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GROUND WATER SURVEY OF THE TOLLEY AREA

RENVILLE COUNTY, NORTH DAKOTA

N.D.S.W.C. PROJECT NO. 1454

NORTH DAKOTA GROUND-WATER STUDIES

NO. 69

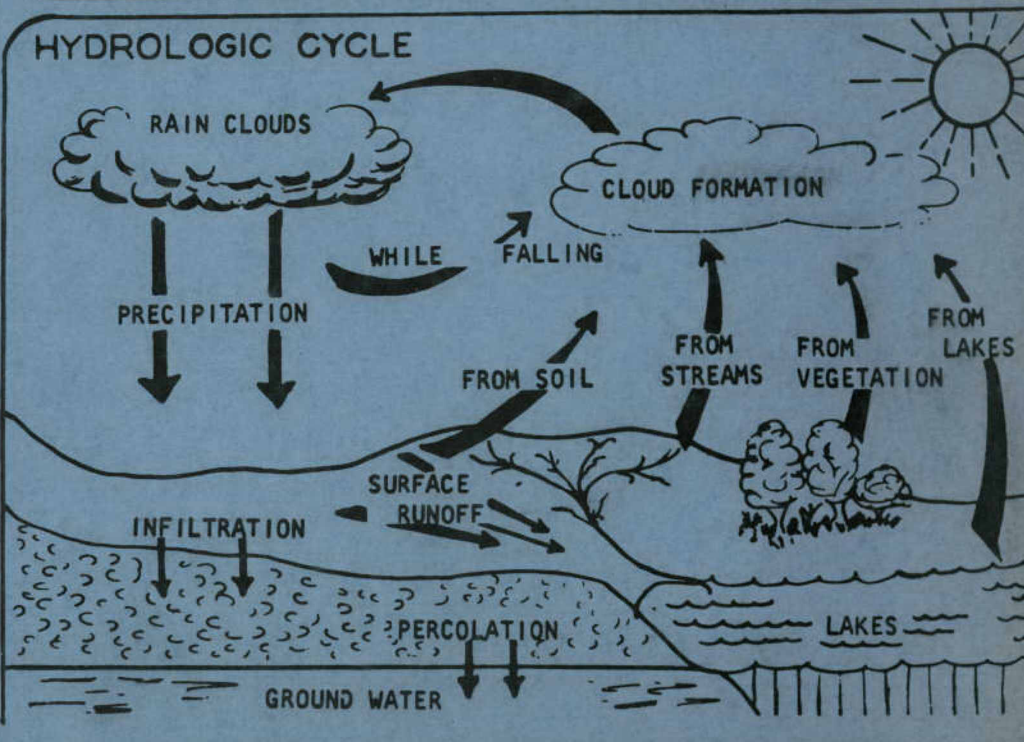
By

Larry L. Froelich
Ground-Water Geologist

PUBLISHED BY

NORTH DAKOTA STATE WATER COMMISSION
State Office Building, 900 Boulevard
Bismarck, North Dakota 58501

- 1968 -



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CONTENTS

ILLUSTRATIONS

TABLES

GROUND-WATER SURVEY OF THE TOLLEY AREA

RENVILLE COUNTY, NORTH DAKOTA

INTRODUCTION

Purpose and Scope

On October 19, 1966, the Tolley Village Board passed a resolution requesting the State Water Commission to perform a ground-water survey of the Tolley area. During April 1967 the Water Commission drilled a series of test holes at selected sites in and around Tolley. The purpose of the test drilling was to determine subsurface geologic conditions and their relationship to ground water availability. In connection with the test drilling an examination of existing water wells was made, one observation well was installed and two water samples were collected for quality determination.

The survey was under direct supervision of the author. Test drilling was done by Lewis Knutson and Hugh Jacobson using the State-owned hydraulic rotary drilling rig. Chemical analyses of water samples were performed by Donald Delzer, State Water Commission Chemist, at the State Laboratories in Bismarck.

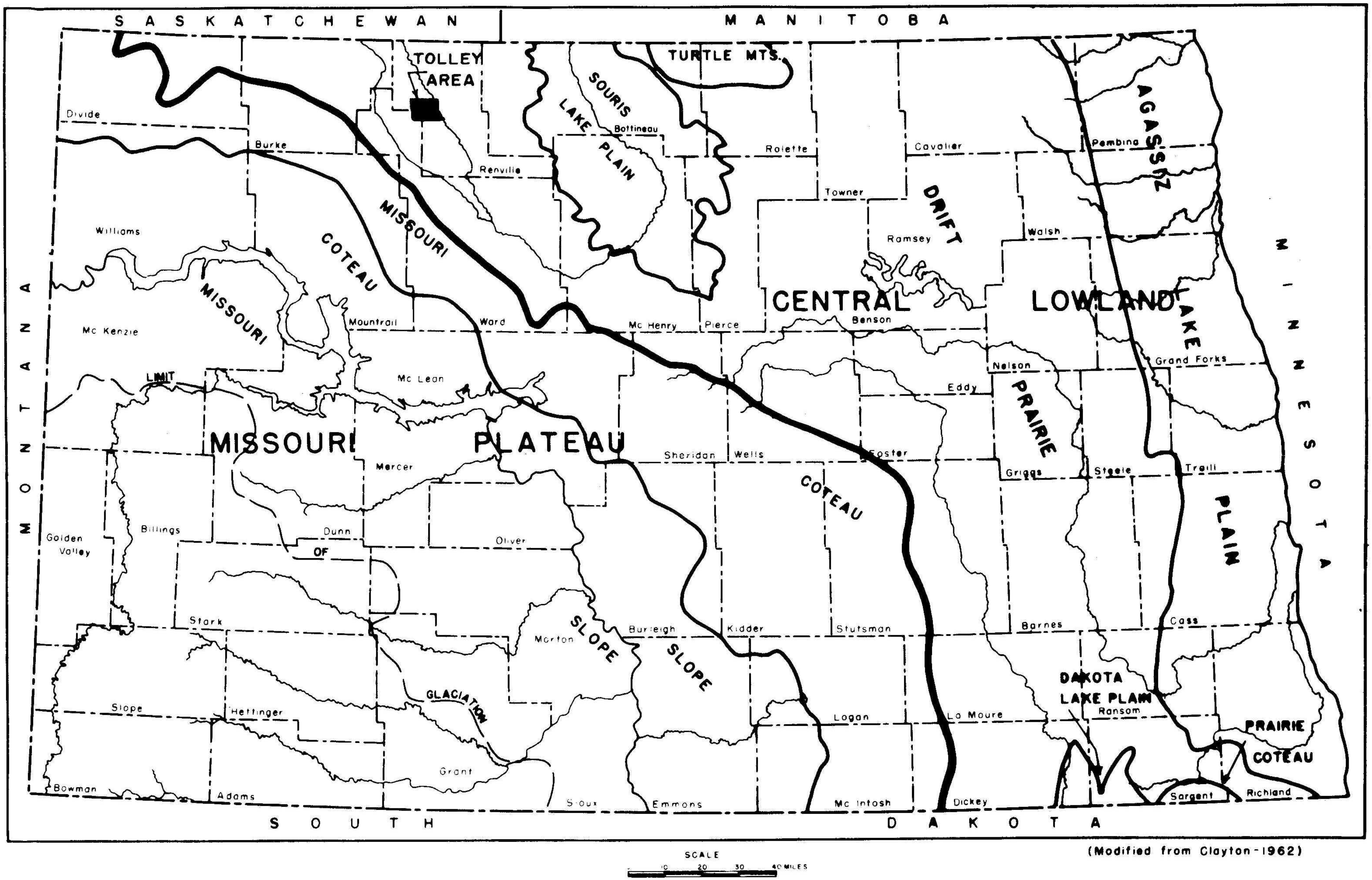

FIGURE I--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC PROVINCES AND LOCATION OF THE TOLLEY AREA

Location and General Features

The Tolley area, as described in this report, consists of 30 square miles including the south half of Township 161 North, Range 86 West and Sections 3 through 10 of Township 160 North, Range 86 West in Renville County and Sections 1, 2, 11 and 12 of Township 160 North, Range 87 West in Ward County. The entire area is located in the Drift Prairie Section of the Central Lowland Physiographic Province as shown in Figure 1.

With the exception of the Souris River valley maximum relief in the Tolley area is about 60 feet, ranging between 1,800 and 1,860 feet above mean sea level. Drainage is generally poor resulting in numerous shallow, undrained depressions, sloughs and marshes. The Souris River, about three miles east of Tolley, constitutes the major drainage and is entrenched to an elevation of approximately 1,600 feet. Gully erosion has progressed as much as one and one-half ($1\frac{1}{2}$) miles from the river.

Tolley is essentially an agricultural community and has a population of about 190. Located two and one-half ($2\frac{1}{2}$) miles south of State Highway 5, it is served by the Minneapolis, St. Paul and Sault St. Marie Railroad. United States Weather Bureau climatological data recorded at Mohall, 15 miles east of Tolley, shows the average temperature to be 40.0° F., based on a 71-year record through 1964. Average precipitation based on the same record is 16.64 inches (U. S. Department of Commerce, 1965).

Present Water Supply

At the present time Tolley does not have a municipal water and sewage system, but some of the residents do have private wells. Effluent discharge is to cesspools. The majority of water used for drinking and general household purposes is commercially hauled from wells at or near Kenmare and Mohall.

This water is stored in privately-owned cisterns. The public school well is perhaps the highest capacity well in town. It is 459 feet deep and had an initial capacity of 15 gallons per minute when drilled in 1961. Because gas accumulates in this well, an automatic time clock has been installed to allow for periodic release of the gas.

Residents of the Tolley area reported a past history of inadequate water supplies both in town and rural areas. Water well records show wells ranging from 7 to 725 feet in depth throughout the area, some farms having both a shallow and deep well. There does not appear to be a consistant well depth in any particular area other than in town where many of the wells are less than 30 feet. Available records for many of the wells in the Tolley area are for wells which have since been abandoned.

Previous Investigations

A general study of North Dakota geology and ground-water resources was made by Simpson (1929), in which he discussed the water-bearing strata of Ward and Renville Counties.

In midsummer 1945 the United States Geological Survey began an investigation of a 5,500 square mile area in the Souris River drainage basin to supply basic geologic data to Federal agencies engaged in the Missouri River Basin Development Program (Lemke, 1960). The Tolley area is included in Lemke's report.

Concurrent with the above mentioned geologic study, the Water Resources Division of the U. S. Geological Survey conducted a hydrologic study of 4,300 square miles within the drainage basin of the Souris River. The interpretive report (LaRocque, Swenson and Greenman, 1963a) was published as North Dakota Ground-Water Study No. 54. An open-file report (LaRocque,

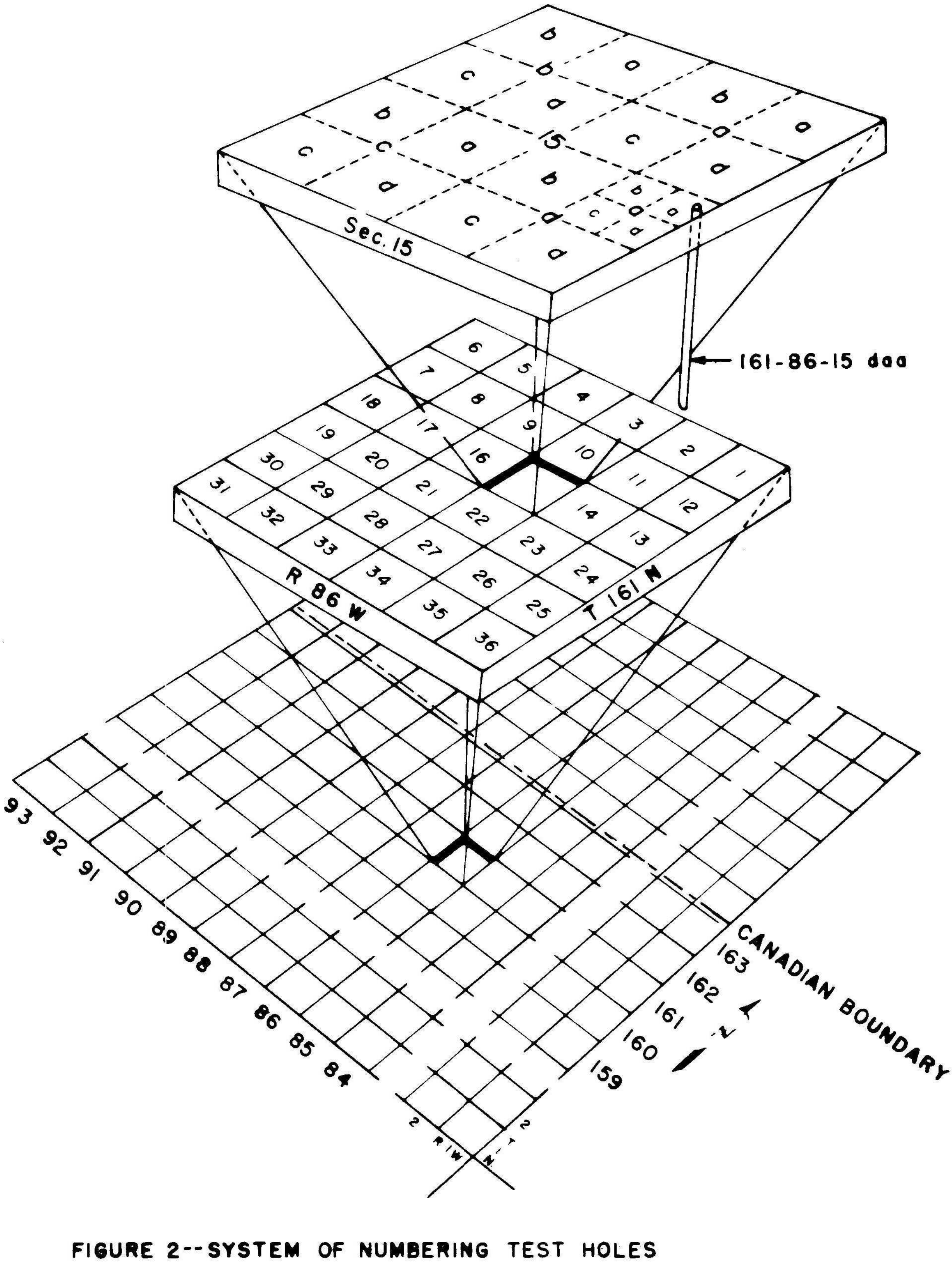

FIGURE 2--SYSTEM OF NUMBERING TEST HOLES

Swenson and Greenman, 1963b), containing tables of data collected during the study, is available for consultation at the U. S. Geological Survey office or the State Water Commission in Bismarck. Some data in the open-file report has been included in this report.

In 1963 the U. S. Geological Survey, in cooperation with the North Dakota Geological Survey and the State Water Commission, began a more comprehensive ground-water survey of Ward and Renville Counties. This survey was completed in 1967 and reports of it are expected to be published in 1968.

System of Numbering Test Holes

The system used to locate test holes included in this report is based on their location in the Federal system of rectangular surveys of public lands as illustrated in Figure 2. The first number denotes the township north and the second 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 section, quarter-quarter section and quarter-quarter-quarter section (10-acre tract). Consecutive terminal numbers are added if more than one test hole is located in a 10-acre tract. Thus test hole 161-86-15daa would be located in the NE$\frac{1}{4}$,NE$\frac{1}{4}$,SE$\frac{1}{4}$ Section 15, Township 161 North, Range 86 West.

GEOLOGY AND OCCURRENCE OF GROUND WATER

With the exception of the deposits in the valley of the Souris River, surficial deposits in the Tolley area consist of glacial drift. Glacial drift is essentially unconsolidated debris deposited by glaciers which crossed over the area during the Pleistocene Epoch. The thickness of glacial drift varies from 250 to 300 feet and is underlain by undifferentiated consolidated sediments collectively referred to as bedrock.

Bedrock

Only sedimentary rocks occupying a position above the Pierre Formation of Late Cretaceous Age were considered during this survey. The Pierre Formation is a dense, gray, marine shale too fine-grained to effectively transmit water to wells. In the Tolley area, the Pierre Formation could be expected to be encountered at a depth of about 1,000 feet (Sid Anderson, North Dakota Geological Survey, personal communication), and is presumably over 1,000 feet thick based on oil well data. Detailed subsurface information below the Pierre Formation is obtainable from the North Dakota Geological Survey in Grand Forks.

Lemke (1960) and LaRocque, et. al. (1963a) have assigned the sediments overlying the Pierre Formation, in ascending order, to the Fox Hills Formation and the Hell Creek Formation of Late Cretaceous Age and the Fort Union Formation of Tertiary Age. The North Dakota Geological Survey and State Water Commission define the Fort Union as a group separated into the Cannonball, Ludlow and Tongue River Formations.

Actually very little detailed stratigraphy has been made of the sediments overlying the Pierre Formation in and around the Tolley area. However, some inferrences can be made from local and regional oil well and water well logs and from areas miles away where the formations are exposed. Even less is known concerning the hydrologic properties of the sediments other than the fact that the upper 200 to 500 feet supply the majority of water to bedrock wells in the Souris River area.

The strata referred to by Lemke and LaRocque as the Fox Hills and Hell Creek Formations are not utilized for a water supply in the Tolley area. The Fox Hills Formation is a source for flowing wells in west central North Dakota and the Hell Creek Formation is a source of water supply in eastern Montana and western North Dakota. It can be assumed both formations may have potential water-bearing capacities in the Tolley area, also.

Lemke (1960, p. 26), based on drill cuttings from the J. H. Kline oil well No. 1 near Carpio, North Dakota, describes the Fox Hills Formation as consisting essentially of light gray, fine to medium-grained sandstone, soft medium gray shale and some soft, shaly siltstone containing finely divided white mica. He describes the Hell Creek Formation (Lemke, 1960, p. 27) as alternating beds of gray fine-grained sandstone, gray siltstone, mudstone, soft, silty shale and minor amounts of bentonite and yellowish brown clay ironstone. Inferred thicknesses of both formations would approximate 250 feet each in the Tolley area, indicating the top of the Hell Creek Formation should be encountered at a depth of approximately 500 feet.

The stratigraphy of the bedrock section between the base of the glacial drift and the top of the Hell Creek Formation is known only to well drillers who have drilled wells in the Tolley area. This section is assigned by Lemke and LaRocque to the Fort Union Formation (Fort Union Group). In describing the log of a water well at Bowbells, 20 miles northwest of Tolley, Lemke (1960, p. 34) indicates the Fort Union Group from a depth of 43 to 710 feet, consists essentially of hard gray shale with occassional 3-and 4-foot beds of sandstone, limestone and lignite. Whether or not the same lithology exists in the Tolley area is not known because driller's logs of the deeper wells are not available.

Water well data that is available for the Fort Union strata in the Tolley area indicates the source of water is mainly fine sand, or sandstone

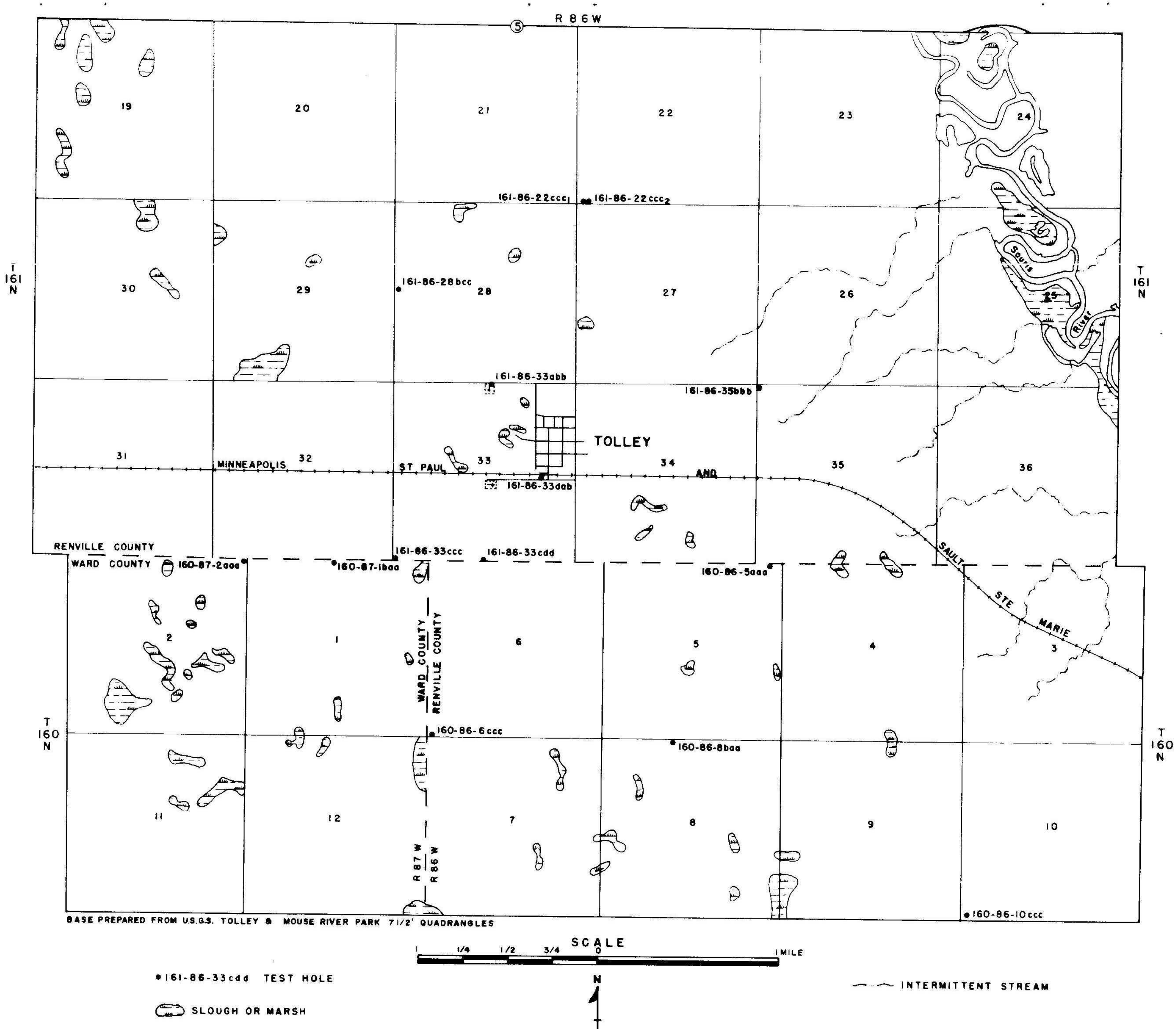

FIGURE 3--MAP OF THE TOLLEY AREA SHOWING LOCATIONS OF TEST HOLES AND RELATED FEATURES

and possibly fractured lignite, of perhaps limited thickness and extent. Many deep well owners reported their wells, if pumped continuously, would become dewatered and pumping would have to be discontinued for a period of time to allow the water level to recover. Well construction may have something to do with this. The gas observed in the Public School well (161-86-33aac) is probably methane ("swamp gas"). Methane occurs naturally as a product of decomposition of organic matter. At the school well the gas was probably trapped by overlying impervious clay and shale beds. Although the Fort Union strata may function as a single hydrologic unit in the Tolley area, it appears doubtful the capacity of a well on a sustained basis could be increased beyond the 15 gallons per minute obtained from the school well when it was drilled in 1961.

Glacial Drift

Glacial drift refers to all stratified or unstratified material deposited directly or indirectly by glacial action. Glacial drift is present throughout the Tolley area and usually varies between 250 and 300 feet thick, the only major exception being in the Souris River valley.

Test drilling revealed the greatest percentage of the drift in the Tolley area is till. Till is characterized by an unstratified mixture of clay, silt, sand grains, pebbles, cobbles and boulders deposited directly by glacial ice with little or no sorting by running water. The upper weathered surface of the till, usually that above the local water table, is characterized by yellow and brown oxidation stains. Below this zone it is olive gray in color and locally termed "blue clay". A buried oxidized till of variable thickness but generally at a depth of about 200 feet was observed in six of the test holes, indicating perhaps at least two major ice advances have crossed the area. Because the major constituents of till are clay and silt, it is considered to be too impermeable to be a source of water supply.

Stratified sediments, including lacustrine clay and silt or sand and gravel, were found associated with the till. Thirty (30) feet of clay and silt were encountered from 220 to 250 feet in test hole 10 (161-87-28bcc, Table 2). The clay and silt deposits, like the till, are too fine-grained to effectively transmit water to wells. Forty-six (46) feet of sorted sand and gravel, separated by two 2-feet thick clay layers, were penetrated in test hole 6 (160-86-8baa) between 217 and 267 feet. The electric log of test hole 6 indicates the clay layers may separate the sand and gravel into three distinct aquifers. An observation well, installed in the second bed of sand and gravel from 235 to 248 feet, had a water level of 27 feet below landsurface. The observation well is $1\frac{1}{4}$-inch in diameter, so no pumping test could be performed. It was pumped with air to obtain a water sample, however.

Sand and gravel deposits are usually water-bearing, but in the Tolley area the poor degree of sorting suggests much of the sand and gravel encountered during test drilling may have been stream-deposited at one time, then later reworked by glacial ice and indiscriminately redeposited as pockets or lenses within a mass of till. Proof of limited extent of these deposits was revealed at test hole 9 (161-86-22ccc, Table 2). Here 15 feet of sand underlain by 9 feet of gravel was penetrated from 98 to 122 feet. After completion of the test hole the rig was moved 10 feet east to install an observation well. Only 6 feet of sand was found between 108 and 114 feet.

Well records (LaRocque, et. at., 1963b) indicate practically all wells developed in the glacial drift in the Tolley area are 30 feet deep or less. The wells were either bored and completed with 8- to 24-inch casing or hand dug and usually 36 to 48 inches in diameter. The drilled bedrock wells generally have 2- and 3-inch casing. Why well drillers ignored the drift below a depth of 30 feet is not completely understood, but the reason probably centers around their knowledge and experience in the area. If the buried sand and gravel deposits associated with the till are pockets and lenses as suspected, they will become rapidly dewatered by continuous pumping; whereas the shallow wells would be recharged by local precipitation and infiltration through joints and fractures in the upper weathered portion of the till and be a dependable source of water as long as rainfall was adequate and care was taken to prevent contamination.

The deposits in the valley of the Souris River valley were not investigated in connection with this survey because of the distance from Tolley. Numerous stock, domestic and municipal wells are presently supplying water along the course of the Souris River and indications are the valley deposits are a source of plentiful ground-water supply.

WATER QUALITY

Ground water is primarily derived from precipitation. The amount and character of minerals dissolved by ground 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 following explanation gives the significance of the various constituents of a complete analysis for a domestic or municipal water supply in North Dakota (Schmid, unpublished report, March, 1965).

Silica (SiO_2) has no physiological or esthetic significance.

Iron (Fe) over 0.3 ppm may cause staining of laundry and fixtures. Over 0.5 ppm iron may be tasted by persons unaccustomed to water with a high iron content. A water with a high iron content will adversely affect the taste of coffee and tea made from such water. Iron removal systems are available.

Calcium and Magnesium (Ca) and (Mg) are the primary causes of hardness. Over 125 ppm magnesium may have a laxative effect on persons unaccustomed to this type of water.

Sodium (Na) has no physiological or esthetic significance, except for persons on salt free diets.

Potassium (K) is essential, in small amounts, to animal nutrition.

Bicarbonate and Carbonate (HCO_3) and (CO_3) have no definite significance in natural water. There are, however, certain standards to be maintained in water treatment plants. A water with high bicarbonate content will tend to have a flat taste.

Sulfate (SO_4) are classed as follows:

0 -300 ppm Low
300 -700 ppm High
Over 700 ppm Very High

250 ppm is the limit set by the U. S. Public Health Service, however, a North Dakota State Department of Health Survey indicates no laxative effect is noticed until sulfates reach 600 ppm. Over 750 ppm there is generally a laxative effect.

Chloride (Cl) over 250 ppm may have a salty taste to persons unaccustomed to high chlorides, persons may become accustomed to higher concentrations.

Fluoride (F) is believed to prevent decay in children's teeth within the limits of 0.9 to 1.5 ppm in North Dakota. Higher concentrations cause mottled teeth.

Nitrate (NO_3) over 45 ppm can be toxic to infants, much larger concentrations can be tolerated by adults. Nitrate in excess of 200 ppm may have a deleterious affect on livestock health.

Boron (B) has no physiological or esthetic significance.

Total Dissolved Solids are classed as follows by a North Dakota State Department of Health Survey:

0 - 500 ppm Low
500 -1400 ppm Average
1400-2500 ppm High
Over 2550 ppm Very High

500 to 1000 ppm total dissolved solids is the limit set by the U. S. Public Health Service; however, persons may become accustomed to water containing 2000 ppm or more.

Hardness is classified by the North Dakota State Department of Health as follows:

0 -200 ppm Low
200 -300 ppm Average
300 -450 ppm High
Over 450 ppm Very High

Calcium and Magnesium are the primary causes of hardness. Hardness, which increases soap consumption, can be removed by water softening systems.

Specific Conductance is a general indication of total dissolved solids and a measure of salinity used primarily for irrigation analyses.

% Na and S.A.R. indicate the sodium hazard of irrigation water.

pH should be between 7.0 and 9.0 for domestic use.

Table 1 lists two complete chemical analyses representative of glacial drift and bedrock waters in the Tolley area. The partial analyses are from LaRocque, et. al. (1963b, Table 6).

In general, bedrock water, from the base of the glacial drift to a depth of about 450 feet is a sodium bicarbonate or sodium sulfate type with high to very high chloride concentrations. These water types are typical of the Tongue River and Ludlow Formations of the Fort Union Group throughout western North Dakota. Below 450 feet to 500 feet or more the water is a sodium chloride type with moderate concentrations of bicarbonates and a low sulfate concentration, and probably represents the Cannonball Formation. All three types of water mentioned are soft with high iron content. An anomalous situation occurs at well 161-86-28cc (Ostlund Well) which is 530 feet deep (See Table 1). Bicarbonates and chlorides are notably lower in water from this well than is common for the bedrock water of the area. A water sample for complete analysis could not be obtained because the farm was vacant at the time this survey was made.

No complete chemical analyses are available of water from wells definitely known to be developed in the Hell Creek or Fox Hills Formations near Tolley. Water in the Hell Creek Formation in western North Dakota is usually a sodium bicarbonate or sodium chloride type. The Fox Hills Formation nearly always yields sodium chloride type water. Both formational waters are characteristically very soft and usually contain high or excessive fluorides.

The analysis of water from well 160-86-8baa is typical of buried sand and gravel deposits in the glacial drift. It is a calcium sulfate type, extremely hard, with high to very high iron content. No analyses are available from shallow drift wells in the Tolley area. A common, but improper, test for shallow well water is its palatability or taste. Samples of such water, should be sent to the local health district or State Health Department periodically to determine the bacteria and nitrate content because of the danger of contamination.

TABLE 1 - CHEMICAL ANALYSES
(Analytical results in parts per million except as indicated)

Location	Well Depth (Feet)	Source*	Date of Collection	Silica (SiO_2)	Total Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Total Dissolved Solids	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	% Sodium	Sodium-absorption-ratio	Specific Conductance (micromhos 25°C)	pH
160-86-5cb	557	Tc	9-11-47							815			1,560									5,540	
160-86-6ab	606	Tc	9- 8-47							945			1,250									4,960	
160-86-8baa	240	Glacial Drift	4-25-67	22	3.5	304	115	289	10	488	0	1,330	64	.2	.2	.27	2,440	1,230	831	34	3.6	2,980	7.6
160-86-8bc	296	Qd	9-11-47							390			54									2,170	
160-86-10cc	682	Tc	9-11-47							975			1,440									5,440	
160-86-10dd	725	Tc	9-11-47							655			2,580									7,960	
160-87-11aa	350	Tlt	9-11-47							1,400			320									2,850	
160-87-11bc	320	Tlt	9-11-47							1,510			320									3,000	
160-87-11dd	410	Tc	9-11-47							1,070			930									4,150	
161-86-19cd	375	Tlt	6-17-47							1,620			250									3,050	
161-86-19dc	365	Tt	6-17-47							1,200			610									3,570	
161-86-20ba	340	Tt	6-18-47							1,040			410									4,080	
161-86-26cb	360	Tt	8-13-47							1,230			730									4,030	
161-86-28cc	530	Tlt	6-17-47							505			250									3,230	
161-86-29dd	440	Tt	6-17-47							1,140			730									3,820	
161-86-30cc	425	Tt	6-17-47							1,270			700									3,860	
161-86-31aa		Tlt	6-18-47							1,480			375									3,480	
161-86-31cc	400	Tlt	6-17-47							1,480			358									3,030	
161-86-33aac	459	Bedrock	4-25-67	8.1	1.4	17	3.5	1,230	4.5	790	0	3.3	1,490	.6	.5	.94	2,960	57	0	98	71	6,020	7.8

* Source abbreviations are taken from LaRocque, et. al., 1963b

Qd indicates glacial drift
Tc, Tlt, and Tt refer to their interpretation of the stratigraphy of the area

SUMMARY

Test drilling revealed only one water-bearing deposit of glacial origin (160-86-8baa) possibly capable of meeting the demands of a municipal supply for Tolley. The quality of the water (See Table 1), however, would require treatment for the removal of iron and hardness. There are records of numerous shallow drift wells, but there is no geologic evidence supporting a significant surficial water-bearing deposit capable of supplying a municipal demand within the area, with the possible exception of the alluvium in the Souris River valley three miles east of Tolley.

The Fort Union Group (Fort Union Formation of some authors) underlies the glacial drift. It is characterized by sodium bicarbonate water in the upper portion underlain by sodium chloride water. Both types are slightly saline, soft and may have high iron content. Either section may also be gaseous and limited as to quantity of water that can be pumped from a single well. The low bicarbonates and chlorides in the Ostlund Well (161-86-28cc) water are anomalous to the area and unexplained.

The Hell Creek and Fox Hills Formations underlie the Fort Union Group in descending order. Neither formation has been recognized to be a source of water in the Tolley area. Both are believed to be potential producers at Tolley. The Hell Creek can be expected to supply sodium bicarbonate type water and the Fox Hills sodium chloride type.

Four (4) possible alternatives Tolley officials might consider in future development of a municipal water supply source are:

1) A large recharge pit excavated several feet below the local water table. A large-diameter screened well could be centrally located and the excavation backfilled with sorted, chlorinated pea gravel. The pit must be located away from sources of contamination, because

recharge will be from local precipitation infiltrating through the soil and underlying glacial drift deposits at the site of the excavation.

2) The deposits in the Souris River valley could be investigated as to quantity and quality of water. A municipal supply from the valley deposits would require three miles of pipeline with approximately 250 feet of lift from the river to Tolley. Surface water from the river should not be considered because water right permits are no longer being issued for Souris River streamflow.

3) A water sample should be obtained from the Ostlund Well about three-fourths (3/4) mile west of Tolley, if possible, for a complete chemical analysis. If the water is acceptable for municipal use, a test hole drilled near the well could determine the nature of the water-bearing formation.

4) A test hole, possibly 1000 feet deep, could be drilled within city limits to determine the existence of aquifers within the Hell Creek and Fox Hills Formations. Water samples from potential aquifers should be obtained during test drilling.

TABLE 2--Logs of Test Holes

Formation	Material	Thickness (Feet)	Depth (Feet)
	160-86-5aaa Tolley Test Hole #7		
Glacial Drift:			
	Topsoil, pebbly sandy silt loam, black	1	1
	Clay, silty and sandy with pebbles and cobbles, dusky yellow to moderate olive brown, moderately soft, moderately cohesive, oxidized (Till)	33	34
	Till, as above, moderate olive brown to light olive gray, partially oxidized, numerous cobbles	14	48
	Boulder, granite, pink	1	49
	Clay, silty and sandy with pebbles and cobbles, olive gray; contains lenses of poorly-sorted sand and gravel	69	118
	Clay, silty to sandy with pebbles, cobbles and occasional boulders, olive gray, moderately soft, cohesive (Till)	106	224
	Clay, very sandy, moderate olive brown, moderately cohesive, oxidized (Till)	18	242
	Clay, silty to sandy with pebbles, olive gray, cohesive, tight (Till)	10	252
	Sand, fine to coarse with gravel and clay lenses, unassorted, 'dirty'	25	277
	Clay, silty and sandy with pebbles and interbedded lenses of poorly-sorted gravel (Till)	17	294
Bedrock:			
	Sand, very fine to fine, clayey, light greenish gray with streaks of dark brown carbonaceous material, moderately soft, moderately cohesive	12	306
	Sandstone, fine-grained, light greenish gray, indurated electric log	1	307

Formation	Material	Thickness (Feet)	Depth (Feet)
	160-86-6ccc **Tolley Test Hole #5**		
Glacial Drift:			
	Topsoil, silty loam, black ---------	1	1
	Clay, silty with pebbles, dusky yellow, moderately soft, slightly cohesive, oxidized (Till) -------	19	20
	Sand, fine and medium, gray, moderately well-sorted ----------------	4	24
	Clay, silty with sand grains, olive gray, moderately soft, cohesive (Till) -------------------------	6	30
	Clay, silty to sandy with pebbles, olive gray, moderately soft, cohesive; occasional thin lenses of medium to coarse sorted sand (Till) -------------------------	41	71
	Clay, sandy with numerous pebbles, olive gray, moderately soft, cohesive, tight (Till) ----------	58	129
	Clay, silty with sand grains and pebbles, olive gray, slightly hard, cohesive, tight (Till) ----	49	178
	Clay, silty and sandy with pebbles, moderate olive brown, moderately soft, moderately cohesive, oxidized (Till) -------------------	18	196
	Gravel, sandy, poorly-sorted; includes thin streaks of clay, 'dirty' ------------------------	8	204
	Clay, silty with sand grains and pebbles, olive gray, slightly hard, tight (Till) -------------	30	234
	Clay, very sandy, olive gray, soft, slightly cohesive --------------	10	244
	Clay, silty and sandy with pebbles and poorly-sorted gravel, olive gray (Till) -------------------	10	254
Bedrock:			
	Clay, very sandy, light greenish gray, interbedded with thin, smooth, light olive gray shale -- electric log	19	273

Formation	Material	Thickness (Feet)	Depth (Feet)
	160-86-8baa **Tolley Test Hole #6**		
Glacial Drift:			
	Topsoil, pebbly silt loam, black ---	1	1
	Clay, silty with pebbles, dusky yellow, moderately soft, cohesive, oxidized (Till) ----------------	5	6
	Clay, silty and very sandy with gravel, moderate olive brown, soft, slightly cohesive, oxidized (Till) ------------------------	20	26
	Clay, silty and sandy with pebbles and cobbles, olive gray, moderately soft, moderately cohesive, includes thin lenses of poorly-sorted sand and gravel, (Till) -	52	78
	Till, as above, with numerous 2- and 3-foot lenses of poorly-sorted gravel ------------------	46	124
	Till, as above, occasional thin lenses of sand and poorly-sorted gravel ------------------------	64	188
	Gravel, sandy and silty, poorly-sorted, 'dirty' ----------------	8	196
	Till, as above, lensed with sand and gravel ------------------------	21	217
	Gravel, fine to coarse, sandy, moderately well-sorted but interbedded, subangular to subrounded	16	233
	Clay, silty, olive gray, soft, cohesive, plastic ----------------	2	235
	Gravel, fine to coarse, sandy, moderately sorted, subangular to subrounded ---------------------	13	248
	Clay, silty, olive gray, moderately soft, cohesive, sticky ---------	2	250
	Gravel, medium and coarse with cobbles, interbedded with fine gravel and some sand, moderately well-sorted but interbedded -----	17	267
	Clay, silty with sand grains, pebbles and cobbles, olive gray, moderately soft, cohesive, thin gravelly streaks ---------------	43	310
Bedrock:			
	Sand, very fine to fine, clayey, greenish gray, tight ------------	5	315
	Shale, silty, varigated grays, smooth, slightly hard -----------	10	325
	Electric log - observation well, 240 feet of 1¼-inch plastic pipe, water sample obtained		

Formation	Material	Thickness (Feet)	Depth (Feet)
	160-86-10ccc U.S.G.S. Test Hole (LaRocque, et.al., 1963b)		
Glacial Drift:			
	Soil	1	1
	Clay, yellow, with some gravel and boulders	25	26
	Clay, sandy, brown, with some gravel	8	34
	Clay, sandy, gray, with some gravel	53	87
	Sand, fine, and gravel	3	90
	Clay, sandy, gray	6	96
	Clay, sandy, gray, with thin strips of gravel	5	101
	Clay, sandy, gray	4	105
	Clay, sandy, gray, with some gravel and lignite fragments	110	215
	Clay, brown	3	218
	Clay, sandy, gray, with some gravel and lignite fragments	63	281
Bedrock:			
	Lignite	1	282
	Clay, sandy, gray	8	290
	Lignite, brown	3	293
	Clay, sandy, gray, with lignite fragments	24	317
	hole filled		
	160-87-1baa Tolley Test Hole #3		
Glacial Drift:			
	Topsoil, silty clay loam, black	1	1
	Sand, coarse, well-sorted, clean	1	2
	Silt, light gray, soft, highly calcareous	3	5
	Clay, silty with sand grains and pebbles, dusky yellow, soft, cohesive (Till)	7	12
	Till, as above, moderate olive brown to olive gray, moderately plastic	11	23
	Sand, medium and coarse, interbedded, well-sorted, subrounded, clean	7	30
	Clay, silty with sand grains, pebbles, occasional cobbles and thin sandy lenses, olive gray, moderately soft (Till)	65	95
	Sand, medium and coarse, light gray, well-sorted, subrounded	4	99

Formation	Material	Thickness (Feet)	Depth (Feet)
	160-87-1baa **Tolley Test Hole #3 (Cont.)**		
	Clay, silty with sand grains and pebbles, thin sandy sections, occasional cobbles, olive gray, moderately soft, cohesive (Till)	77	176
	Till, as above, interbedded with smooth clay, silt, sand and some gravel ------------------------	64	240
Bedrock:			
	Shale, brown, carbonaceous with thin streaks of lignite --------	5	245
	Lignite, black, fissile -----------	9	254
	Shale, light gray with brownish black carbonaceous streaks, slightly to moderately hard, very tight ---------------------	8	262
	electric log		
	160-87-2aaa **Tolley Test Hole #4**		
Glacial Drift:			
	Topsoil, silty loam, black --------	1	1
	Clay, silty with sand grains, pebbles and numerous cobbles, dusky yellow to moderate olive brown, soft, cohesive, plastic, oxidized (Till) -------------------	23	24
	Clay, silty with sand grains and pebbles, olive gray, moderately soft, cohesive (Till) ----------	17	41
	Gravel, medium, well-sorted, subrounded ------------------------	3	44
	Till, as above, silty to sandy ----	20	64
	Till, as above, very sandy and gravelly ----------------------	6	70
	Clay, silty to sandy with pebbles and occasional cobbles, olive gray, moderately soft (Till) ---	56	126
	electric log - bedrock not encountered		

Formation	Material	Thickness (Feet)	Depth (Feet)
	161-86-22ccc Tolley Test Hole #9a (10' East of #9)		
Glacial Drift:			
	Topsoil, pebbly silt loam, black ---	1	1
	Clay, sandy and pebbly, yellowish gray to dusky yellow to moderate olive brown, cohesive, oxidized (Till) ------------------------	24	25
	Clay, silty with sand grains, pebbles and occasional sandy sections, olive gray, moderately soft (Till) --------------------	73	98
	Sand, medium, light gray, well-sorted, subangular, lignitic ----	15	113
	Gravel, fine and medium, moderately well-sorted, angular to subrounded ------------------------	9	122
	Clay, silty with sand grains and pebbles, olive gray, moderately soft, cohesive (Till) -----------	101	223
	Clay, sandy with pebbles and cobbles, light olive gray to olive gray with moderate olive brown sections, slightly hard, slightly brittle, partially oxidized (Till) ------------------------	53	276
	Gravel, predominantly coarse with cobbles, clayey to sandy, 'dirty'	8	284
Bedrock:			
	Shale, silty, medium bluish gray, tight, smooth -------------------	10	294
	Sand, fine, clayey, greenish gray, slightly friable ---------------	11	305
	electric log		
	161-86-22ccc2 Tolley Test Hole #9a (12' east of #9)		
Glacial Drift:			
	Topsoil, pebbly silt loam, black ---	1	1
	Clay, sandy and pebbly, yellowish gray to moderate olive brown, cohesive, oxidized (Till) -------	24	25
	Clay, silty with sand grain, pebbles and occasional sandy sections, olive gray, moderately soft (Till)	83	108
	Sand, fine and medium, clayey, gray, 'dirty' -----------------------	6	114
	Clay, silty to sandy with pebbles, olive gray, moderately soft, cohesive (Till) ------------------	12	126
	bedrock not encountered		

Formation	Material	Thickness (Feet)	Depth (Feet)
	161-86-28bcc Tolley Test Hole #10		
Glacial Drift:			
	Topsoil, pebbly silt loam, black --	1	1
	Clay, sandy and pebbly, dusky yellow to moderate olive brown, moderately soft, cohesive, oxidized (Till) ------------------	33	34
	Till, as above, very gravelly -----	6	40
	Clay, silty to sandy with pebbles and occasional cobbles, numerous sand lenses, olive gray, moderately soft, cohesive (Till) -----	82	122
	Clay, silty with pebbles and cobbles, occasional sandy sections, olive gray, stiff, cohesive, (Till) ------------------------	58	180
	Clay, sandy with pebbles, moderate olive brown, slightly hard, moderately brittle, oxidized (Till)	16	196
	Till, as above, interbedded gravel lenses ------------------------	13	209
	Till, as above, less gravel, sandy, oxidized ----------------------	11	220
	Clay and silt, interbedded, laminated, olive gray to olive black, plastic, sticky, tight ---------	30	250
	Clay, silty and sandy with pebbles, olive gray, moderately soft, cohesive, gravel at the base (Till) ------------------------	32	282
Bedrock:			
	Shale, silty, light greenish gray, smooth, slightly brittle, tight electric log	18	300

Formation	Material	Thickness (Feet)	Depth (Feet)
	161-86-33abb U.S.G.S. Test Hole 2326		
Glacial Drift:			
	Clay, silty to sandy with pebbles and cobbles, dark yellowish brown, soft, cohesive, numerous gravel layers, oxidized (Till) --	29	29
	Clay, silty to very sandy with pebbles and occasional cobbles and boulders, olive gray to dark greenish gray, moderately soft, moderately cohesive, (Till) -----	66	95
	Till, as above, less sand ----------	113	208
Bedrock:			
	Clay, sandy, dark greenish gray and olive gray, hard, cohesive, compact -------------------------	33	241
	electric log		
	161-86-33ccc Tolley Test Hole #2		
	Roadfill, compacted clay, black ----	4	4
Glacial Drift:			
	Clay, silty with occasional sand grains and pebbles, dusky yellow to moderate olive brown, soft, very cohesive, oxidized (Till)---	16	20
	Clay, silty to sandy with pebbles and occasional cobbles, olive gray, moderately soft, cohesive, tight (Till) -------------------	13	33
	Sand, medium to coarse, tan, well-sorted, subrounded --------------	2	35
	Clay, silty with sand grains, olive gray, moderately soft, cohesive, tight (Till) -------------------	2	37
	Sand, medium to coarse with fine gravel, well-sorted -------------	4	41
	Clay, silty to sandy with coarse sand grains and pebbles, olive gray, moderately soft, cohesive (Till) --------------------------	43	84
	no electric log		

Formation	Material	Thickness (Feet)	Depth (Feet)
	161-86-33cdd Tolley Test Hole #1		
Glacial Drift:			
	Topsoil, pebbly fine sandy loam, black -------------------------	1	1
	Clay, silty to pebbly, light gray, soft (Till) -------------------	3	4
	Gravel, poorly-sorted, very rusty -	1	5
	Clay, silty and sandy with pebbles, dusky yellow to moderate olive brown, soft (Till) ------------	6	11
	Clay, silty with much fine sand, numerous pebbles, olive gray, moderately soft, cohesive (Till)	45	56
	Clay, olive gray to olive black, moderately soft, cohesive, plastic, tight --------------------	6	62
	Clay, silty and sandy with numerous limestone and lignite grains and pebbles, occasional cobbles and boulders, olive gray, moderately soft, cohesive (Till) ---------	138	200
	Clay, silty and sandy with pebbles, moderate olive brown, moderately soft, cohesive, partially oxidized (Till) ------------------	12	212
	Clay, silty to very sandy with pebbles and cobbles, olive gray, moderately soft, very cohesive, (Till) -----------------------	42	254
	Till, as above, very clayey with numerous cobbles and boulders --	19	273
	Gravel, clayey, poorly-sorted, subangular -----------------------	5	278
Bedrock:			
	Shale, silty, light olive gray to olive gray with interbedded greenish gray sandy shale and carbonaceous material ---------- electric log	16	294

Formation	Material	Thickness (Feet)	Depth (Feet)
	161-86-33dab Tolley Test Hole #11		
Glacial Drift:			
	Topsoil, pebbly loam, black --------	1	1
	Clay, silty and sandy with pebbles, yellowish gray and dusky yellow, soft, crumbly, fractured, oxidized (Till) -------------------	9	10
	Clay, silty and sandy with pebbles, moderate olive brown to light olive gray, soft, slightly cohesive, partially oxidized (Till) -	9	19
	Clay, silty to sandy with pebbles and thin lenses of sorted sand, olive gray, moderately soft, cohesive (Till) ------------------	56	75
	Sand, medium, gray, well-sorted, subrounded ---------------------	5	80
	Clay, silty to sandy with pebbles, olive gray, moderately soft, cohesive (Till) ------------------	25	105
	Sand, medium, interbedded with fine sand and clayey silt, light gray, loose to slightly cohesive ------	8	113
	Clay, silty to sandy with pebbles, very sandy sections and occasional streaks of gravel, sandy sections usually lignitic,olive gray, soft to moderately soft, generally cohesive (Till) ------------------	108	221
	Gravel, medium and coarse, little sand, moderately well-sorted, subangular and subrounded -------	9	230
	Clay, silty with sand grains and pebbles, olive gray, moderately soft, very cohesive, tight (Till)	20	250
	Silt, clayey, light olive gray and olive gray, laminated, soft, slightly to moderately cohesive -	15	265
	Clay, silty to sandy with pebbles and sorted lenses of clay, sand and gravel, boulder at 294 feet, olive gray, moderately soft, cohesive (Till) ------------------	31	296
Bedrock:			
	Shale, silty and sandy, thinly interbedded, varigated grays, greens and browns, carbonaceous, moderately soft to slightly hard ------ electric log	34	330

Formation	Material	Thickness (Feet)	Depth (Feet)
	161-86-35bbb **Tolley Test Hole #8**		
Glacial Drift:			
	Topsoil, pebbly loam, black -------	1	1
	Clay, sandy and gravelly, yellowish gray to dusky yellow, soft, crumbly, fractured, oxidized (Till) ------------------------	6	7
	Clay, silty to sandy with pebbles and cobbles, dusky yellow to moderate olive brown, soft to moderately soft, slightly to moderately cohesive, oxidized (Till) ------------------------	19	26
	Clay, silty to sandy with pebbles and occasional thin sorted sand and gravel lenses, olive gray, moderately soft, cohesive (Till)	156	182
	Till, as above, contains much poorly-sorted, 'dirty' gravel --	32	214
	Clay, silty and sandy with pebbles and cobbles, occasional sand lenses, olive gray, slightly hard, tight (Till) -------------	40	254
	Clay, sandy with pebbles and sections of loose sorted medium-grained sand, olive gray, moderately soft, generally moderately cohesive (Till) ---------------	14	268
Bedrock:			
	Sand, very fine to fine, clayey, greenish gray, soft, slightly friable, lignitic -------------	10	278
	Sandstone, fine-grained, light greenish gray, indurated, $CaCO_3$-cement ------------------------		278+
	electric log		

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