HATTON WATER SUPPLY SURVEY

STEELE, TRAILL, AND

GRAND FORKS COUNTIES, NORTH DAKOTA

N.D.S.W.C. PROJECT NO. 762

NORTH DAKOTA GROUND-WATER STUDIES

NO. 66

By

Clifford H. Beeks Jr.

Ground - Water Geologist

Published By

North Dakota State Water Commission

1301 State Capitol

Bismarck, North Dakota

- 1967 -

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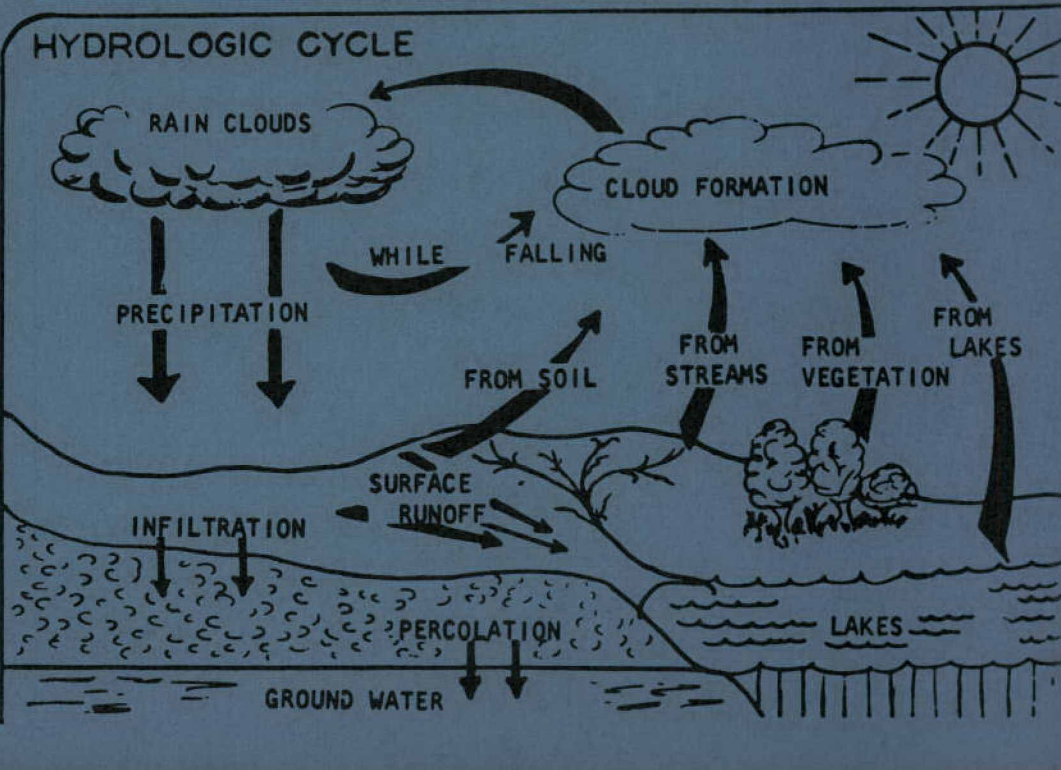

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INTRODUCTION

Purpose and Scope

In December 1964, the City of Hatton requested a supplementary ground-water investigation. Purpose of the investigation was to locate additional water supplies to supplement the Hatton municipal supply which is being depleted. A previous study (Adolphson, 1962) failed to locate substantial quantities of water.

Field work for the investigation began in May 1965 and consisted of a selected well inventory, test drilling, observation well installation, chemical analyses of water samples for quality determination and compiling of available existing data.

The study was under the supervision of Milton O. Lindvig, Ground-Water Engineer. Sample description logs were written by Alain Kahil, State Water Commission Geologist. The test drilling was done by Lewis Knutson and Jim Haman using the state-owned hydraulic rotary drilling rig. Chemical analyses were performed by Donald Delzer, State Water Commission Chemist, at the State Laboratories in Bismarck.

The purpose of this report is to present additional information on ground-water conditions in the Hatton area. It is a supplement to a previous report GROUND WATER IN THE HATTON AREA, TRAILL AND STEELE COUNTIES, NORTH DAKOTA by D. G. Adolphson, United States Geological Survey, published in 1962 as North Dakota Ground-Water Study No. 39.

Location and General Features

The Hatton area, as described in this report, consists of 40 square miles including portions of Township 148 North, Range 53 West; Township 148 North, Range 54 West; and Township 149 North, Range 53 West. The entire area is located within the Agassiz Lake Plain district of the Central Lowland Physiographic Province of North Dakota as shown in Figure 1. Surface elevations are approximately 1,000 to 1,100 feet above sea level, increasing to the west.

The entire study area lies upon the Elk Valley delta, a deltaic deposit of glacial Lake Agassiz. Several beach ridges cross the area trending in a north-south direction. The Goose River and its tributaries have dissected relatively deep narrow valleys in these deposits and drain the entire area. In general, the topography resembles a flat plain (Adolphson, 1962, p. 3).

Hatton, population 856 (1960 Census), is primarily an agricultural community. It is located on North Dakota Highway 18 and is served by the Great Northern Railroad. U. S. Weather Bureau climatological data recorded at Mayville, 10 miles southeast of Hatton, shows the average temperature to be 41.2°F based on a 70-year record through 1965. Average annual precipitation based on the same period is 18.04 inches (U. S. Department of Commerce, 1966).

Present Water Supply

The present Hatton water supply is obtained from two wells located on the east side of Railroad Avenue between Fourth and Fifth Streets. Well No. 1 was drilled in 1937 to a depth of 242 feet. It is equipped with a submersible pump set at a depth of 228 feet. There is 10 feet each of 6-inch and 8-inch well screen. Well No. 2, drilled in 1947, is 239 feet deep. It is equipped with an 18-stage vertical turbine pump set at a depth of 178 feet. The two pumps are powered by 7½ horsepower motors. The water is pumped into a 50,000

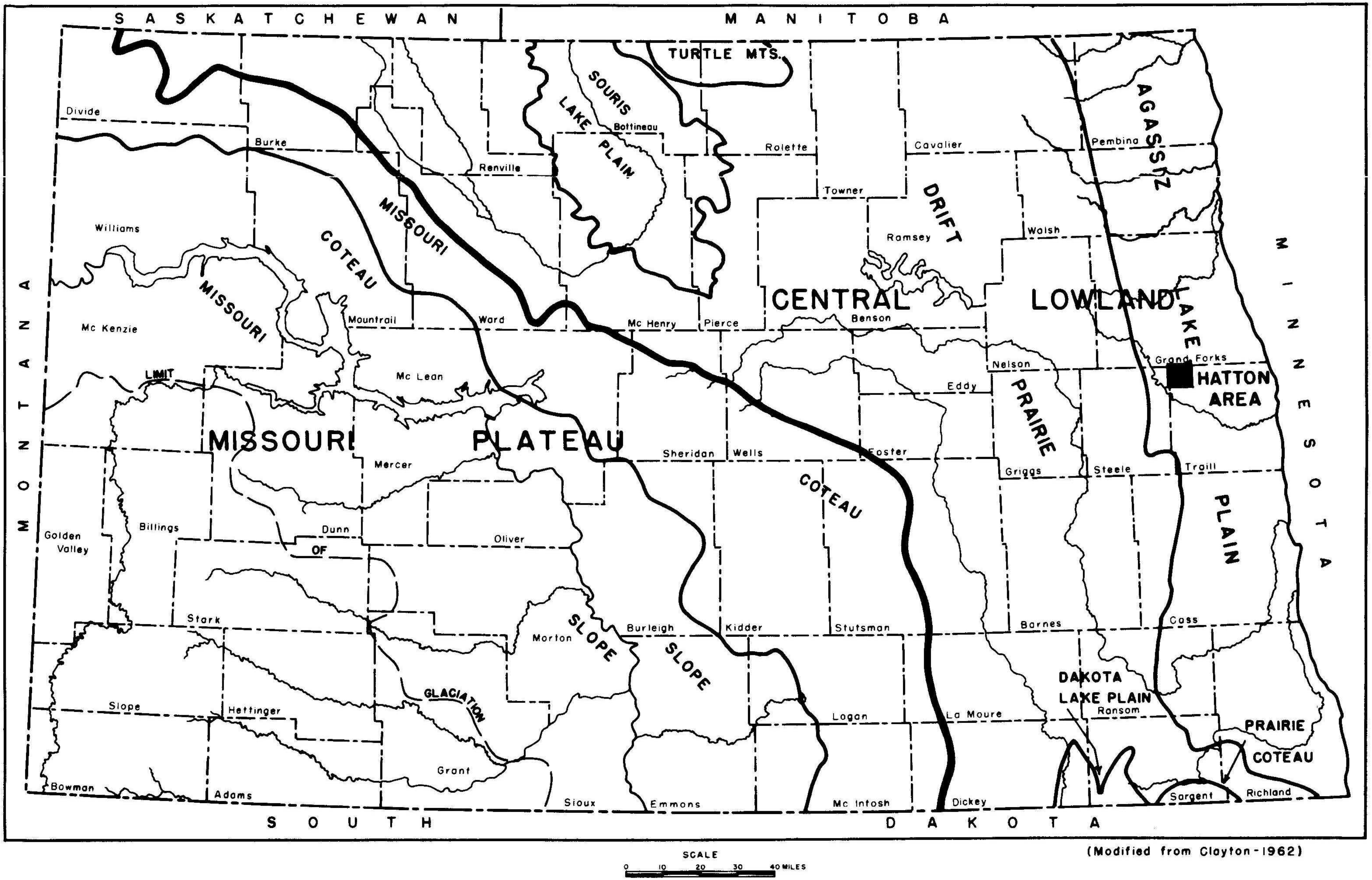

FIGURE I-- MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC PROVINCES AND LOCATION OF THE HATTON AREA gallon storage tank located west of Washington Avenue between Sixth and Seventh Streets (Kirkham, Michael and Associates, 1964, p.1).

Water levels in the city wells at Hatton have been declining since the installation of the first well in 1937. The extent of the decline is shown by 13 water level measurements taken from 1937 to the present (Table 1).

TABLE 1 -- WATER LEVELS IN CITY WELLS AT HATTON (Kirkham, Michael and Associaties, 1964, p.2; 1967, written communication)

	1937	30 feet below land surface
	1942	43
	1947	44
	1954	104
January	1960	94
January	1961	112
January	1962	104
January	1963	105
January	1964	110
October	1964	120
January	1965	118
January	1966	128
January	1967	130

Previous Investigations

In June 1955, the City of Hatton requested assistance in locating an additional municipal water source. Results of the investigation were published in 1962 in a report by D. G. Adolphson. The report indicated that small to medium quantities of ground water may be available from the Tintah and

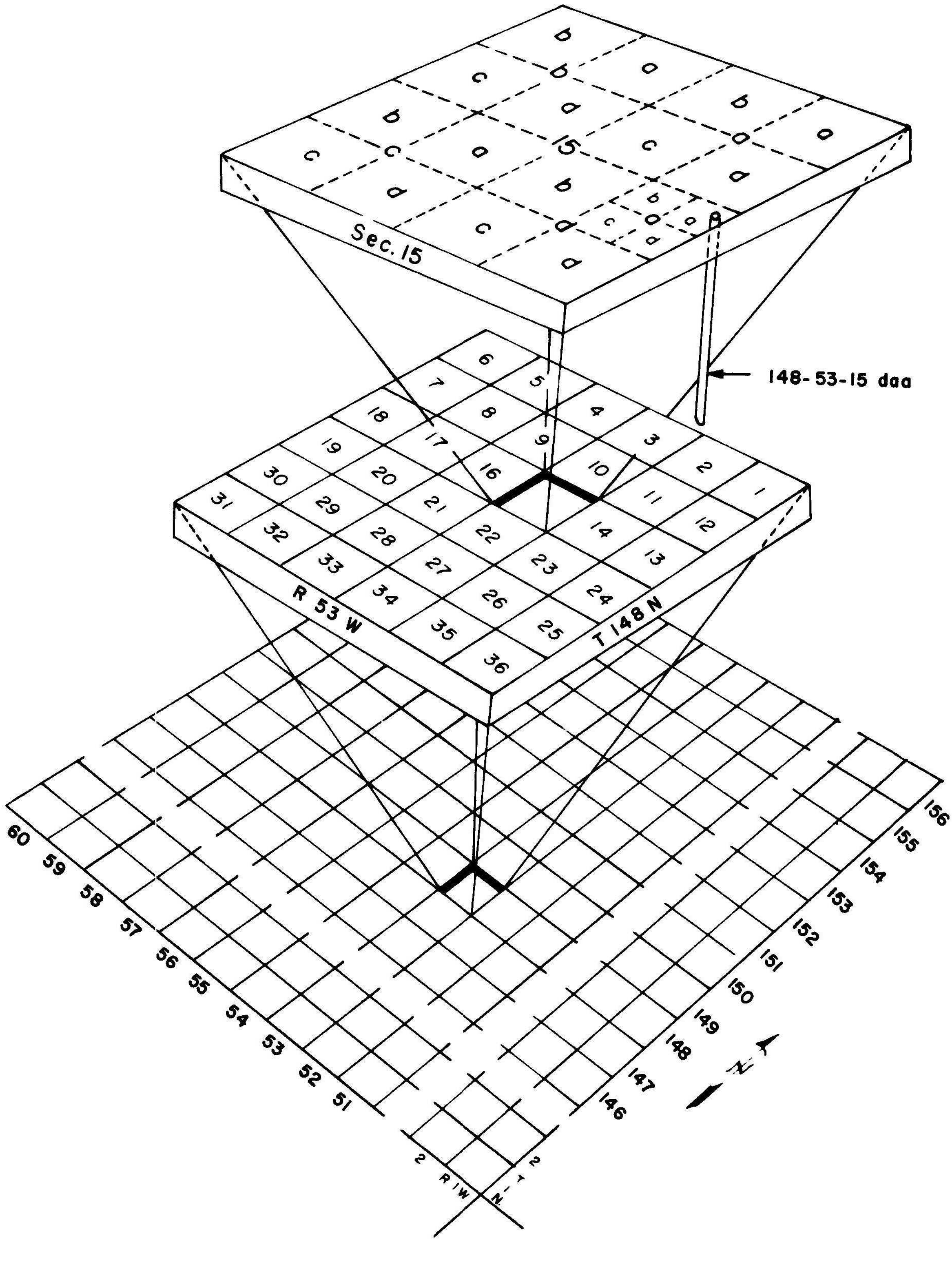

FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

McCauleyville beach deposits and from the Elk Valley delta deposits west of the City. The recommendation was that more data were needed to make an appraisal of the quality of water in the delta deposits.

A study of the municipal water system was made by Kirkham, Michael and Associates in 1964. The study was initiated by the Hatton City Council. Recommendations were made concerning the maintenance and improvement of the distribution system and a water supply exploration program.

Well-Numbering System

The well-numbering system used in this report and illustrated in Figure 2 is based on the location of the well in the federal system of rectangular surveys of public lands. The first number denotes the township north of a base line that is located in Arkansas. The second number denotes the range west of the Fifth Principal Meridian. 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 148-53-15daa would be located in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, SE$\frac{1}{4}$ of Section 15, Township 148 North, Range 53 West.

GEOLOGY AND GROUND-WATER CONDITIONS

Nearly everywhere at varying depths, the subsurface material is saturated with water. To be utilized as a water source, the saturated subsurface material must yield water to wells in sufficient quantities for the intended purpose. A formation that yields water to wells is known as an aquifer. Factors governing the amount of water available from an aquifer are thickness and areal extent, permeability, depth to water, amount of artesian head and recharge.

Deposits of four geologic origins were encountered during test drilling in the Hatton area. Bedrock, undifferentiated in this report, consists mostly of shale. Overlying the bedrock is glacial till and associated sand and gravel deposits composed of debris deposited by continental glaciers. The Elk Valley delta deposits overlie the till. They were deposited by sediment-laden water entering glacial Lake Agassiz. The delta sediments lie at the surface except in limited areas where the Lake Agassiz beach ridges overlie the delta. The beach ridges, indicating the receding levels of Lake Agassiz, are the most recently formed features in the Hatton area.

All test holes drilled in the study area were terminated in bedrock. The locations of the test holes are shown in Figure 3. In Figure 4, graphic logs of selected test holes illustrate the lithologic and stratigraphic relationships of the area. Descriptive logs of the test holes are in Table 5.

Bedrock

The bedrock in the Hatton area has not been penetrated to the Precambrian. A well located at 148-53-19b terminates in shale at a depth of 714 feet (Simpson, 1929, p. 242).

The sample description log for a 598 foot test hole at 148-53-14aaa (Adolphson, 1962, P. 14) indicates three bedrock formations may have been encountered. The oldest formation is a gray to reddist brown fossiliferous shale of Ordovician Age, possibly of the Winnipeg group. Overlying this formation is a section of light colored shale and quartz sand, probably the Cretaceous Dakota Group (Hansen, N. D. Geological Survey, 1967, oral communi-

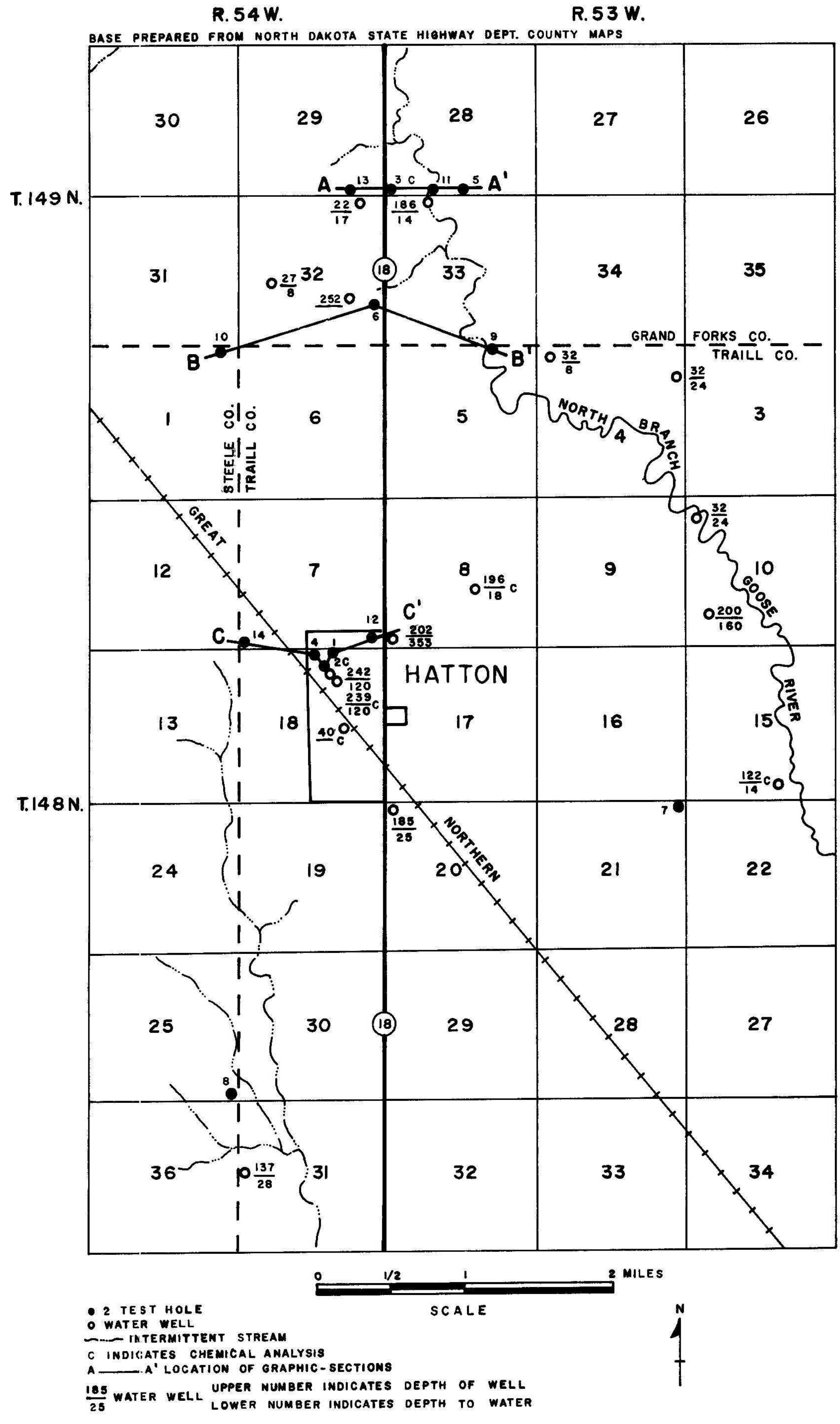

FIGURE 3-- HATTON AREA MAP SHOWING LOCATION OF SELECTED WELL, TEST HOLES AND GEOLOGIC GRAPHIC-SECTIONS

cation). Wells completed in sand sections of the Dakota often flow, but the water is highly mineralized and unsuitable for most purposes (Adolphson, 1962, p. 8). The uppermost bedrock formation of the Hatton area is a dark colored calcareous shale. Hansen (N. D. Geological Survey, 1967, oral communication) has tentatively indentified it as the Belle Fourche Formation of Cretaceous Age.

Glacial Drift

Glacial drift refers to all stratified or unstratified materials deposited directly or indirectly by glacial action. In the Hatton area, it includes all the material overlying the bedrock and is generally more than 200 feet thick.

Till and Associated Sand and Gravel Deposits

Till is a heterogeneous mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glaciers with little or no transporation or sorting by running water. Unoxidized till is usually olive gray to dark greenish gray in color. It consists predominantly of clay and silt and is too fine-grained to readily yield water to wells.

Stratified sand and gravel deposits are commonly associated with till. These deposits will yield water to wells and are commonly utilized as water sources. They vary considerably in thickness and in areal extent. Recharge of these aquifers is usually slow because they are generally enclosed within the relatively impermeable till. Hatton obtains its present water supply from this type of aquifer.

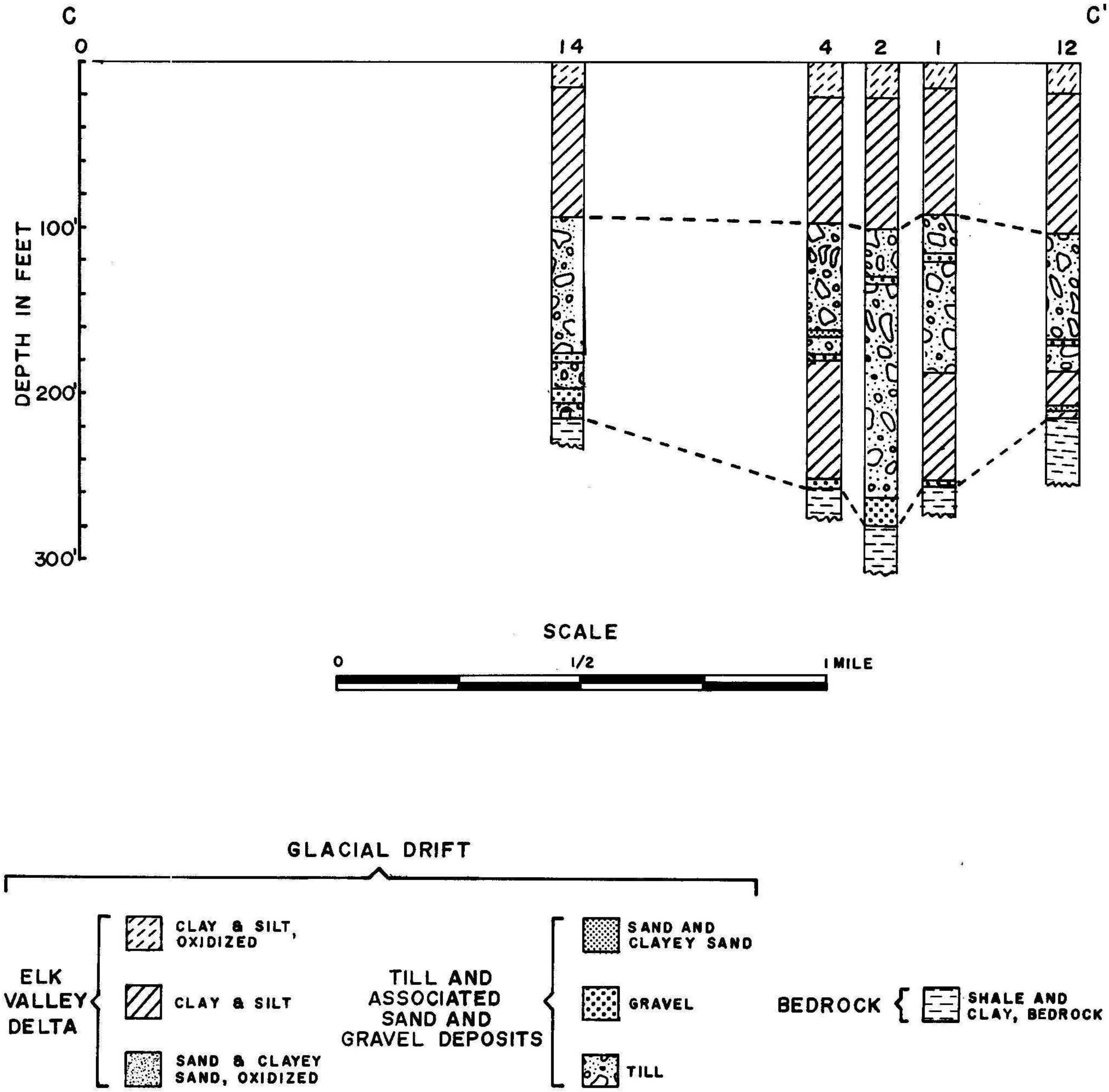

FIGURE - 4 GRAPHIC SECTION OF SELECTED TEST HOLES IN THE HATTON AREA (LOCATION OF GRAPHIC SECTION C—C' SHOWN IN FIGURE 3)

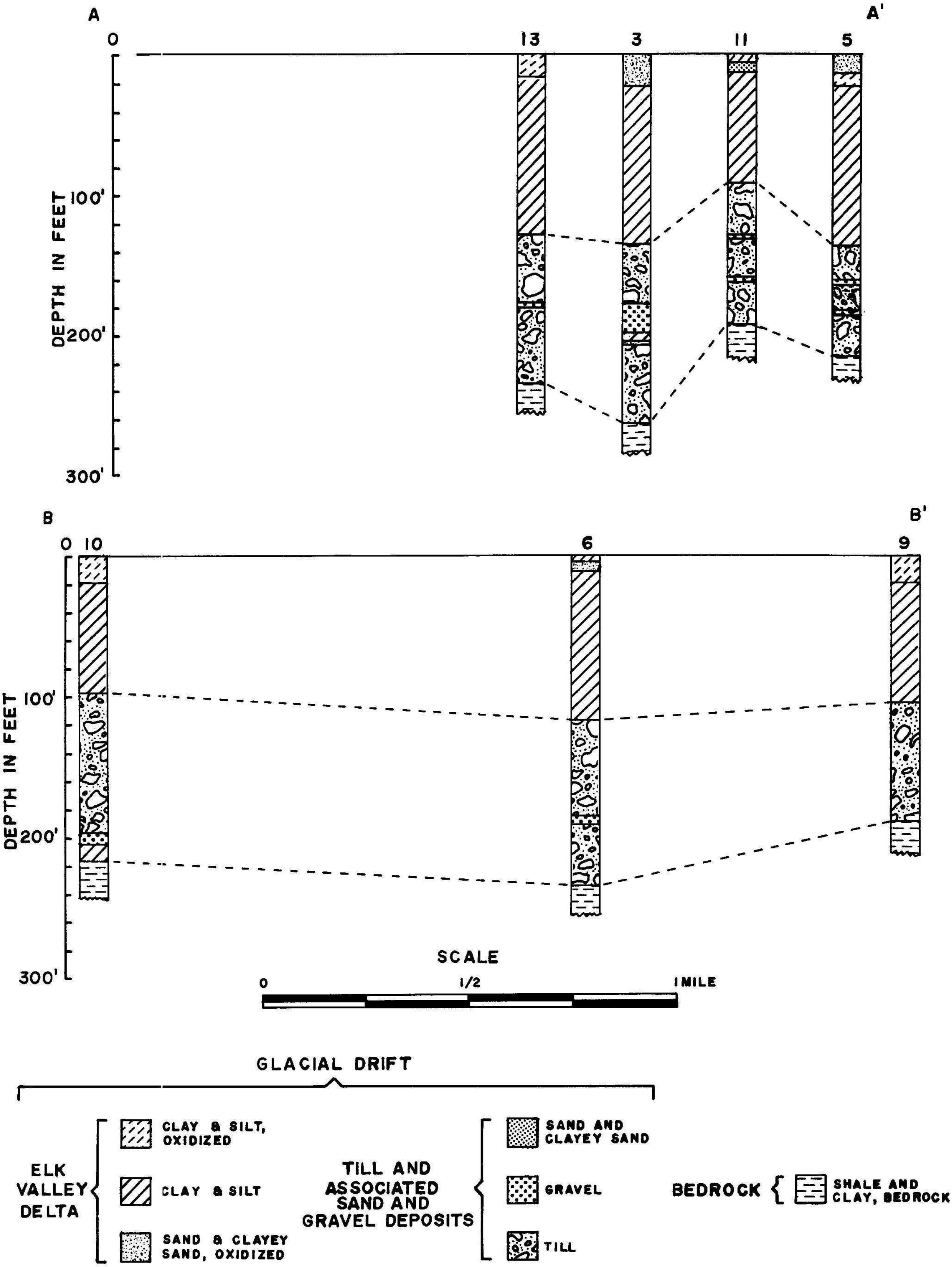

FIGURE--5 GRAPHIC SECTION OF SELECTED TEST HOLES IN THE HATTON AREA (LOCATION OF GRAPHIC SECTIONS A—A', B—B' SHOWN IN FIGURE 3)

Elk Valley Delta

The Elk Valley delta sediments consist of stratified clay, silt and fine sand. They are olive gray to greenish gray except the upper 20 feet where they assume various shades of yellow due to oxidation.

Adolphson (1962, p. 6) mentions a sandy zone in the delta sediments located west of Hatton that may yield sufficient ground water to augment the present Hatton water supply. Further investigation in this area in 1965 failed to locate any significant sand deposits. A few shallow wells have been developed in the delta sediments, but yield only small quantities of water.

Lake Agassiz Beach Deposits

The Lake Agassiz beach deposits are usually in the form of low rounded ridges trending in a general north-south direction (Simpson, 1929, p. 240). Saturated sand and gravel often occurs in these deposits and has been utilized as a water source on some farms. The water is generally of excellent quality, but because of the limited areal extent and thickness of the beach ridges in the vicinity of Hatton, these features would not produce adequate quantities for a municipal supply.

AQUIFER TEST

At test hole 762-3 (149-53-28ccc) a section of gravel 21 feet thick was encountered within the till (Table 4). In November 1965, a test well was constructed at this location. An aquifer test was conducted to determine if the gravel would yield sufficient quantities of water to supplement the Hatton water supply.

The test well construction and aquifer test were accomplished by Layne-Minnesota Company under the supervision of Kirkham, Michael and Associates, consulting engineers. The test well was drilled 118.5 feet southeast of test hole 762-3 and an observation well, in this report referred to as the east observation well, was drilled 110 feet east of the well.

The well was pumped at 80 gallons per minute. After 22 hours the pumping equipment malfunctioned and only drawdown readings were recorded. After repairs, a second test was conducted. The well was pumped for 42 hours and drawdown readings were taken at the observation wells. Drawdown at the end of 42 hours was 58 feet at the east observation well and 51.5 feet at test hole 762-3. Eight minutes after the pump had been stopped, the water level in the test well was 117 feet below the original static level. The recovery rate was extremely slow. Fifty-eight hours after the pumping ceased, water levels in all wells were more than 15 feet below the original static water level. The water level at the east observation well was more than five feet below the static water level nine days after pumping ceased. (Kirkham, Michael and Associates, 1967, written communication).

Coefficients of transmissibility were computed for each of the three wells. The coefficient of transmissibility indicates the ability of the aquifer to transmit water. It is defined as the rate of flow of water in gallons per day through a vertical strip of aquifer one foot wide and extending the full saturated height under a hydraulic gradient of 100 per cent at a temperature of 60°F. The coefficients of transmissibility for the wells were determined by plotting drawdown versus time on semi-logarithmic paper. Coefficients of transmissibility determined by this method are as follows:

Test Well	1320 gallons per day per foot
Test Hole 762-3	650 gallons per day per foot
East Observation Well	580 gallons per day per foot

The low transmissibility coefficients, rapid drawdown and slow recovery of water levels indicate that the aquifer will not provide an adequate quantity of water to the City of Hatton.

WATER QUALITY

Ground water is derived primarily from rain and snowmelt. The amount and character of minerals dissolved by the water depends on 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 public supply and domestic use is commonly evaluated in relation to standards of the United States Public Health Service for drinking water. Table 2 lists in part standards adopted by the United States Public Health Service.

TABLE 2 -- DRINKING WATER STANDARDS OF THE UNITED STATES PUBLIC HEALTH SERVICE

Iron (Fe)	.3 ppm *
Magnesium (Mg)	125 ppm
Sulfate (SO_4)	250 ppm
Chloride (Cl)	250 ppm
Fluoride (F)	1.5 ppm
Nitrate (NO_3)	45 ppm
Total Dissolved Solids	500 ppm

* ppm - parts per million

The presence of sodium in water may affect persons suffering from heart, kidney or circulatory ailments. Because individual intake of sodium varies, no recommended limit for sodium is established.

TABLE 3 -- 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		% Sodium	SAR	Specific conductance	pH
																		as $CaCO_3$	noncarbonate				
148-53-7aab	38	Silt	8-18-65	17	1.00	83	36	50	6.3	429	0	80	22	1.2	0.9	0.25	500	354	3	23	1.2	842	7.8
148-53-8dbb	196	Fine Gravel	5- 5-65	31	0.22	32	10	266	11	598	0	12	155	0.7	4.9	1.4	818	121	0	81	11	1340	7.9
148-53-15dc	122		5- 6-65	25	0.27	95	21	126	10	514	0	165	27	0.3	.0	1.1	696	324	0	45	3	1080	7.9
148-53-18acb	40	Sand	8-13-65	18	0.04	230	106	31	4.6	488	0	543	64	0.6	19	0.00	1250	1010	610	6	0.4	1630	7.7
Repeat Sample	"	"	6-21-66	28	0.16	243	100	19	4.4	478	0	540	75	0.8	12	0.08	1460	1020	627	4	0.3	1740	7.5
148-53-18adc$_1$	277	Gravel	5-27-65	26	0.06	20	2.7	276	9.2	621	0	29	106	0.7	0.9	2.1	850	61	0	89	15	1250	7.9
148-53-18adc$_2$	239		6- 8-65	28	0.59	27	7.0	250	9.7	616	0	12	99	0.6	1.1	1.65	732	96	0	83	11	1200	8.1
149-53-28ccc	284	Gravel	6- 7-65	23	0.62	43	8.0	218	14	434	0	92	155	0.5	0.7	1.60	709	140	0	70	8	1410	8.2
149-53-33bac	186	Sand and Gravel	6- 8-65	23	0.35	38	12	199	13	384	0	31	169	0.5	0.8	1.60	630	146	0	73	7.2	1140	8.2

High total dissolved solids may impart an objectionable taste to water. The North Dakota State Department of Health classifies total dissolved solids as low from 0 to 500 ppm, average from 500 to 1400 ppm, high from 1400 to 2500 ppm and very high over 2500 ppm.

Excessive hardness in water, while having no pathological effects, will cause increased soap consumption and scaling. Hardness, as classified by the North Dakota State Department of Health is low from 0 to 200 ppm, average from 200 to 300 ppm, high from 300 to 450 ppm and very high over 450 ppm.

Excessive sulfate content in water may cause laxative effects. United State Public Health Service standards for sulfate are 250 ppm, but a North Dakota State Department of Health survey indicates no laxative effect until a concentration of 600 ppm is reached.

Table 3 lists nine complete analyses from representative waters in the Hatton area. Total dissolved solids exceed United States Public Health Service standards in every sample. By North Dakota State Department of Health Standards total dissolved solids are rated as average for the samples. Hardness is very high at well 148-53-18acb, high at 148-53-15dc and low at all others. All the wells are within the standards for sulfate, though well 148-53-18acb exceeds United States Public Health Service standards.

Water samples collected at 148-53-18aab and 148-53-7aab are from wells developed in Elk Valley delta sediments. All other samples analyzed were taken from wells terminating in sand and gravel deposits associated with till. Water analysis for wells in the Lake Agassiz beach deposits and the bedrock formations are not included in this report, but are included in the previous report by Adolphson (1962, p. 10).

TABLE 4 -- 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 wells: Measured depths in feet and tenths; reported depths in feet.

Type of well: Dr, drilled; Du, dug; Dv, driven, Bo, bored; Je, jetted; gpm, gallons per minute.

Use of water: D, domestic; I, irrigation; U, unused; PS, public supply; S, stock; T, 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
148-53-4adc	Maurice Smestad	32	72			24		D.S.	Fine Sand	
148-53-4bb	Rachel Digneis	32	36			8		D		
148-53-5aba		210	4 3/4	Dr.			6- 4-65	T		
148-53-7aab	ND State Water Commission #2390	38	4	Dr.	8-17-65			D	Silt	Complete chemical analysis
148-53-7ccc		221	4 3/4	Dr.			8-13-65	O	Gravel	
148-53-7ddd		252	4 3/4	Dr.			8-12-65	T	Gravel	
148-53-8cc	Olaf Bye	202	6	Dr.		35.3	5- 6-65	D.S.I.		
148-53-8dbb	Arnold Brandon	196	4	Dr.		18		D.S.	Fine Gravel	Complete chemical analysis
148-53-10b	Olaf Bye	200±				160		D.S.		
148-53-10c	Theodore Huss	45	60			30				
148-53-15dc	David Holter	122	3			14	1963	D.S.I.		Complete chemical analysis
148-53-18abb$_1$		273	4 3/4	Dr.	6- 1-65			T	Gravel	
148-53-18abb$_2$		273	4 3/4	Dr.	5-24-65			T	Gravel	
148-53-18abd		305	4 3/4	Dr.	5-25-65			O	Gravel	Complete chemical analysis
148-53-18abd$_1$	City of Hatton	242				120	1964	PS		
148-53-18abd$_2$	City of Hatton	239	6		12-12-47	120	1964	PS		Complete chemical analysis
148-53-18acb	City of Hatton	40		Du.	1930			PS	Sand	Complete chemical analysis
148-53-20bbb	Dr. Roehl	185	6	Dr.		25		D	Sand	

TABLE 4 -- RECORDS OF WELLS AND TEST HOLES (CONT.)

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

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

Type of well: Dr, drilled; Du, dug; Dv, driven; Bo, bored; Je, jetted; gpm, gallons per minute

Use of water: D, domestic; I, irrigation; U, unused; PS, public supply; S, stock; T, 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
148-53-21aaa		252	4 3/4	Dr.	6- 3-65			T		
148-53-31bcc	Paul Vaagene	137	2			28		D.S.	Sand & Gravel	
148-54-1aab		242	4 3/4	Dr.	6- 4-65			T	Gravel	
148-54-25ddd		210	4 3/4	Dr.	6- 3-65			T		
149-53-28ccc		284	4 3/4	Dr.	5-26-65			O	Gravel	Complete chemical analysis
149-53-28cdc		210	4 3/4	Dr.	6- 7-65			O	Gravel	
149-53-28cdd		231	4 3/4	Dr.	6- 2-65			T	Gravel	
149-53-29dcd		252	4 3/4	Dr.	8-13-65			T	Gravel	
149-53-32aab	Odin Johnson	22	32			17		D		
149-53-32cbc	G. P. Skjoiten	27	30			8		D	Very Fine Sand	
149-53-32dad		252	4 3/4	Dr.	6- 2-65			T	Gravel	
149-53-33bac	Lockert Thompson	186	6	Dr.		14		D.S.	Sand & Gravel	Complete chemical analysis

RECOMMENDATION

This study revealed no additional ground-water sources in the Hatton area that would be feasible for development as a municipal water supply. The aquifers in the Lake Agassiz beach deposits and the glacial drift are not large enough and Elk Valley delta sediments are too impervious to yield more than small quantities of water. Water obtained from bedrock formations is of undesirable quality (Adolphson, 1962, p. 10).

It is recommended that the City of Hatton consider development of a surface-water source. A project involving the construction of a dam on the Goose River west of the City (North Dakota State Water Commission Project No. 1425) is presently in the planning stages. Water impounded by the dam should provide an adequate municipal water supply.

TABLE 5 -- LOGS OF TEST HOLES

Test holes 762-1 through 762-14 were drilled by the State Water Commission in 1965. Descriptive logs of the test holes are in the following table and are a composite of information from the driller's logs, geologists sample descriptions, and resistivity and self potential electric logs. Colors used in the description of the samples are from the rock color chart by Goddard and other (1951). Colors described are of wet samples. Grain size classification is based on C. K. Wentworth's scale from Pettijohn (1957).

148-53-5aba
Test Hole 762-9

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black, (topsoil)	1	1
	Silt, clayey, medium yellowish brown, moderately cohesive, calcareous . . .	17	18
	Silt, clayey, olive gray, moderately cohesive, calcareous	86	104
	Clay, silty, sand grains, pebbles, predominantly shale and limestone, olive gray, moderately brittle, calcareous (Till)	9	113
	Clay, silty, sandy, gravelly, predominantly shale and limestone, olive gray, calcareous (Till)	43	156
	Clay, silty, sand grains, pebbles, dark olive gray, moderately brittle, very calcareous (Till)	31	187
Bedrock, Undifferentiated:			
	Clay, silty, dark olive gray, moderately brittle, very calcareous, white mottles	23	210

Electric Log

148-53-7ccc
Test Hole 762-14

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	2	2
	Clay, silty, grayish orange, moderately cohesive and plastic	13	15
	Silt, clayey, sandy, dark greenish gray, poorly cohesive and plastic . .	78	93

148-53-7ccc
Test Hole 762-14 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, sand grains, pebbles, olive gray, poorly cohesive and plastic (Till)	32	125
	Clay, silty, sand grains, pebbles, olive gray, with thin layers of clay, silty and sandy, dark greenish gray; moderately brittle (Till).	21	146
	Clay, silty, sand grains, pebbles, olive gray, moderately brittle (Till)	20	176
	Gravel, fine to coarse, sandy, clayey, angular, poorly sorted, predominantly limestone and shale. .	3	179
	Clay, silty, sandy, gravelly, predominantly limestone and shale, olive gray (Till)	6	185
	Clay, silty, sandy, pebbles, olive gray (Till)	4	189
	Clay, silty, sand grains, pebbles, gravel layers, olive gray (Till) . .	7	196
	Gravel, fine to coarse, clayey, erratics, poorly sorted	7	203
	Clay, silty, brownish gray, moderately brittle, calcareous, white mottles, some till	10	213
Bedrock, Undifferentiated:			
	Clay, silty, brownish gray, moderately brittle, calcareous, white mottles	8	221

Electric Log
Observation Well

148-53-7ddd
Test Hole 762-12

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Clay, silty, sandy, dusky yellow to pale olive, moderately cohesive, very calcareous	9	10
	Clay, very silty, dusky yellow, moderately cohesive, very calcareous. .	8	18
	Clay, silty, sandy, dark greenish gray to olive gray, poorly cohesive, calcareous	84	102
	Clay, silty, sand grains, pebbles, predominantly shale and limestone, dark greenish gray to olive gray, moderately cohesive, calcareous (Till)	33	135
	Clay, silty, sandy, pebbles, olive gray, calcareous (Till)	12	147
	Clay, silty, sand grains, pebbles, olive gray, moderately cohesive, calcareous (Till)	18	165
	Gravel, fine to medium, sandy, subangular to subrounded, poorly sorted, predominantly shale	4	169
	Clay, silty, sandy, pebbles, olive gray, calcareous (Till)	18	187
	Clay, sandy, dark greenish gray, moderately cohesive, calcareous. . .	9	196
	Clay, sandy, brownish gray, moderately cohesive, calcareous	12	208
	Sand, fine, well sorted	2	210
	Clay, sandy, brownish gray, moderately cohesive, calcareous	3	213

148-53-7ddd
Test Hole 762-12 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Bedrock, Undifferentiated:			
	Clay, silty, olive gray, moderately brittle,very calcareous, white mottles	35	248
	Limestone, extremely brittle, consolidated	1	249
	Clay, silty, olive gray, moderately brittle, very calcareous, white mottles	3	252

Electric Log

148-53-18abb1
Test Hole 762-4

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Silt, clayey, sandy, dark yellowish orange, moderately cohesive, plactic, calcareous	19	20
	Silt, clayey, sandy, olive gray to dark greenish gray, poorly cohesive and plastic, calcareous	77	97
	Clay, silty, many sand grains, pebbles, predominantly shale and limestone, dark greenish gray to olive gray, moderately brittle, calcareous (Till).	17	114
	Clay, silty, sandy, many pebbles, a few erratics, pebbles are shale, erratics are limestone, olive gray, moderately brittle, calcareous, (Till).	47	161
	Sand, fine to medium, well sorted . .	2	163

148-53-18abb$_1$
Test Hole 762-4 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, sandy, many pebbles, a few erratics, pebbles are shale, erratics are limestone, olive gray, moderately brittle, calcareous (Till)	13	176
	Gravel, fine to coarse, predominantly limestone and granite	2	178
	Clay, silty, sandy, olive green, moderately brittle, very calcareous	72	250
	Gravel, fine to coarse, sandy, a little clay, subrounded, moderate sorting	6	256
Bedrock, Undifferentiated:			
	Clay, silty, sandy, dark olive gray, moderately brittle, calcareous, white mottles	17	273

Electric Log

148-53-18abb$_2$
Test Hole 762-1

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Clay, silty, sandy, moderate yellowish brown, moderately cohesive, moderately brittle, calcareous	14	15
	Clay, silty, sandy, olive gray to greenish gray, moderately cohesive, plastic, calcareous	77	92

148-53-18abb$_2$
Test Hole 762-1 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, sand grains, pebbles, olive gray to dark greenish gray, moderately cohesive plastic, calcareous (Till)	22	114
	Gravel, fine to medium, sandy, angular, poorly sorted, predominantly shale	5	119
	Clay, silty, sand grains, pebbles, erratics, predominantly shale, dark greenish gray to olive gray, moderately brittle, calcareous (Till) . .	54	173
	Clay, silty, gravelly, predominantly shale, olive gray, calcareous (Till)	3	176
	Clay, silty, sand grains, pebbles, erratics, predominantly shale, dark greenish gray to olive gray, moderately cohesive, moderately brittle, calcareous (Till)	10	186
	Clay, silty, sandy, olive black, moderately cohesive, moderately brittle, very calcareous	24	210
	Clay, silty, very sandy, olive gray, moderately cohesive, moderately brittle, very calcareous	41	251
	Granite boulder.	2	253
Bedrock, Undifferentiated:			
	Shale, olive black, moderately cohesive, brittle, calcareous, white mottles	20	273

Electric Log

148-53-18abd
Test Hole 762-2

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, gravelly, black (topsoil)	1	1
	Clay, silty, sandy, moderate yellowish brown to dark yellowish orange, moderately cohesive, calcareous . . .	20	21
	Silt, clayey, sandy, olive gray, slightly cohesive, calcareous, laminated	71	92
	Clay, silty, olive gray, moderately cohesive, laminated	10	102
	Clay, very silty, sand grains, pebbles, predominantly shale, olive gray to dark greenish gray, moderately cohesive, calcareous (Till) . .	27	129
	Gravel, fine to coarse, sandy, predominantly shale with limestone and quartz, angular to subangular, poorly sorted	4	133
	Clay, silty, gravelly, predominantly shale, olive gray, moderately cohesive, calcareous (Till)	13	146
	Silt, clayey, a few sand grains, pebbles, olive gray, moderately cohesive, calcareous (Till)	53	199
	Clay, silty, gravelly, predominantly shale, olive gray, moderately cohesive, calcareous (Till)	63	262
	Gravel, fine to coarse, sandy, predominantly shale, limestone, and lignite, angular to rounded, poorly sorted	17	279
Bedrock, Undifferentiated:			
	Shale, olive black, moderately cohesive, brittle, calcareous, white mottles	26	305

Electric Log
Observation Well

148-53-21aaa
Test Hole 762-7

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Sand, fine, silty, clayey, yellowish brown, non-cohesive, calcareous. .	9	10
	Clay, silty, dark greenish gray, moderately cohesive, calcareous. . . .	117	127
	Clay, sandy, silty, gravelly layers, predominantly shale and limestone, greenish gray, moderately cohesive, calcareous (Till).	8	135
	Clay, silty, a few sand grains, pebbles, predominant shale, olive gray, moderately cohesive, calcareous (Till).	11	146
	Clay, silty, sand grains, pebbles, erratics, gravelly, olive gray, moderately cohesive, calcareous (Till)	79	225
Bedrock, Undifferentiated:			
	Clay, silty, olive black to brownish black, moderately cohesive, brittle, calcareous, white mottles . .	27	252

Electric Log

148-54-1aab
Test Hole 762-10

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Clay, silty, sandy, medium yellowish brown, poorly cohesive, calcareous . .	17	18
	Silt, clayey, greenish gray, poorly cohesive, calcareous	80	98

148-54-laab
Test Hole 762-10 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, sand grains, pebbles, predominantly shale and limestone, olive gray, moderately brittle calcareous (Till)	9	107
	Clay, silty, gravelly, erratics, predominantly limestone and shale, olive gray, calcareous (Till).	4	111
	Clay, silty, sand grains, pebbles predominantly shale, olive gray, calcareous (Till).	16	127
	Clay, silty, gravelly, olive gray, calcareous (Till).	9	136
	Clay, silty, sand grains, pebbles predominantly shale, olive gray, calcareous (Till).	7	143
	Clay, silty, sandy, a few pebbles, olive gray, calcareous (Till).	33	176
	Clay, silty, sandy, pebbles, predominantly shale and erratics, olive gray, calcareous (Till).	21	197
	Gravel, fine to coarse, sandy, a little clay, poorly sorted, predominantly limestone	7	204
	Clay, sandy, dark greenish gray, poorly cohesive, brittle, very calcareous	14	218
Bedrock, Undifferentiated:			
	Clay, silty, olive gray, moderately brittle, very calcareous, white mottles.	24	242

Electric Log

148-54-25ddd
Test Hole 762-8

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Clay, silty, grayish orange, moderately cohesive, very calcareous. . . .	9	10
	Silt, clayey, grayish orange, moderately cohesive, calcareous	7	17
	Silt, clayey, olive gray to dark greenish gray, moderately cohesive, calcareous	53	70
	Clay, silty, sand grains, pebbles, predominantly shale and limestone, olive gray to dark greenish gray, moderately cohesive, calcareous. . . .	12	82
	Clay, silty, sand grains, pebbles, gravel layers, predominantly shale and limestone, olive gray to dark greenish gray, moderately cohesive, calcareous (Till).	13	95
	Clay, silty, sandy, gravelly, predominantly shale, olive gray, moderately cohesive, calcareous (Till). .	44	139
	Silt, clayey, olive gray, moderately cohesive, brittle, calcareous.	16	155
	Clay, very silty, sand grains, pebbles, gravelly, predominantly shale and limestone, olive gray, moderately cohesive, brittle, calcareous (Till)	35	190
Bedrock, Undifferentiated:			
	Clay, silty, olive gray, moderately cohesive, brittle, very calcareous, white mottles.	20	210

Electric Log

149-53-28ccc
Test Hole 762-3

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Sand, fine, clayey, well sorted, calcareous, oxidized.	19	20
	Clay, silty, very sandy, dark greenish gray, non-cohesive, slightly calcareous.	94	114
	Clay, silty, olive gray, moderately cohesive, brittle, very calcareous . .	21	135
	Clay, silty, sand grains, pebbles, predominantly shale and limestone, olive gray to dark greenish gray, moderately cohesive, calcareous (Till)	43	178
	Gravel, fine to medium, very sandy, clayey, poorly sorted, angular to subrounded, predominantly shale and limestone.	10	188
	Gravel, fine to coarse, sandy, a little clay, poorly sorted, angular to subrounded, predominantly shale and limestone.	11	199
	Clay, silty, sandy, dark greenish gray to olive gray, moderately cohesive, calcareous	5	204
	Sand, fine to medium, clayey	2	206
	Clay, silty, sand grains, pebbles, predominantly shale, olive gray, moderately cohesive, calcareous (Till)	36	242
	Clay, silty, a few erratics, olive black, moderately cohesive, calcareous.	21	263
Bedrock, Undifferentiated:			
	Clay, silty, olive black, moderately cohesive, calcareous, white mottles. .	21	284

Electric Log
Observation Well

149-53-28cdc
Test Hole 762-11

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Clay, silty, sandy, grayish orange to dusky yellowish green, non-calcareous.	7	8
	Sand, fine to medium, well sorted. . .	5	13
	Silt, clayey, olive gray to dark greenish gray, calcareous, laminated	78	91
	Clay, silty, sand grains, pebbles, predominantly limestone and quartz, greenish gray, calcareous (Till) . . .	3	94
	Clay, silty, sand grains, pebbles, predominantly shale, olive gray to dark greenish gray, calcareous (Till)	34	128
	Gravel, fine to coarse, predominantly limestone, moderately poor-sorting . .	1	129
	Clay, silty, sand grains, pebbles, predominantly shale, olive gray to dark greenish gray, calcareous (Till)	5	134
	Clay, silty, sandy, erratics, gravelly, olive gray (Till).	11	145
	Clay, silty, sand grains, pebbles, predominantly shale, olive gray to dark greenish gray, calcareous (Till)	14	159
	Gravel, fine to coarse, erratics, predominantly limestone, poortly sorted .	4	163
	Clay, silty, sand layers, sand grains, pebbles, erratics, gravelly, predominantly shale, olive gray, brittle, calcareous (Till).	27	190

149-53-28cdc
Test Hole 762-11 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Bedrock, Undifferentiated:			
	Clay, silty, olive black, brittle, very calcareous, white mottles	20	210

Electric Log
Observation Well

149-53-28cdd
Test Hole 762-5

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Sand, fine to medium, predominantly quartz, limestone, and shale, subrounded, well sorted	11	12
	Clay, silty, sandy, yellowish brown, moderately cohesive, moderately plastic, calcareous.	9	21
	Clay, silty, sandy, olive gray to dark greenish gray, slightly to moderately cohesive, calcareous	114	135
	Clay, silty, sand grains, pebbles, predominantly shale and limestone, olive gray to dark greenish gray, moderately cohesive, calcareous (Till)	11	146
	Clay, silty, sand grains, pebbles, gravelly, predominantly shale and limestone, olive gray to dark greenish gray, moderately to very cohesive, calcareous (Till).	14	160
	Gravel, fine to coarse, clayey, predominantly shale and limestone, subangular to subrounded.	4	164

149-53-28cdd
Test Hole 762-5 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, sand grains, pebbles, gravelly, predominantly shale and limestone, olive gray to dark greenish gray, moderately to very cohesive, calcareous (Till).	18	182
	Gravel, fine to coarse, erratics, clayey, predominantly limestone and shale, subangular to subrounded. . . .	4	186
	Clay, silty, sand grains, pebbles, gravelly, predominantly shale and limestone, olive gray to dark greenish gray, moderately to very cohesive (Till)	11	197
	Clay, silty, sand grains, pebbles, dark greenish gray, moderately cohesive, calcareous (Till)	16	213
Bedrock, Undifferentiated:			
	Clay, silty, dark greenish gray, moderately cohesive, calcareous	18	231

Electric Log

149-53-29dcd
Test Hole 762-13

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Clay, sandy, silty, moderate yellowish brown to pale olive, moderately cohesive, calcareous	17	18
	Clay, sandy, silty, olive gray to dark greenish gray, non-cohesive to moderately cohesive, calcareous . . .	72	90

149-53-29dcd
Test Hole 762-13 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, dark greenish gray to olive gray, moderately cohesive, calcareous	40	130
	Clay, silty, sand grains, pebbles, predominantly shale and limestone, dark greenish gray to olive gray, moderately cohesive, moderately brittle, calcareous (Till)	48	178
	Gravel, fine to coarse, many erratics, predominantly shale and granite. . . .	2	180
	Clay, silty, sand grains, pebbles, predominantly shale, limestone, and quartz, olive gray to dark greenish gray, moderately cohesive, calcareous (Till).	38	218
	Clay, silty, sand grains, pebbles, olive gray, moderately cohesive, calcareous, white mottles (Till) . . .	15	233
Bedrock, Undifferentiated:			
	Clay, silty, olive gray, moderately cohesive, moderately brittle, calcareous, white mottles	19	252

149-53-32dad
Test Hole 762-6

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, black (topsoil)	1	1
	Clay, sandy, silty, grayish orange, slightly cohesive, calcareous.	3	4
	Sand, silty, predominantly shale and quartz, subrounded, well sorted, calcareous, oxidized.	7	11

149-53-32dad
Test Hole 762-6 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, sandy, dark greenish gray, slightly cohesive, calcareous	34	45
	Clay, silty, sandy, olive gray, moderately cohesive, brittle, calcareous.	71	116
	Clay, silty, sand grains, pebbles, predominantly shale and limestone, olive gray to dark greenish gray, moderately cohesive, calcareous (Till).	12	128
	Clay, silty, sandy, pebbles, predominantly shale and limestone, olive gray, moderately cohesive, calcareous (Till).	47	175
	Clay, silty, sandy, pebbles, erratics, gravelly, predominantly shale and limestone, olive gray, moderately cohesive, brittle, calcareous (Till).	9	184
	Gravel, fine to coarse, sandy, predominantly shale and limestone, angular to rounded, poorly sorted . .	6	190
	Clay, silty, sand grains, pebbles, gravelly, predominantly limestone and shale, olive gray, moderately cohesive, moderately plastic, calcareous (Till).	18	208
	Clay, silty, sandy, pebbles, olive gray, moderately cohesive, moderately brittle, calcareous (Till).	27	235
Bedrock, Undifferentiated:			
	Clay, silty, olive black, moderately cohesive, brittle, very calcareous, white mottles	17	252

Electric Log

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