale fragments, gray; could be till or bedrock	19	280

No Electric Log

REFERENCES

Abbott, G. A. and Voedisch, F. W., 1938, The municipal ground-water supplies of North Dakota: No. Dak. Geol. Survey Bull. 11, pp. 74-75.

Brookhart, J. W. and Powell, J. E., 1961, Reconnaissance of geology and ground water of selected areas in North Dakota: No. Dak. Ground-Water Studies No. 28, pp. 6-34.

Clayton, Lee, 1962, Glacial geology of Logan and McIntosh Counties, North Dakota: No. Dak. Geol. Survey Bull. 37, p. 10.

Schmid, R. W., 1964, Ground water in the Rolla area, Rolette County, North Dakota: No. Dak. Ground-Water Studies 57, 47 p.

Simpson, H. E., 1929, Geology and ground- water resources of North Dakota: U. S. Geol. Survey Water Supply Paper 598, pp. 214-217, 296-297.

United States Department of Commerce, 1965, Climatological data (of) North Dakota: U. S. Dept. of Comm., Weather Bureau, Annual Summary 1965, v. 73, no. 13, pp. 196 and 198.