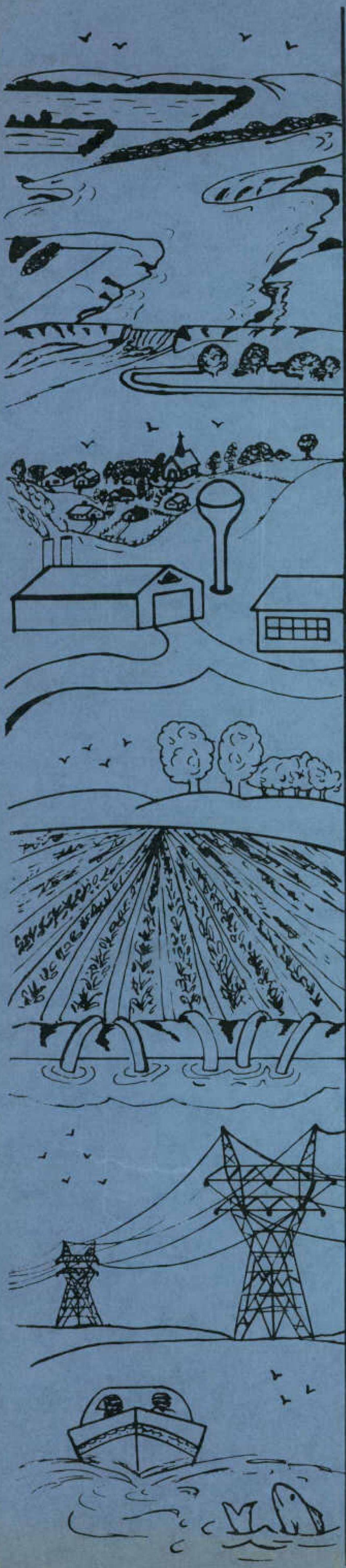


GROUND-WATER SURVEY OF THE AMENIA AREA

CASS COUNTY, NORTH DAKOTA

N.D.S.W.C.C. PROJECT NO.1322

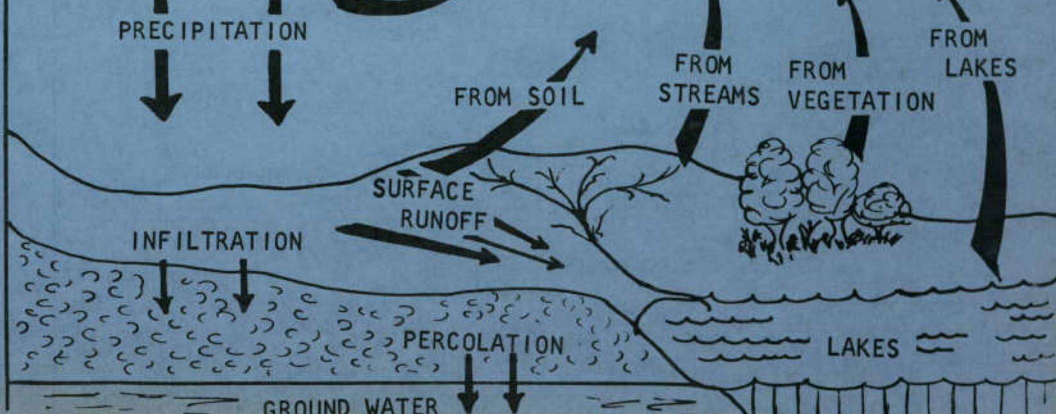
By
Larry L. Froelich, Geologist

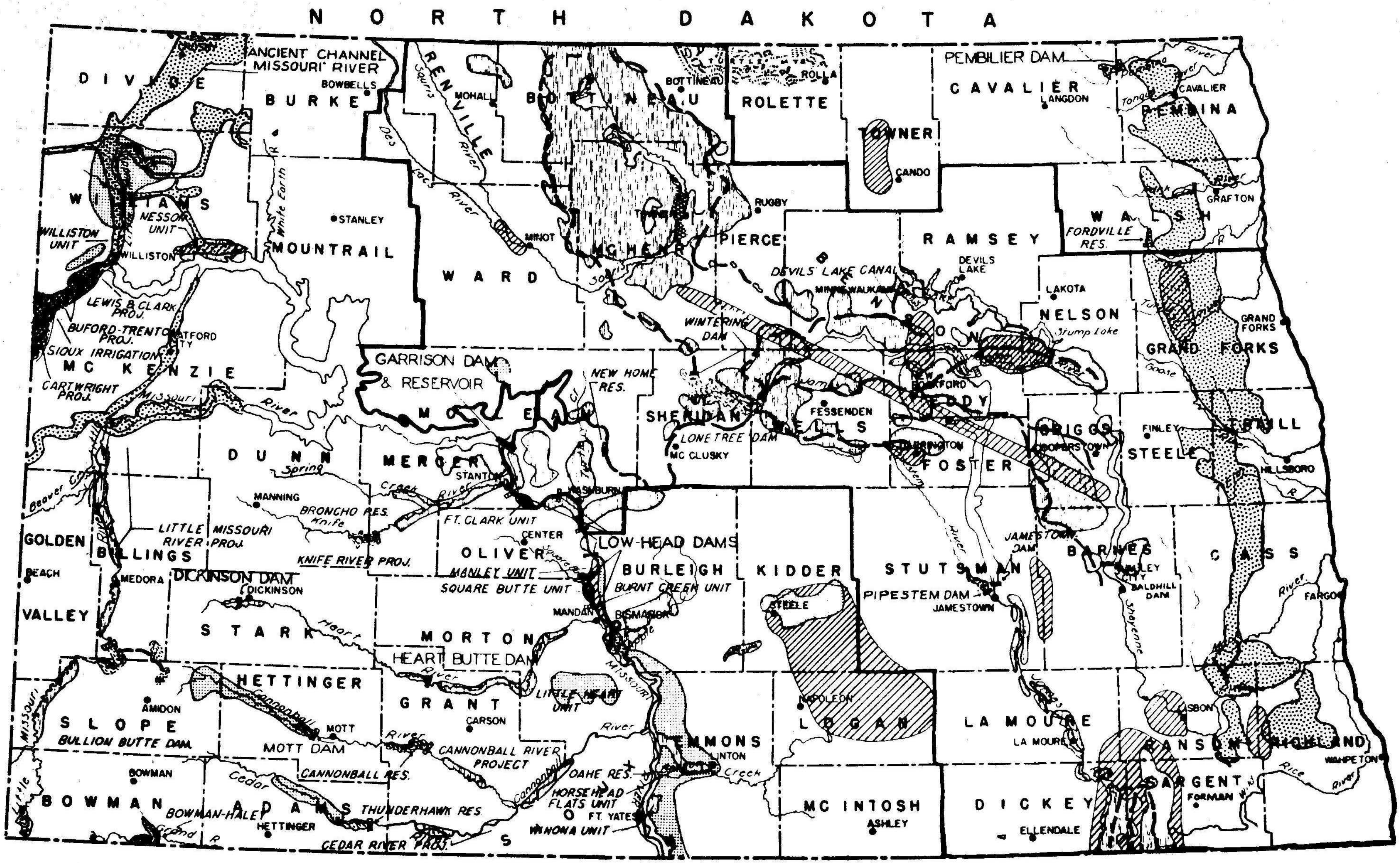
NORTH DAKOTA GROUND WATER STUDIES

NO. 59

PUBLISHED BY
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
1301 STATE CAPITOL, BISMARCK, NORTH DAKOTA

1964





NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

LANDS UNDER IRRIGATION

AREAS CONSIDERED IRRIGABLE

AREAS BEING INVESTIGATED

PROPOSED FOR INVESTIGATION

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CASS COUNTY, NORTH DAKOTA

INTRODUCTION

Amenia, population 117 (1960 census), is in central Cass County (See Fig. 1). The village is served by a branch line of the Great Northern Railway and State Highway 18. The average temperature is 40.9°F as recorded in the annual summaries of the U. S. Weather Bureau from 1950 to 1962. Average precipitation for the same period is 20.51 inches. The elevation is 954 feet above sea level at the Great Northern depot in Amenia.

This study was made by the State Water Commission in June 1963 to locate an additional supply of water for the village. The survey was under the direct supervision of the author. Test drilling was done by Lewis and Lanny Knutson. Chemical analyses were performed by the State Laboratories, Bismarck.

Simpson (1929, p. 97-108) discussed the geology and ground water of Cass County in a general study of the State. Abbott and Voedisch (1938, p. 50-51) include a chemical analyses from the Amenia area in their discussion of municipal supplies. Two North Dakota Ground-Water Studies have been performed near Amenia; these are the Fargo study (Dennis, et al., 1949) and the Hunter area (Brookhart and Powell, 1961). A county-wide ground-water study is presently in progress in Cass County. Field work is scheduled for completion in 1965, reports are scheduled for 1967.

The present water supply (1964) at Amenia consists of two flowing wells. Well 1, on the west side of main street, is 271 feet deep, and Well 2, on the east side, is 286 feet deep. Water storage facilities have not been provided for, therefore, the water is drained into an underground pressure tank to

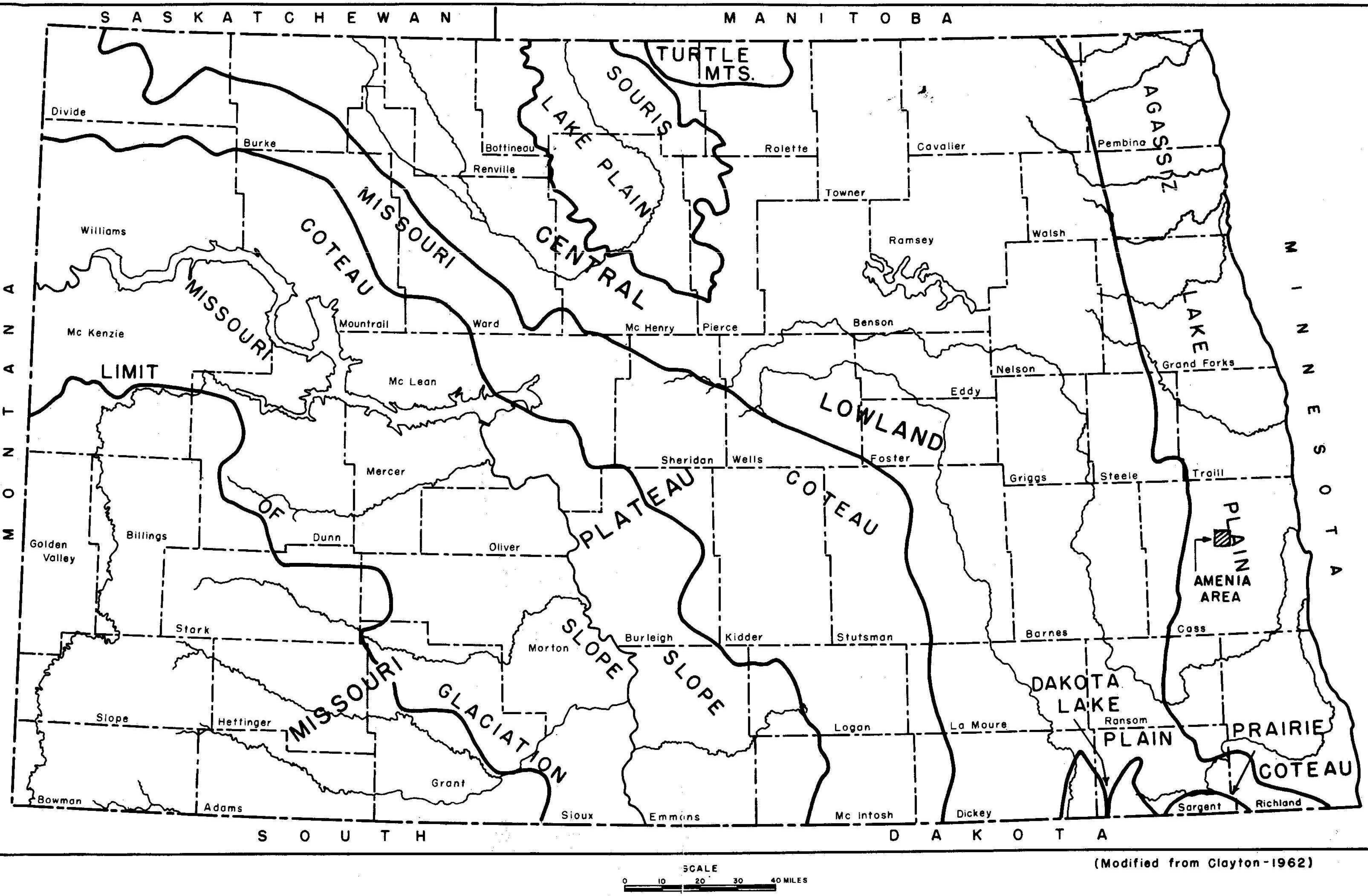

FIGURE I--MAP SHOWING PHYSIOGRAPHIC PROVINCES OF NORTH DAKOTA AND LOCATION OF THE AMENIA AREA

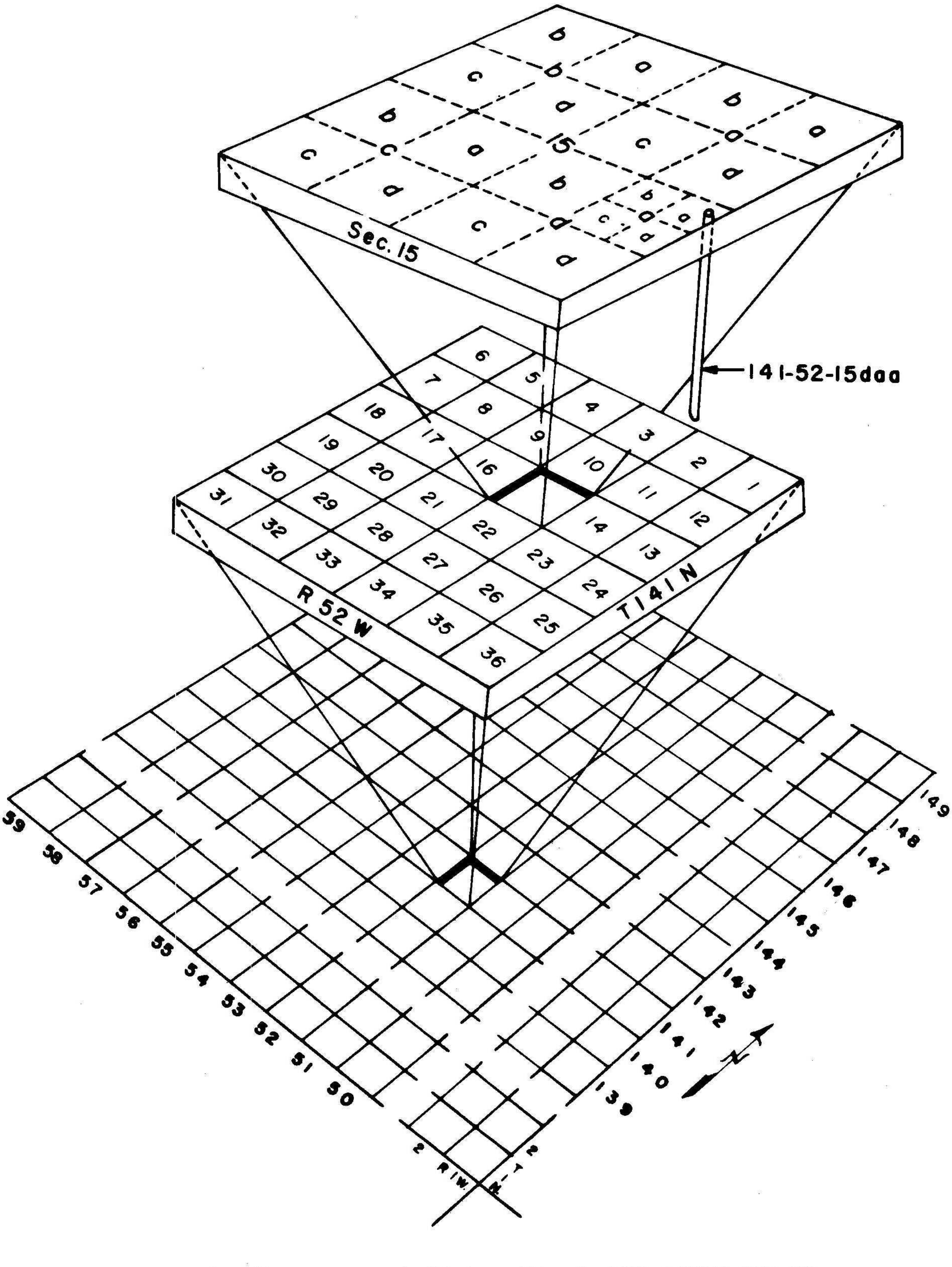

FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

supply water, under pressure, to the residents of the village. The water supply is generally adequate under average conditions; but because of the low yield of the wells (approximately 5 gallons per minute each) and the lack of storage facilities, water is not available for peak demands or fire protection. Water mains and laterals were installed several years ago and are reported adequate.

The well-numbering system used in this report, illustrated in Fig. 2 is based upon the location of the well within the grid established by the U. S. Bureau of Land Management's survey of the area. The first number denotes the township north of the base line that extends laterally across the middle of Arkansas, - the second number denotes the range west of the fifth principal meridian, - and 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). Thus, well 141-52-15daa is in the NE$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$ of Section 15, Township 141 North, Range 52 West.

GEOLOGY AND HYDROLOGY

The Amenia area, as described in this report, consists of 16 square miles in Township 141 North, Range 52 West. The area is located on a broad flat glacial-lake plain formerly occupied by glacial Lake Agassiz. The only topographic features worthy of note in the area are the shallow valley of the Rush River and the gentle ridge that trends northeast-southwest from the south center of Section 21 (Fig. 3).

The Rush River is a Recent stream with few tributaries. Alluvium in the narrow channel is thin and consists essentially of clay and silt. It is not a good source of water supply in the area, although well 141-52-24bdd

(Fig. 3) is apparently receiving a meager supply from a sandy alluvial deposit. The U. S. Geological Survey maintains a gaging station near the highway bridge .6 mile north of Amenia. The drainage area upstream from the station consists of 116 square miles. Average discharge of the Rush River at the gaging station for 16 years (1946-1962) was 7.51 c.f.s. (cubic feet per second). The Rush River is perennial, however, short periods of no flow have been recorded during each year.

The gentle ridge in Section 21 was believed to be an extension of the McCauleyville Beach, a depositional feature of glacial Lake Agassiz. No beach deposits were encountered in test hole 6 (Fig. 3), therefore, the ridge is believed to be an erosional feature of Lake Agassiz and probably a wave-cut terrace of scarp. No water-bearing materials were encountered at this site.

Surface materials throughout most of the Amenia area consists of yellowish brown to gray lake clay. The thickness of the clay ranges from 17 to 31 feet and averages 26 feet. A second buried clay unit was encountered in test holes 2 and 5 with thicknesses of 5 and 12 feet, respectively. The second clay unit may represent local ponding of glacial meltwater during the last glacial advance or they may indicate a glacial lake prior to Lake Agassiz. Thirteen test holes in the Hunter area (Brookhart and Powell, 1961), 13 miles north of Amenia, encountered a second clay unit which strongly suggests the existence of two glacial lakes in the Red River Valley. The lake clays do not yield water to wells.

The principal source of water supply to wells in the Amenia area is the sand and/or gravel deposits associated with glacial till. Till is a heterogeneous mixture of clay, silt, sand, pebbles, cobbles, and boulders that was deposited by the glacier with little or not sorting by running water. The

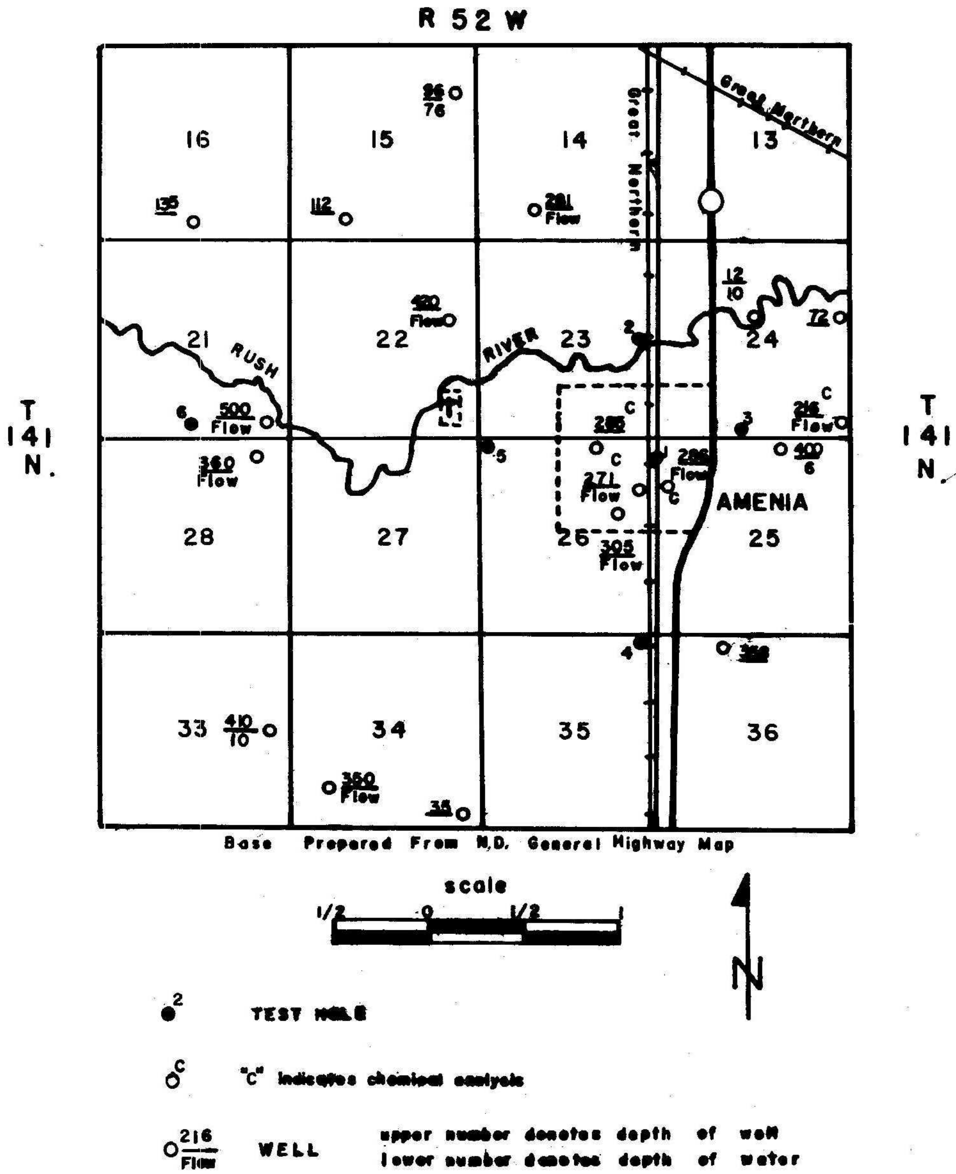

FIGURE 3--- MAP OF AMENIA AREA SHOWING LOCATION OF SELECTED WELLS AND TEST HOLES

sand and gravel was deposited by streams on, along, within, or beneath the ice sheet. Two distinct tills are present in the Amenia area; a dark gray, tight, clayey till and a light gray, more permeable, very sandy clay till. Both tills are essentially impermeable, but function as a weak aquifer supplying water to the deposits of sand and gravel. Wells penetrating sand or gravel recover water under artesian pressure and many are flowing wells. The pressure is believed,by the author,to be due to valley artesian conditions with the increase in head to the west where the till emerges in the Central Lowland from beneath the Agassiz Lake Plain (Fig. 1).

The Benton Shale immediately underlies the glacial drift. It consists essentially of a brownish black, silty to sandy clay or shale. In test hole 1, (Fig. 3, Table 4) a white to light greenclay was encountered below typical Benton Shale sediments. This clay is believed to be a decomposition product of underlying granitic rocks. Unaltered granite probably exists at a depth of 614 feet at test hole 1, however, samples were not recovered for positive identification. Neither the Benton Shale or the granite, unaltered or decomposed, are sources of a municipal supply in the Amenia area.

WATER QUALITY

The quality of water for public supply and domestic use commonly is evaluated in relations to standards of the U. S. Public Health Service for drinking water. These standards, adopted in 1914 to protect the health of the travelling public, were revised several times in subsequent years. The latest revision by the U. S. Public Health Service (1962) is, in part, as follows:

Table I -- Drinking water standards of the U. S. Public Health Service -

Constituent	Maximum Concentration
Iron (Fe)- - - - - - - - - - - -	.3 ppm 1/
Sulfate (SO_4) - - - - - - - - -	250 ppm
Chloride (Cl)- - - - - - - - - -	250 ppm
Fluoride (F) - - - - - - - - - -	1.7 ppm 2/
Nitrate (NO_3)- - - - - - - - - -	45 ppm
Dissolved Solids - - - - - - - -	500 ppm

1/ ppm - parts per million
2/ Based on 5-year annual average of maximum daily air temperature at Amenia, North Dakota

Table 3 lists chemical analyses of 5 water well samples, one taken directly from the Rush River, and one taken directly from the tap in the post office. All samples, with the exception of the WDAY-TV transmitter station well and the tap water, exceeded the limit of iron, however iron concentration up to 1 ppm is still considered good. Sodium content is high in all but the Rush River sample. Sodium in percentage over 50% in water used on plants, lawns, and gardens is harmful. The sulfate content is exceeded in all samples and may exert a laxative effect on persons unaccustomed to drinking the water. The chloride concentration was exceeded in all but the Rush River and tap water samples, however, the concentrations were not sufficiently high to give the water a salty taste.

The school well and village well 1, and also well 141-52-23 taken from Abbott and Voedisch (1938), contain excessive concentrations of fluorides. Determination of fluoride in drinking water has become very important following the discovery (Smith, et al., 1931) that it is the definite causitive agent to the disfiguring dental malady known as enamel dystrophy, or more commonly as mottled enamel of teeth. Extremely small concentrations of fluoride are

TABLE 2 -- RECORD OF

(analytical results in parts

Location	Depth of well (feet)	Aquifer	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)
141-52-22dda	-	Rush River	6-13-63	25	.76	142	69	130	17	444
*141-52-23	300	-	1936(?)	35	.8	82	50	625	--	327
141-52-24ddd	216	Sand	6-13-63	20	.30	124	54	302	13	249
141-52-25bbc	280	-	6-13-63	23	.60	120	49	524	17	298
**141-52-26bbb	Tap in post office	-	11- 6-62	---	0	120	46	352	--	232
141-52-26ada	259.5	-	6-13-63	17	.56	40	19	720	14	273
141-52-26aba	285	-	6- 2-63	22	.44	56	15	738	7.5	322

* From Abbott and Voedisch, 1938, p. 50-51

** From N. D. State Department of Health, 1964

CHEMICAL ANALYSES

per million except as indicated)

Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Total dissolved solids	Total hardness as $CaCO_3$	Total hardness non-carbonate	% Sodium	Sodium Absorption Ratio SAR	Specific conductance mmhos/cm	pH
9.6	491	46	.6	3.0	.15	1,220	640	260	30	2.3	1,893	8.3
--	920	393	2.2	11	--	2,364	268	--	--	--	--	--
0	571	294	.6	5.0	.86	1,576	530	325	55	5.8	2,370	7.9
0	818	402	.8	6.0	2.10	2,162	500	255	69	11	3,168	8.1
36	825	71	.5	4.4	--	1,687	490	--	--	--	2,010	8.4
14	900	394	2.7	5.5	2.70	2,230	180	0	89	24	3,574	8.4
0	914	418	3.4	6.0	2.56	2,394	200	0	88	24	3,762	8.2

sufficient to produce harmful effects, however, fluoride in concentrations of .8 to 1.5 ppm in water drunk by children is generally believed to be beneficial in the reduction of tooth decay. Other than mottled enamel, Abbott (1937, p. 10) states other pathological effects caused by excessive fluorides such as alteration of bone structure, enlargement of the thyroid gland, reduction of calcium content of the blood with serious disturbance of the body metabolism, high blood pressure, and the development of marked nervous disorders.

Total dissolved solids are quite high in all samples. The U. S. Public Health Service allows a concentration of 1000 ppm where water of better quality is not available, however this limit was also exceeded in all samples. Nearly all waters that contain more than 1000 ppm dissolved solids have a taste due to the dissolved minerals. The North Dakota State Department of Health recommends a maximum hardness concentration of 140 ppm. This limit was exceeded in all samples, but the concentration can be easily removed by a water softener.

Perhaps the best source of acceptable quality water in the Amenia area is the Rush River. The water from the WDAY-TV station well is of fairly good quality compared to other wells in the area.

RECOMMENDATIONS

There are three possible ways residents of the Amenia area may enhance their water supply. First, one or more additional wells may be drilled into the glacial drift. A test hole should precede each well to determine if water-bearing deposits of sand and gravel are available at the site. The well or wells will yield only small amounts of water and the quality may be such that it will require treatment. Secondly, an artificial reservoir might be constructed near the Rush River and water from the river can be utilized for the municipal supply. Lastly, the residents of Amenia might contact residents of other villages and towns in the vicinity, as well as the farmers, and construct a pipeline network to a proven area of readily available good quality water.

TABLE 3 -- RECORDS OF SELECTED WELLS AND TEST HOLES

Type of well: Dr, drilled; Du, dug

Use of water: D, domestic; PS, public supply; S, stock; T, test hole

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Use of water	Aquifer	Remarks
141-52-14cdc	Frank King	281	3	Dr	-	Flow	D,S	-	Hard.
141-52-15ada	Omar Erb	96	3	Dr	-	76	D,S	Gravel	Hard, doesn't kill grass.
141-52-15ccd	Elmer Nohr	112	3	Dr	-	-	D,S	-	Hard.
141-52-16cdd	Clemence Kuklok	135	3	Dr	-	-	D,S	-	Soft.
141-52-21cdd	Test hole 6	63	4 3/4	Dr	6-22-63	-	T	-	See log.
141-52-21ddd	Smith Investment Co.	500	2	Dr	-	Flow	D,S	-	
141-52-22add	C.G. Anderson	420	2	Dr	-	Flow	D,S	-	Salty.
141-52-23daa	Test hole 2	357	4 3/4	Dr	6-18-63	-	T	-	See log.
141-52-24add	Paul L. Cripe	72	3	Dr	-	-	D,S	-	
141-52-24bdd	Paul L. Cripe	12	36	Du	-	10	D,S	Sand	Hard.
141-52-24dcc	Test hole 3	357	4 3/4	Dr	6-19-63	-	T	-	See log.
141-52-24ddd	WDAY-TV station	216	4	Dr	1962	Flow	D	12' of sand	Chemical analysis.
141-52-25abb	Eugene Cederburg	400	3	Dr	-	6	D	Sand	Hard, doesn't kill grass.
141-52-25bbb	Test hole 1	614	4 3/4	Dr	6-21-63	-	T	-	See log.
141-52-25bbc	Village well #2	286	5	Dr	-	Flow	PS	-	Chemical analysis.
141-52-26aba	Amenia School	285	4	Dr	-	-	D	-	Chemical analysis.
141-52-26ada	Village well #1	271	5	Dr	-	Flow	PS	-	Chemical analysis.
141-52-26ad	Monroe Fornes	305	3-1¼	Dr	-	Flow	D,S	Gravel	Hard.
141-52-26bbb	Test hole 5	357	4 3/4	Dr	6-20-63	-	T	-	See log.
141-52-28aa	Kenneth Lindstrom	360	2	Dr	-	Flow	D,S	Gravel	Soft, salty, kills grass.
141-52-33add	Leo. L. Baumler	410	3-1¼	Dr	-	10	D,S	Fine sand	Soft, kills grass & weeds.
141-52-34cca	William Johnson	350	3	Dr	-	Flow	D	-	Soft, salty, kills grass.
141-52-34ddd	Alphons Schneider	35	3	-	-	-	D	-	Soft, salty, doesn't kill grass.
141-52-35aaa	Test hole 4	357	4 3/4	Dr	6-19-63	-	T	-	See log.
141-52-36baa	William Sinz	358	3-1¼	Dr	-	-	D,S	-	Soft.

TABLE 4 -- Logs of Test Holes

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 6 141-52-21cdd			
Glacial Drift:				
	Topsoil, very fine sandy loam, black...	2	0	2
	Clay, sandy, yellowish gray............	3	2	5
	Clay, silty to sandy with pebbles, dusky yellow to moderate olive brown, moderately soft, oxidized (till)...........................	18	5	23
	Clay, silty to sandy with pebbles, olive gray, tight, unoxidized (till).	17	23	40
	Silt, clayey with sand grains and pebbles, olive gray, tight, cohesive (till)...........................	23	40	63
	Test Hole 2 141-52-23daa			
Glacial Drift:				
	Topsoil, silty loam, black............	1	0	1
	Clay, silty to sandy, yellowish gray, soft............................	2	1	3
	Clay, sandy, dark to dusky yellowish brown, soft, occasional snail fragments.........................	7	3	10
	Clay, dusky yellow to light olive brown with greenish gray and black areas, soft, smooth, plastic.........	12	10	22
	Silt, clayey with sand grains and pebbles, dusky yellow, soft, cohesive, oxidized (till)....................	17	22	39
	Silt, clayey with sand grains and pebbles, olive gray, tight, unoxidized (till)...........................	26	39	65
	Clay, olive gray, soft, smooth,plastic.	5	65	70
	Clay, sandy, olive gray, moderately soft to slightly hard; contains thin lenses of fine to medium, subangular to subrounded, poorly sorted gravel (till)...........................	5	70	75
	Clay, silt to sandy with pebbles, olive gray, moderately soft, tight (till)...........................	32	75	107
	Clay, very sandy, light olive gray, soft, moderately compacted, gravelly in spots (till)..................	27	107	130

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 2 141-52-23daa (continued)			
	Gravel, fine to coarse, subangular to subrounded, poorly sorted..........	3	130	133
	Clay, sandy with pebbles, olive gray, moderately soft (till); very gravelly, rough drilling........................	17	133	150
	Boulder, limestone....................	2	150	152
	Clay, silty to sandy with pebbles and cobbles, olive gray, moderately soft, tight; rough drilling in spots (till).	58	152	210
	Clay, silty and sandy, olive gray, variable amounts of gravel (till).....	27	210	237
	Clay, sandy with numerous gravel lenses, olive gray, rough drilling (till).....	33	237	270
	Clay, very sandy, light olive gray, soft, slightly friable, gravelly (till)	72	270	342
Benton Shale:				
	Clay, silty to sandy, olive gray to olive black, moderately soft,massive, noncalcareous; contains light olive gray streaks and light greenish gray silt and fine sand..................	15	342	357
	Test Hole 3 141-52-24dcc			
Glacial Drift:				
	Topsoil, silty loam, black..............	2	0	2
	Silt, clayey, olive black, crumbly, porous.............................	3	2	5
	Clay, silty, yellowish gray, soft, oxidized...........................	5	5	10
	Clay, yellowish gray to dusky yellow with greenish gray areas, soft, smooth, plastic, slippery, tight, oxidized....	16	10	26
	Clay, siltyand sandy with pebbles, olive gray, soft, cohesive,unoxidized (till)............................	42	26	68
	Gravel, fine to coarse, poorly sorted...	4	68	72
	Clay, silty with sand and pebbles, olive gray, soft, tight, cohesive (till)....	28	72	100
	Clay, very sandy, light olive gray, soft, slightly friable, gravelly near base of section (till)...................	27	100	127

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 3 141-52-24dcc (continued)			
	Clay, silty with sand, pebbles and cobbles, olive gray, moderately soft, tight (till)........................	63	127	190
	Clay, very sandy, light olive gray, moderately soft, slightly friable; very gravelly and rough drilling in parts (till)......................	63	190	253
	Gravel, fine to coarse, clayey..........	7	253	260
	Clay, sandy, olive gray, many thin gravel layers (till).................	12	260	272
	Clay, silty to very sandy, light olive gray to olive gray, moderately soft to slightly hard; gravelly and hard drilling in parts (till)..............	67	272	339
Benton Shale:				
	Clay, silty, olive black, moderately soft, moderately to tightly consolidated, noncalcareous.................	18	339	357
	Test Hole 1 141-52-25bbb			
	Railroad fill - fine to coarse sand and fine to medium gravel...............	4	0	4
Glacial Drift:				
	Clay, light olive gray, soft, smooth, plastic..............................	6	4	10
	Clay, dusky yellow to light olive gray, smooth, slippery, oxidized............	16	10	26
	Clay, olive gray, soft, smooth, unoxidized..............................	6	26	32
	Clay, moderate olive brown, soft, smooth, partially oxidized..................	4	32	36
	Clay, silty to sandy with pebbles, moderate olive brown, soft, cohesive, oxidized (till)....................	4	36	40
	Clay, silty to sandy with pebbles, olive gray, tight, unoxidized (till); contains interbedded olive gray uniformly sorted silty clay.........................	36	40	76
	Sand, fine to coarse, moderately sorted.	5	76	81

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 1 141-52-25bbb (continued)			
	Clay, silty to sandy with pebbles and gravel stringers, olive gray, moderately soft, cohesive (till); rough drilling in parts.............	22	81	103
	Clay, very sandy, light olive gray, soft, moderately compacted, slightly to moderately cohesive (till); very gravelly with cobbles and boulders, rough drilling.....................	36	103	139
	Clay, silty to sandy with pebbles, cobbles, and boulders, olive gray, moderately soft, tight, cohesive (till)...........................	27	139	166
	Gravel, fine to coarse, poorly sorted..	2	166	168
	Clay, silty to sandy with sand and gravel stringers,olive gray, cohesive (till); rough drilling.....................	16	168	184
	Clay, very sandy, light olive gray, soft, moderately compacted, cohesive (till); gravelly in parts...........	12	184	196
	Clay, sandy with pebbles, olive gray, moderately soft, tight, cohesive (till); occasional gravelly stringers, cobbles, and boulders................	61	196	257
	Gravel, fine to coarse, poorly sorted, rough drilling.....................	3	257	260
	Clay, silty to sandy with pebbles and thin gravel lenses, olive gray, moderately soft, tight, cohesive, moderately plastic (till)...........	55	260	315
	Sand, fine to medium, olive gray, well-sorted, subrounded.................	4	315	319
	Clay, silty to sandy, olive gray, moderately soft, cohesive (till); occasional gravel stringers, cobbles, and boulders.......................	19	319	338
	Till, as above, cobbles and boulders more common.........................	19	338	357
Benton Shale:				
	Clay, silty, olive black, moderately soft, slightly calcareous; with sandy reddish brown clay and pitch black oily clay.............................	19	357	376

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 1 141-52-25bbb (continued)			
	Clay, sandy (very fine), light greenish gray, rounded, friable, micaceous, noncalcareous; with light buff to yellowish gray clay and olive gray silt	17	376	393
Bedrock, Undifferentiated:				
	Clay, white to light gray, very soft, noncalcareous	6	393	399
	Clay, dusky yellow to moderate olive brown, soft, oxidized (?), slightly calcareous	11	399	410
	Clay, olive gray, soft, calcareous; included partially oxidized (?) moderate olive brown streaks and calcite crystals	29	410	439
	Clay, light green, soft, smooth, noncalcareous; with white, soapy clay and occasional indurated areas	91	439	530
	Clay, white and light green, smooth	84	530	614
	Note: Unaltered granite is believed to exist at 614 feet, but no samples were recovered.			
	Test Hole 5 141-52-26bbb			
Glacial Drift:				
	Topsoil, silty loam, black	2	0	2
	Clay, dark yellowish brown to yellowish gray, soft, smooth, plastic, oxidized.	23	2	25
	Clay, olive gray, soft, smooth, plastic, unoxidized	7	25	32
	Clay, silty to sandy with pebbles, olive gray, moderately soft, tight, cohesive (till)	29	32	61
	Clay, olive gray, smooth, soft, plastic	12	61	73
	Clay, silty to sandy with pebbles and gravel stringers, olive gray, moderately soft, cohesive (till); rough drilling	10	73	83

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 5 141-52-26bbb (continued)			
	Gravel, fine to coarse, poorly sorted, generally subrounded................	3	83	86
	Clay, silty to gravelly, olive gray (till)..........................	11	86	97
	Gravel, fine to medium, moderately sorted..........................	2	97	99
	Clay, sandy to gravelly, light olive gray (till)......................	7	99	106
	Gravel, fine to medium, moderately sorted..........................	2	106	108
	Clay, very sandy with pebbles and gravel stringers, light olive gray, soft, slightly friable (till)............	26	108	134
	Sand, fine to medium, clayey, light olive gray, loose, well-sorted......	4	134	138
	Clay, silty to sandy with pebbles, cobbles and boulders, olive gray, moderately soft, tight, cohesive (till); rough drilling....................	42	138	180
	Clay, sandy to gravelly, light olive gray, moderately soft, slightly friable (till)....................	30	180	210
	Clay, silty to sandy with cobbles and boudlers, olive gray, moderately soft, tight, cohesive (till); rough drilling..........................	72	210	282
	Clay, silty to sandy with gravel stringers, olive gray, moderately soft, cohesive (till)..........................	52	282	334
Benton Shale:				
	Clay, sandy, olive black, soft,moderately consolidated, noncalcareous; contains light gray and grayish brown sandy clay..........................	23	334	357

TABLE 4 -- Logs of Test Holes - Continued

Test Hole 4
141-52-35aaa

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
Glacial Drift:				
	Topsoil, very fine sandy loam, black..	2	0	2
	Silt, sandy, yellowish gray, soft.....	3	2	5
	Sand, fine, dark yellowish brown, well-sorted, subrounded.................	4	5	9
	Clay, yellowish gray, soft, smooth, plastic, oxidized..................	8	9	17
	Clay, silty to sandy with pebbles, moderate olive brown, soft,cohesive, oxidized (till)..................	22	17	39
	Clay, silty to sandy with pebbles, olive gray, soft, tight, cohesive, unoxidized (till).................	24	39	63
	Clay, silty with very fine sand and pebbles, olive gray, soft, tight, cohesive (till)...................	9	63	72
	Clay, silty to sandy with occasional gravel stringers, olive gray, tight, cohesive (till)..................	34	72	106
	Clay, very sandy, light olive gray, soft, slightly friable (till); occasional gravel stringers.........	43	106	149
	Clay, silty and sandy with pebbles, olive gray, moderately soft, tight, cohesive (till); gravel stringers...	38	149	187
	Clay, sandy, light olive gray to olive gray, moderately soft, slightly plastic (till)...........................	23	187	210
	Clay, silty to sandy with pebbles, olive gray, very tight (till).......	52	210	262
	Clay, silty to sandy with gravel stringers, olive gray, moderately soft, cohesive (till)...............	11	262	273
	Gravel and boulders, very hard drilling..........................	8	273	281
	Clay, silty to sandy with pebbles, olive gray, moderately soft to slightly hard, compacted, cohesive (till)...........................	63	281	344
Benton Shale:				
	Clay, sandy, olive black, moderately soft, massive, noncalcareous; some light gray clay....................	13	344	357

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