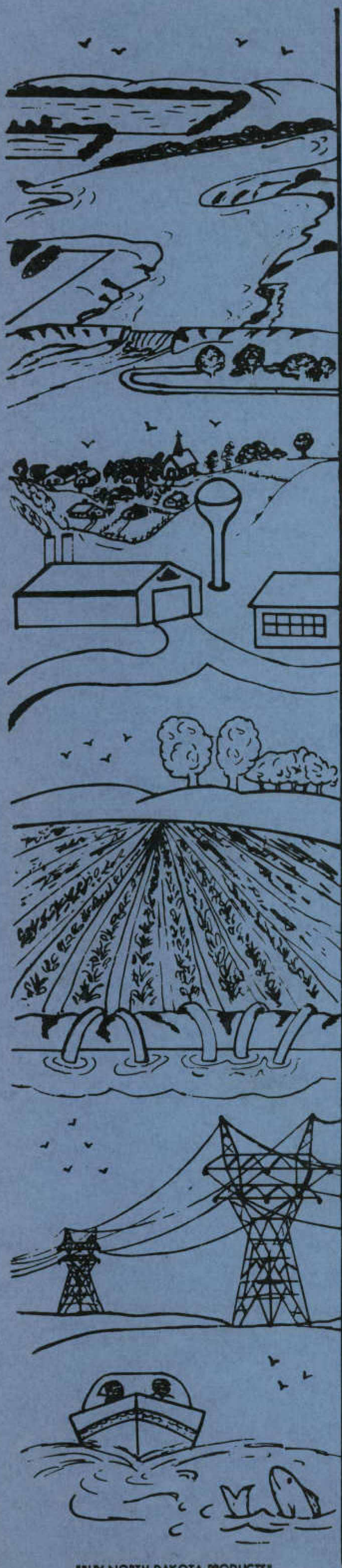


"BUY NORTH DAKOTA PRODUCTS"

GROUND WATER IN THE VICINITY OF RYDER

WARD COUNTY, NORTH DAKOTA

S.W.C.C. PROJECT NO. 931

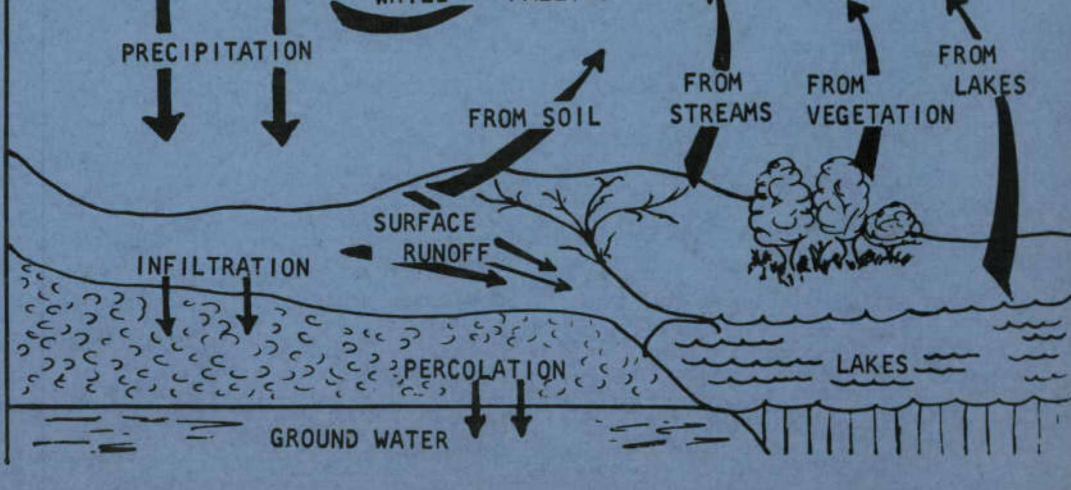
BY
R. W. SCHMID, GEOLOGIST

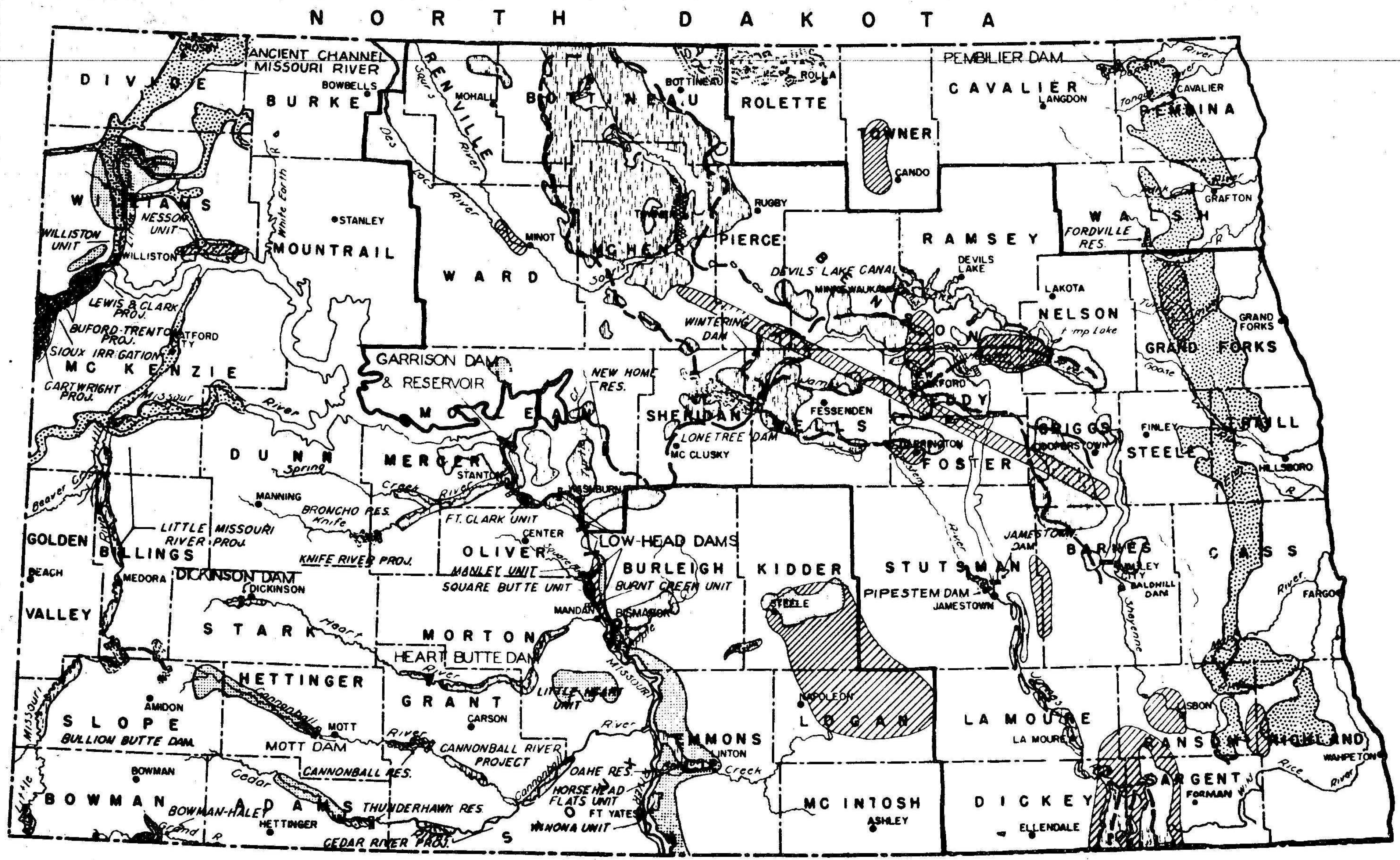
NORTH DAKOTA GROUND WATER STUDIES

NO. 53

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

1963





NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

- LANDS UNDER IRRIGATION
- AREAS CONSIDERED IRRIGABLE
- AREAS BEING INVESTIGATED
- PROPOSED FOR INVESTIGATION

DAM & RESERVOIR SITES: EXISTING; UNDER CONSTRUCTION OR PROPOSED

PROPOSED CANALS

GARRISON DIVERSION CONSERVANCY DISTRICT BOUNDARY

GROUNDWATER AQUIFERS

GROUND WATER IN THE VICINITY OF RYDER, WARD COUNTY, NORTH DAKOTA
SWCC PROJECT NO. 931

By
R. W. Schmid, Geologist

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AND ILLUSTRATIONS

GROUND WATER IN THE VICINITY OF RYDER, WARD COUNTY, NORTH DAKOTA

INTRODUCTION

The Village of Ryder, population 264 (1960 census), is in the southwestern corner of Ward County. The Village is situated four miles south of State Highway 23 on State Highway 28 and is served by the Soo Line Railroad. Ryder is located near the center of the 36 square mile study area (figures 1 and 3).

The average annual precipitation, from 1931 to 1961, recorded by the U. S. Weather Bureau Stations at Parshall and Max are 14.9 and 16.8 inches respectively. Most of the precipitation occurs during the growing season. The mean annual temperature at Minot from 1915 to 1958 was 39.5°F.

At the time this investigation was initiated, the Village of Ryder had a sewer system but no village water supply. Homes and businesses caught rain water in cisterns, hauled well water from nearby farms, or pumped water from shallow wells. A deep well at the creamery is used for fire protection. The purpose of this study was to determine the availability of an adequate supply of potable ground water for the Village of Ryder. A village water system has been installed after a preliminary report summarizing the results of field test work was sent to the village board on May 11, 1962.

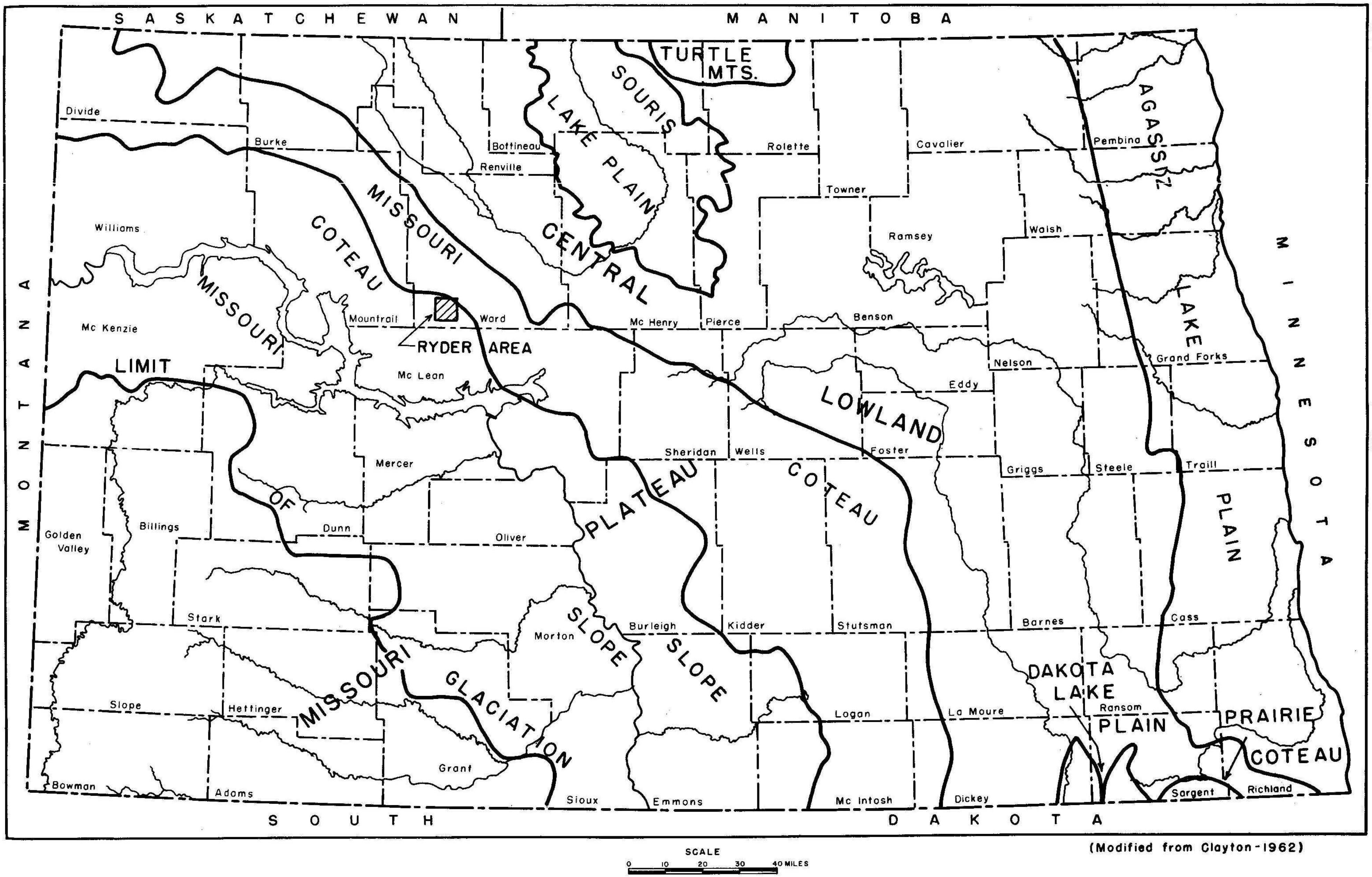

FIGURE 1--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC UNITS AND LOCATION OF THE RYDER AREA

Simpson (1929, p. 250-262) briefly discussed the groundwater resources of Ward County in a general study of the whole state. Abbott and Voedish (1938) made analyses of well water from Ryder in a study of municipal ground water supplies in the state. Andrews (1939) covered the Ryder area in lignite study of the Minot area.

The cooperation of the Village Board, Consulting Engineer L. W. Veigel, residents of Ryder, Reinhard, Wahl, and area farmers was of considerable assistance to this project. Lewis Knutson, driller, operating a state-owned Failing 1500 rotary drill rig, did the test drilling.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is illustrated in figure 2 and 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 numeral denotes the township north of the base line which extends laterally across the middle of Arkansas; the second numeral denotes the range west of the fifth principal meridian, and the third numeral 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 151-86-15daa is in the NE$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$ of Sec. 15, T. 151 North, R. 86 West. Similarly, well 152-86-33ddd is the well located in the SE$\frac{1}{4}$SE$\frac{1}{4}$SE$\frac{1}{4}$ of Sec. 33, T. 152 North, R. 86 West.

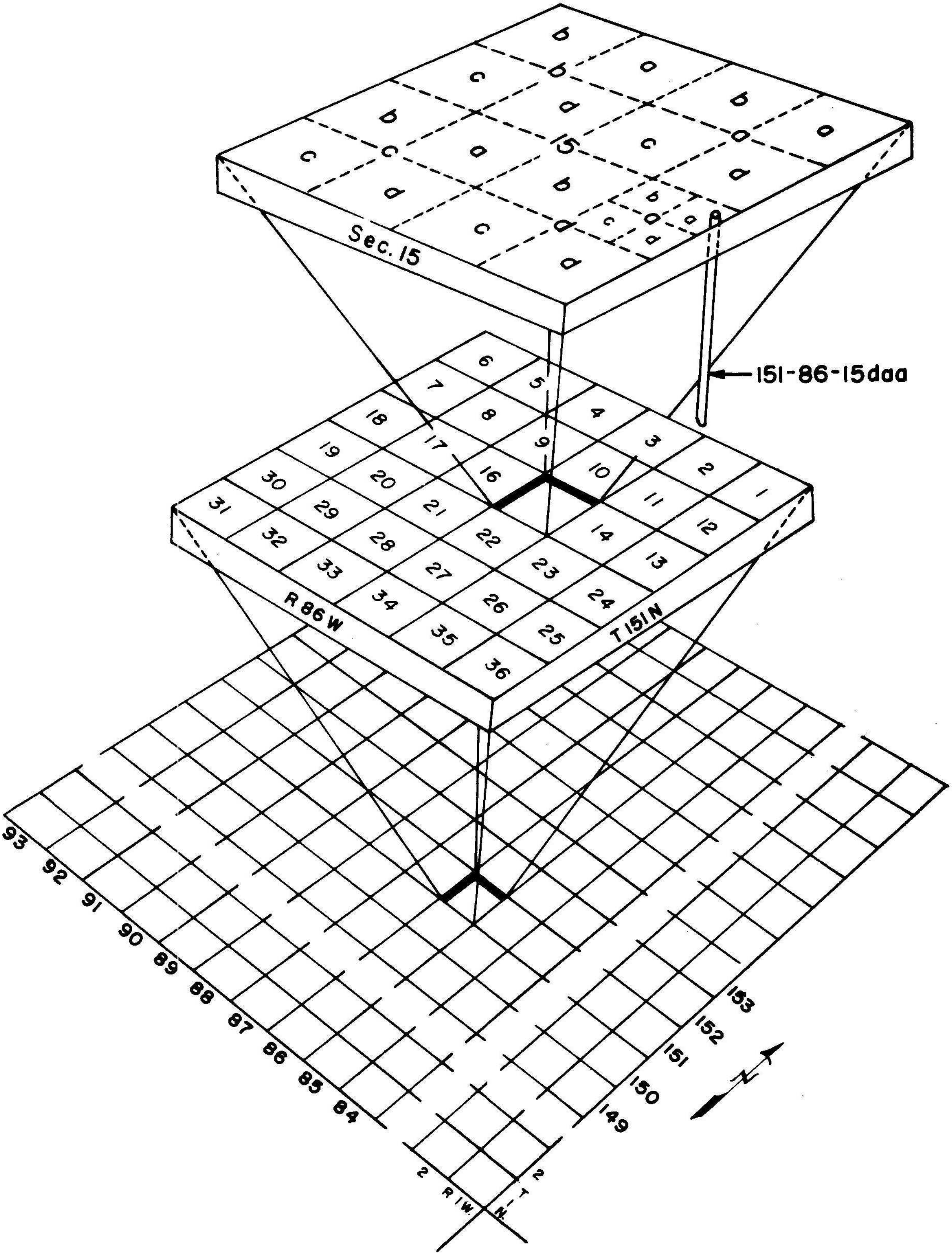

FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

GLACIAL GEOLOGY

The area studied (figure 1) is located in the glaciated Missouri Plateau section of the Great Plains physiographic province (Fenneman, 1931). The northeastern corner of the area lies in the Missouri Coteau district and has no integrated drainage but does contain many closely spaced, undrained depressions. The main portion of the area is situated in the Coteau Slope district (Clayton, 1962, p. 14) which has partly integrated drainage. The drainage is generally only one or two miles to a swamp or slough.

Test hole data (table 4) shows that there is as much as 124 feet of glacial drift in this area. The 24 test holes surveyed vary in elevation from 2096 to 2138 feet above sea level, a difference in elevation of 42 feet. The Tertiary Tongue River Formation of the Fort Union Group, which formed the pre-glacial surface of the area, varies in elevation from 1986 to 2048 feet above sea level in the 15 surveyed test holes reaching bedrock (Tongue River Formation). The pre-glacial surface, therefore, has half again as much relief as the present day surface.

The Missouri Coteau district (figure 3), a topography pockmarked with many potholes, is a dead ice moraine formed as stagnant ice melted beneath a cover of super-glacial till (Clayton, 1962). The area between the Missouri Coteau and the Village of Ryder is a nearly level plain of stratified sediments ranging from clay to gravel as shown by test holes 9, 10, 11, 13, 16 and 17 (152-86-33ddd, 151-86-4aaa, -11bcb,-11baa,and-3ddd.) The water-lain material encountered above till in these test holes ranges from 4 to 42 feet deep, thinning as it approaches the Missouri Coteau. This material was derived from the ablation moraine (dead-ice moraine

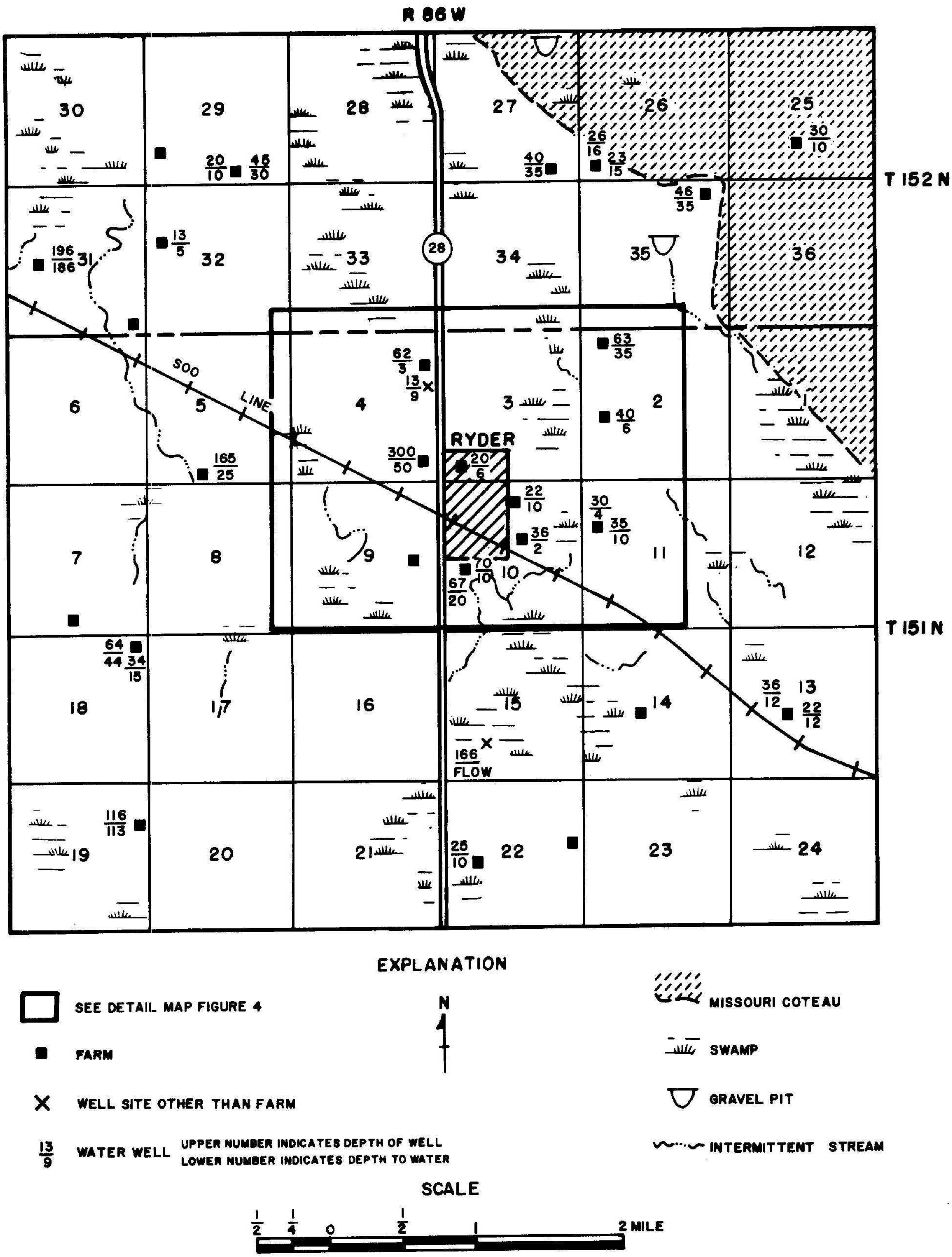

FIGURE 3--MAP OF RYDER AREA

that is still underlain by unmelted ice) of the Missouri Coteau district which at that time was higher than now due to the underlying ice. The material was deposited by a number of small streams, both sub-glacial and super-glacial, as a delta in Lake Ryder (Andrews, 1939). Glacial Lake Ryder could have been 50 feet deep in the Ryder area as ground elevations to the south and southwest of the Ryder area are all 2150 feet or more above sea level. The outlet for this glacial lake must have been west of Ryder, probably Deep Water Creek in southeastern Mountrail County. The ice dam behind which Lake Ryder formed was probably situated close to the Ward-Mountrail County line west of Ryder. The glacial lake was not in existence long because there are no noticeable lake bottom sediments on the ground moraine of the Coteau Slope district. The ground moraine is an undulating till plain comprising the remainder of the Ryder area.

The ice advance (readvance "A", see table 1), that carried the material forming the present surface of the Ryder area retreated in an orderly manner north and northeast to the edge of the Coteau Slope District. At the Missouri Coteau the glacier stagnated, probably due to the melting which thinned the ice enough to prevent further movement. Until the ice dam melted, the Coteau Slop district in the Ryder area was covered by the waters of the Lake Ryder which were derived from melting stagnate ice on the Missouri Coteau.

TABLE I

Correlation of Wisconsin Stage Terminology

This Report	Lemke and Colton (1958)
Readvance "A" Advance "A"	Post-Tazewell - Pre-Two Creeks
Advance "B"	Tazewell (?)
Advance "C?"	Iowan (?)

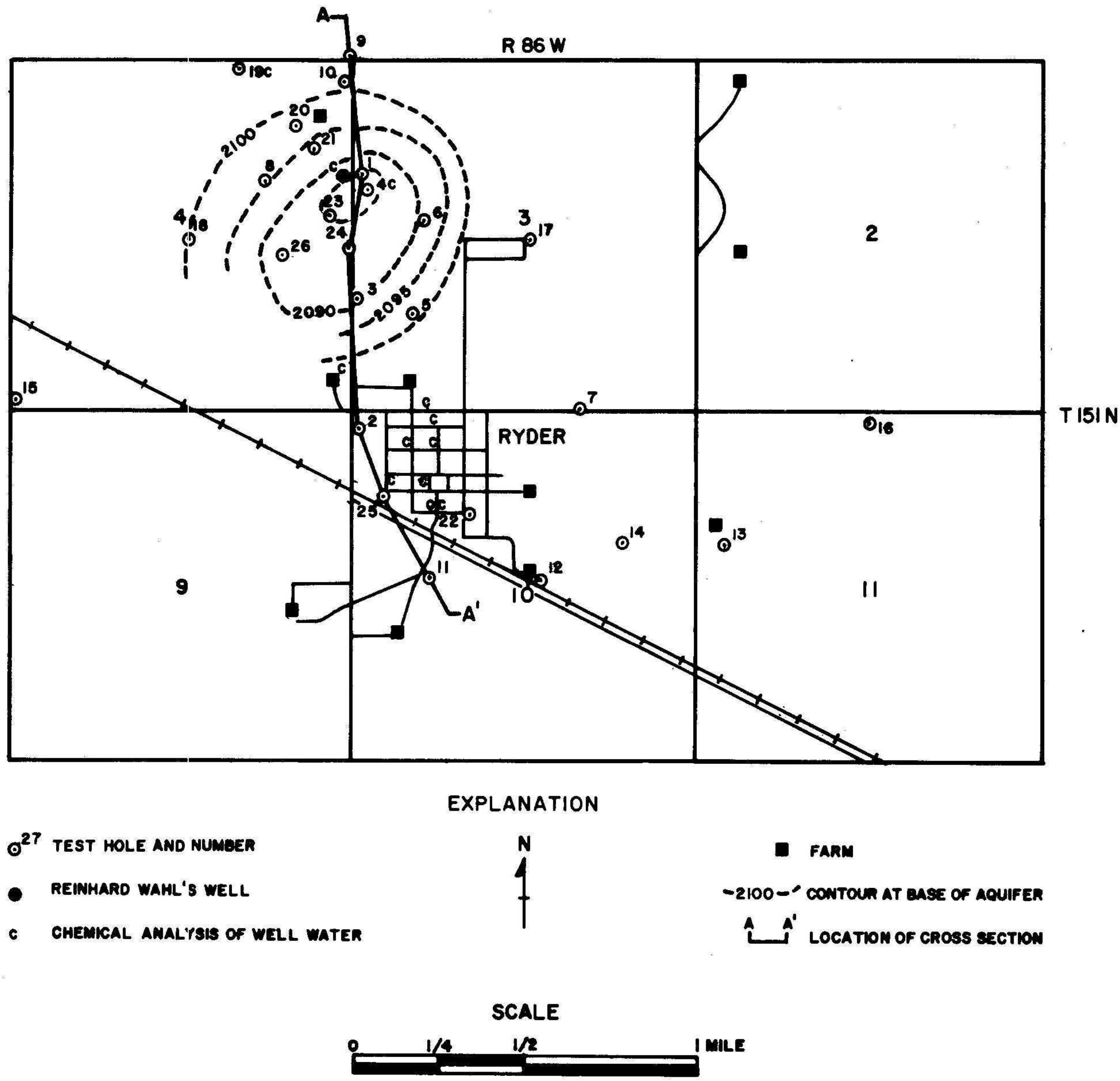

FIGURE 4--DETAIL MAP OF RYDER AREA

Readvance "A" covered an area of outwash which probably was deposited during a minor retreat of the ice from the Ryder area. The outwash (see Hydrology) is covered with less than 20 feet of till and is the only area where differentiation of the minor readvance "A" from the major advance "A" is possible (test hole 1, figure 5). The period between the retreat of advance "A" and its return, readvance "A", was probably quite short. The only weathering in evidence on the advance "A" surface is a result of weathering down through the material deposited by re-advance "A". Nearly all of the material deposited by readvance "A" has been oxidized.

Drift of advance "A" and readvance "A" is about 45 feet thick, including the outwash deposited between them. Approximately the lower half of this drift sheet is unweathered till which, in more than half of the test holes, overlies a thickness of interglacial sediments, predominantly silt with some clay, sand and gravel. Most of the interglacial sediments are unoxidized which indicates deposition just ahead of advance "A" which covered the sediments and protected them from weathering processes.

The top of the buried zone of oxidation (figure 5) is, in most cases, at the base of the interglacial sediments. Some of the test holes encountered oxidized sediments in the interglacial material (test hole 24, figure 5). The oxidized or weathered sediments were deposited a considerable length of time before the unoxidized sediments and were probably derived from the retreating glacier of advance "B".

The till deposited by advance "B" is deeply weathered, up to twice the thickness of oxidation occurred on the post-advance "B" surface as has occurred on the present or post-readvance "A" surface.

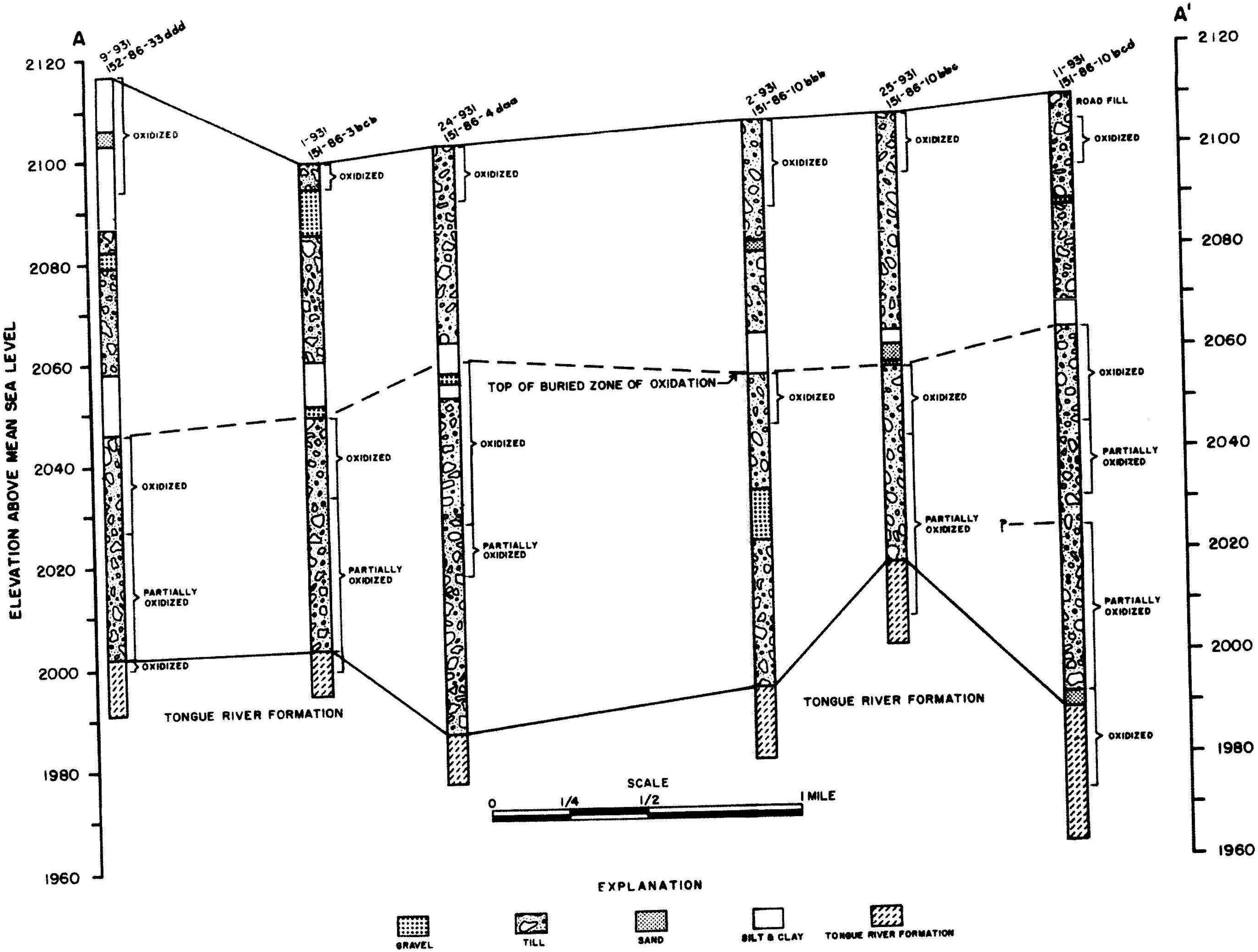

FIGURE 5--CROSS SECTION OF SELECTED TEST HOLES IN THE RYDER AREA

(LOCATION OF SECTION SHOWN IN FIGURE 4)

If all factors were equal this buried zone of oxidation represents a period of weathering twice as long as the present surface has been weathered. However, climatic and water table conditions can change and these are two of the most important factors governing oxidation. Oxidation seldom occurs beneath the water table but is generally restricted to the zone of aeration (Thornbury,1954). However, the thickness of buried zone of oxidation plus the even greater depth of partial oxidation indicates a great length of time, at least somewhat longer than since the retreat of readvance "A" and the drainage of Lake Ryder. Partial oxidation shows up in the test hole samples as cuttings of both oxidized and unaltered till, and is probably the result of oxidation penetrating along joints in the nearly impermeable till (Flint, 1955, p. 54). This type of oxidation occurs primarily along vertical joints but short horizontal joints also provide paths for weathering penetration. In time this results in unoxidized blocks of till surrounded by oxidized till; oxidation is complete when the encroaching oxidation completely obliterates the unoxidized block.

The buried zone of oxidation is present in 25 of the 26 test holes drilled in the Ryder area. This oxidized surface of pre-advance "A" age has also been detected in six test holes near the Ryder area. These are located 7 and 12 miles east, 8 miles west, and 3 miles north, 6 miles northeast, and 13 miles southwest of Ryder. Five of these test holes are located in the Missouri Coteau district while the test hole 8 miles west of Ryder is in the Coteau Slope district.

In some of the test holes at Ryder the oxidized and partially oxidized till overlies unaltered till above the bedrock, in others, however, some oxidation had penetrated the Tongue River Formation. In test hole 11 (figure 5) the buried weathered till overlies six feet of unaltered till. In this test hole the unaltered till of advance "B" overlies a partially oxidized till of an earlier ice sheet (advance "C?"). It seems likely that most of the deposits of advance "C?" were removed by advance "B" and subsequently incorporated in the till deposited by advance "B", this is a usual occurrence. Distinct evidence of two ice sheets, such as a buried zone of weathering, is not a common occurrence in deposits of Wisconsin Age. Because the unaltered zone of advance "B" till is only 6 feet thick it is possible that it is only a block of unaltered till surrounded by oxidized joints. If the latter assumption is correct, there is no evidence of advance "C?" and advance "B" is the earliest glacier detected in this area.

Advance "C?" or the earliest Wisconsin glaciation of the area removed some or all of the weathered material from the pre-Wisconsin or Tongue River surface. Since the Tongue River Formation sands are more permeable than the overlying till, it is possible to have completely oxidized bedrock underlying a partially oxidized till. Because of this, it is impossible to determine whether the bedrock was weathered prior to the Wisconsin Age glaciation or oxidized by weathering working downward through the overlying till cover deposited by advance "C?" or advance "B".

HYDROLOGY

Upon completion of field work a preliminary report in letter form, May 11, 1962, was sent to the Village Board of Ryder. This letter recommended a well be dug in the vicinity of test holes 1 and 4 (figure 4). With this recommendation, L. W. Veigel, Consulting Engineer for Ryder, had a pit dug with a dragline shovel at a point 100 feet east of test hole 1. On June 2nd and again on August 14th this pit was pumped to determine the amount of water available to a well at this site. During the second test, the water level was pumped down about 6.5 feet from the static water level and kept constant for more than ten hours. The pumpage during this ten hour period varied from 34 g.p.m. (gallons per minute) to 41 g.p.m. and averaged about 37 g.p.m.

The well was constructed November 8th through 11th. The pit was dewatered during this period and on the 11th the flow into the pit from the formation was down to 48 g.p.m. The well is made of 3 six foot long sections of concrete pipe 84 inches in diameter, the lower section consists of porous concrete to allow water from the aquifer to enter the well.

This aquifer varies in thickness from 0 to 10 feet and has an area of approximately one square mile. The top of the aquifer is from 3 to 17 feet beneath the surface in 13 of the 15 holes drilled in the area of the aquifer. In 2 of the holes the aquifer was absent. The contours on the detail map of the Ryder area (figure 4) show that water percolating through the thin till cover into the sand and gravel of this aquifer will move toward the new village well. Since there is no surface drainage, all precipitation falling in the area (west 1/2 of Sec. 3 and most of Sec. 4 of T. 151 North, R. 86 West)will either return to the atmosphere by evapo-transpiration or will enter the aquifer. Most of the precipitation is lost through plant transpiration and evaporation but if five per cent of average annual precipitation over one square mile enters and remains in the aquifer it is equal to approximately 25 g.p.m. continuous pumping rate.

The Village owns a deep well, known as the creamery well, that obtains its water from the Tongue River Formation. This well (151-86-10bda) is 304 feet deep, with a depth to water of 90 feet. The main use for water from this well at the present is for fire protection. A log of the Soo Line well at Ryder (Simpson, 1929, p. 251) indicates water in lignite beds near the 300 foot depth and sandy shale from 338 to 361 feet. The creamery well may be in a sand strata as it is reported to pump some sand.

WATER QUALITY

Chemical analyses data (table 1) of 21 water samples from the Ryder area show a considerable diversity in quality. Only four of the samples are completely acceptable by the water quality standards of the North Dakota State Department of Health (table 2). Two of the four acceptable samples are from the Reinhard Wahl well (151-86-4add) and the other two are from test holes 4 and 19 (151-86-3bcb and -4aba).

Ten of the analyses shown are from Abbott and Voedish (1938). Nine of these indicate a high degree of sewage contamination by their high concentrations of nitrates which result from such contamination. Many of these shallow wells in Ryder were dry by the time this study was made, probably because a sewage system had been installed thereby removing most of the recharge.

The last five analyses on table 1 are from the Wahl well (151-86-4add), the creamery well (151-86-10bbd) and three mixtures of water from these two sources. These analyses were done by Ken Kary of the North Dakota State Department of Health in order to determine the quality that could be obtained by blending water from the two aquifers. A half and half blend would result in water of approximately the same or better quality water than the city supplies of nearby Max and Parshall. A blend of 75 per cent from the new city well and 25 per cent from the creamery well would be very close to the water quality standards of the State Health Department.

RECOMMENDATIONS

The recommendations that a well be constructed near test holes 1 and 4 (151-86-3bcb) was given in a preliminary report and has been followed by the Village (See Hydrology, p. 13). Plans have also been made to permit blending of water from the new well and the creamery well in town. Blending should be attempted only when there are extreme demands on the supply system or if the water level in the new well declines significantly. A system should be set up so that an accurate water level record can be kept for the new well. Such a record would be invaluable for any future development.

If recharge isn't sufficient to keep the water level up, the aquifer could be exposed to more direct recharge in a number of locations. Any method of slowing evaporation from potholes in the aquifer area would also add considerable water to the aquifer.

TABLE 2 ----------

Analyses in parts per million except pH

Location	Sample Source	Depth (feet)	Source of Analyses (a)	Date	Total Dissolved Solids	Total Alkalinity $CaCO_3$	Total Hardness $CaCO_3$	Iron Fe
151-86-3bcb	Test Hole #4-931	31	State	5- 3-62	536		380	0.3
151-86-3ccd	E. F. Erb	16	NDGS	-	1446	374	780	0.2
151-86-4aba	Test Hole #19-931	52	Health	5-22-62	600	283	330	
151-86-4add	Reinhard Wahl	14	Health	4-10-62	745	330	420	0.3
151-86-4ddd	Frank Bradley	300	Health	4- 9-62	3234	1225	25	3.6
151-86-10bac	E. E. Fredeen	26	NDGS	-	1058	352	747	0.2
151-86-10bba	Sig Olness	25	NDGS	-	2385	436	965	0.2
151-86-10bba	Ole Olness	21	NDGS	-	1509	364	661	0.02
151-86-10bba	Ryder School	25	NDGS	-	945	294	430	0.0
151-86-10bba	Ryder School	20	NDGS	-	837	306	368	0.02
151-86-10bba	Ryder School	16	NDGS	-	1006	334	403	0.3
151-86-10bbc	A. Anderson	28	NDGS	-	2111	310	1200	0.2
151-86-10bbd	Motor Inn	48	NDGS	-	1461	282	1195	0.7
151-86-10bbd	Creamery Well	304	Health	4- 9-62	3511	1215	80	3.1
151-86-10bca	O.K. Cafe	24	NDGS	-	1931	286	1010	1.4
151-86-27cb	Phil Hanson	183	State	3-16-62	2664		100	1.0
(c)	100% #1							
151-86-4add	Reinhard Wahl	14	Health	5-22-62	650	305	410	
	100% #2							
151-86-10bbd	Creamery Well	304	Health	5-22-62	3384	1100	140	
-	50% #1 & 50% #2	-	Health	5-22-62	1976	710	270	
-	25% #1 & 75% #2	-	Health	5-22-62	2750	910	210	
-	75% #1 & 25% #2	-	Health	5-22-62	1330	505	340	

(a) Analyses from the State Laboratories Department (State), the North Dakota Bulletin 11 by Abbott and Voedisch (1938).

(b) North Dakota State Department of Health and North Dakota Geological Survey

(c) Analyses of Wahl and Creamery Well waters and three mixtures of water from

Chemical Analyses of Water From The Ryder Area

Calcium Ca	Magnesium Mg	Sodium Na	Chloride Cl	Sulphate SO_4	Bicarbonate $CaCO_3$ (b)	Carbonate CO_3	Nitrate NO_3	pH
			8	110	300	Absent	Absent	7.8@25°C
104	125	186	42	633	370		106	
		20	Trace	88	278	Absent	11	
96	44	38	20	140	322	Absent	4	7.45@22°C
10	0	957	145	650	1110	54	33	8.4@22°C
181	70	19	74	250	344		89	
52	202	376	413	849	425		1.8	
36	138	277	285	436	355		53	
20	91	145	13	346	287		89	
19	77	147	34	252	302		89	
23	82	187	60	326	326		62	
256	135	158	173	402	302		707	
276	122	Trace	156	569	275		44	
16	10	1016	135	850	1137	30	33	8.25@22°C
159	148	168	248	386	279		354	
			4	1238	728	Absent	Absent	8.0@25°C
		Trace	20	83	298	Absent	11	
		900	115	900	1072	Trace	33	
		444	65	460	692	Absent	11	
		695	100	710	888	Absent	22	
		225	44	295	492	Absent	22	

State Department of Health (Health) and North Dakota Geological Survey (NDGS)

analyses converted from HCO_3.

the two sources.

TABLE 3 -- Water Quality Standards
From North Dakota State Department of Health
Sanitary Engineering Services

Characteristic	Permissible Concentrations (Parts per million except pH)	Objections To Excessive Concentrations
Iron (Fe)	0.3	Esthetic Staining of Laundry
Magnesium (Mg)	125	Possible Laxative Effect
Sodium (Na)	250	Possible Physiological Effect
Sulphates (SO_4)	250	Possible Laxative Effect
Chloride (Cl)	250	Possible Laxative Effect
Nitrate (NO_3)	43.4	Possible Physiological Effect (toxic to infants)
Total Solids	1000-1500	Possible Laxative Effect
pH	Less than 10.6	Possible Laxative Effect

TABLE 4 -- Logs of Test Holes

The following test hole logs are a composite of information from the driller's log, the geologist's sample description, and the resistivity and potential electric logs.

Color nomenclature, from Goddard, and others (1951), indicates the color of wet samples.

The grain size classification is C.K. Wentworth's scale from Pettijohn (1957).

Elevations are to mean sea level datum as surveyed from two bench marks at Ryder.

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-3bcb T.H. 1-931 Elevation 2099 feet		
Glacial Drift			
	Till, yellowish gray, calcareous, oxidized	3	3
	Till, dark yellowish orange, sandy, calcareous, oxidized	2	5
	Gravel, granule to cobble, subrounded	9	14
	Till, olive gray, calcareous	25	39
	Clay, olive gray, silty, calcareous	9	48
	Gravel, granule, silty	2	50
	Till, light olive brown to light olive gray, calcareous, oxidized	14	64
	Till, moderate olive brown to olive gray, calcareous, partially oxidized	32	96
Tongue River Formation			
	Sandstone, fine to very fine, greenish gray with dark yellowish orange oxidized specks	4	100
	Shale, medium bluish gray, silty	5	105

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-3bcb* **T.H. 4-931** **Elevation 2101 feet**		
Glacial Drift			
	Till, moderate yellowish brown, calcareous, oxidized..................	10	10
	Gravel, granule to cobble, subrounded....	6½	16½
	Till, olive gray, calcareous............	15	31½

* T.H. 4-931 was drilled 195 feet south of T.H. 1-931; a water sample was taken.

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-3bcd **T.H. 6-931** **Elevation 2098 feet**		
Glacial Drift			
	Till, yellowish gray, calcareous,oxidized	3	3
	Sand, very fine to very coarse, gravelly, subrounded, predominantly quartz.......	4	7
	Till, light olive brown, calcareous, oxidized.............................	2	9
	Till, olive gray, calcareous............	24	33
	Clay, dusky yellow to light olive gray, silty, calcareous, partially oxidized..	4	37
	Till, dusky yellow, calcareous, oxidized.	5	42
	151-86-3cbc **T.H. 3-931** **Elevation 2103 feet**		
Glacial Drift			
	Till, moderate yellowish brown, calcareous, oxidized.....................	9	9
	Gravel, granule to pebble, sandy, subrounded............................	5	14
	Till, olive gray, calcareous............	17½	31½
	151-86-3cbd **T.H. 5-931** **Elevation 2105 feet**		
Glacial Drift			
	Clay, yellowish gray, sandy, calcareous, oxidized..............................	3	3

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-3cbd **T.H. 5-931** **Elevation 2105 feet** **(continued)**		
Glacial Drift (continued)			
	Sand, medium, subangular, predominantly quartz	2	5
	Till, dark yellowish orange to moderate olive brown, calcareous, oxidized	3	8
	Till, olive gray, calcareous	27	35
	Till, dark yellowish orange to medium yellowish brown, calcareous, oxidized	18	53
	Till, moderate yellowish brown to olive gray, calcareous, partially oxidized	46	99
Tongue River Formation			
	Shale, dusky yellow to greenish gray, silty, calcareous, partially oxidized	3	102
	Shale, light bluish gray to medium bluish gray, well indurated, calcareous	3	105
	151-86-3dbb **T.H. 17-391** **Elevation 2126 feet**		
Glacial Drift			
	Sand, very fine to very coarse, subrounded	6	6
	Silt, moderate yellowish brown, sandy, calcareous, oxidized	14	20
	Silt, dark yellowish orange, calcareous, oxidized	5	25
	Silt, dark greenish gray, calcareous	4	29
	Till, olive gray, calcareous	30	59
	Clay, olive gray, silty, calcareous	5	64
	Clay, moderate yellowish brown, silty, calcareous, oxidized	2	66
	Till, moderate yellowish brown, calcareous, oxidized	14	80
	Till, dark yellowish orange to light olive gray, calcareous, partially oxidized	10	90
	Clay, moderate yellowish brown with some light olive gray, silty, calcareous, mostly oxidized	13	103
	Till, olive gray with some moderate yellowish brown, calcareous, slightly oxidized	12	115
Tongue River Formation			
	Shale, silty and sandstone, fine, variegated, calcareous to non-calcareous, oxidized and unoxidized	11	126

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-3dcd T.H. 7-931 Elevation 2098 feet		
Glacial Drift			
	Till, dark yellowish orange, calcareous, oxidized............................	11	11
	Till, olive gray, calcareous.............	19	30
	Till, dark yellowish orange, calcareous, oxidized............................	32	62
	Till, variegated (orange, brown and gray) calcareous, partially oxidized.........	23	85
Tongue River Formation			
	Sandstone, light olive gray, very fine to fine, indurated, calcareous , oxidized.	4	89
	Shale, very dark yellowish orange, calcareous, oxidized..................	1	90
	Shale, medium bluish gray, well indurated	4½	94½
	151-86-4aaa T.H. 10-931 Elevation 2117 feet		
Glacial Drift			
	Clay, moderate yellowish brown, silty, calcareous, oxidized..................	9	9
	Clay, moderate yellowish brown to olive gray, silty, laminae, calcareous, partially oxidized....................	5	14
	Sand, very fine to medium, predominantly quartz................................	1	15
	Clay, olive gray with some moderate yellowish brown, silty, calcareous, partially oxidized....................	9	24
	Silt, olive gray, clayey, calcareous.....	6	30
	Till, olive gray, calcareous.............	29	59
	Silt, olive gray, clayey, calcareous.....	4	63
	151-86-4aac T.H. 20-931 Elevation 2096 feet		
Glacial Drift			
	Soil..................................	1	1
	Till, moderate yellowish brown, calcareous, oxidized..................	11	12

TABLE 4 -- Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-4aac T.H. 20-931 Elevation 2096 feet (continued)		
Glacial Drift (continued)			
	Till, olive gray, calcareous.............	27	39
	Silt, olive gray, calcareous.............	2	41
	Sand, fine to medium, angular quartz.....	15	56
	Till, moderate yellowish orange, calcareous, oxidized..................	7	63
	151-86-4aad T.H. 21-931 Elevation 2110 feet		
Glacial Drift			
	Soil....................................	1	1
	Till, moderate yellowish brown, calcareous, oxidized..................	9	10
	Gravel, granule to cobble, sandy, subrounded...............................	6	16
	Till, olive gray, calcareous.............	23	39
	Silt, olive gray, very sandy, calcareous.	46	85
	Sand, very fine to very coarse, very silty, calcareous......................	9	94
	Silt, olive gray, with gravel, granule to pebble, calcareous.................	9	103
	Till, olive gray with some dark yellowish orange, calcareous, slightly oxidized..	7	110
Tongue River Formation			
	Shale, medium bluish gray, silty, indurated.............................	5½	115½
	151-86-4aba T.H. 19-931 Elevation 2100 feet		
Glacial Drift			
	Soil....................................	1	1
	Clay, yellowish gray, very silty, calcareous, oxidized..................	6	7
	Sand, medium to very coarse, subangular, predominantly quartz..................	6	13
	Clay, moderate yellowish brown, silty calcareous, oxidized..................	4	17

TABLE 4 -- Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-4aba T.H. 19-931 Elevation 2100 feet (continued)		
Glacial Drift (continued)			
	Sand, medium to very coarse, subrounded..	2	19
	Till, olive gray, calcareous............	24	43
	Silt, olive gray, calcareous............	2	45
	Silt, moderate yellowish brown, calcareous, oxidized..................	7½	52½
	151-86-4acc T.H. 18-931 Elevation 2105 feet		
Glacial Drift			
	Soil..................................	1	1
	Till, moderate yellowish brown, calcareous oxidized; gravel from 4 to 5 feet................................	11	12
	Till, olive gray, calcareous............	3	15
	Gravel, granule to pebble, sandy subangular...............................	2	17
	Till, olive gray, calcareous............	27	44
	Silt, olive gray, calcareous............	9	53
	Silt, dark yellowish orange, calcareous, oxidized..............................	4	57
	Till, dark yellowish orange to moderate yellowish brown, calcareous, oxidized..	14	71
	Till, moderate yellowish brown to olive gray, calcareous, partially oxidized; gravel from 93 to 94 feet..............	36	107
	Till, olive gray, calcareous............	9	116
Tongue River Formation			
	Shale, greenish gray, calcareous.........	10	116
	151-86-4adb T.H. 8-931 Elevation 2104 feet		
Glacial Drift			
	Soil..................................	2	2
	Till, moderate yellowish brown, calcareous, oxidized......................	2	4

TABLE 4 -- Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-4adb **T.H. 8-931** **Elevation 2104 feet** **(continued)**		
Glacial Drift (continued)			
	Gravel, granule to pebble, clayey........	5	9
	Till, moderate yellowish brown, calcareous, oxidized....................	7	16
	Till, olive gray, calcareous.............	26	42
	Silt, olive gray, calcareous.............	11	53
	Till, dark yellowish orange, calcareous, oxidized..............................	10	63
	151-86-4add **T.H. 23-931** **Elevation 2106 feet**		
Glacial Drift			
	Gravel, granule to pebble................	1	1
	Till, moderate yellowish brown, calcareous, oxidized..................	10	11
	Gravel, granule to pebble, sandy, subrounded, oxidized......................	7	18
	Sand, medium to very coarse, gravelly, subrounded............................	3	21
	Till, olive gray, calcareous.............	17	38
	Clay, medium gray, silty, calcareous.....	10	48
	Till, olive gray, calcareous.............	7	55
	Till, moderate yellowish brown, calcareous, oxidized..................	29	84
	151-86-4ccc **T.H. 15-791** **Elevation not determined**		
Glacial Drift			
	Soil.....................................	1	1
	Till, moderate yellowish brown, calcareous, oxidized..................	21	22
	Till, dark yellowish brown, calcareous, oxidized..............................	5	27
	Till, olive gray, calcareous.............	14	41

TABLE 4 -- Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-4ccc T.H. 15-791 Elevation not determined (continued)		
Glacial Drift (continued)			
	Silt, olive gray, calcareous............	6	47
	Till, light olive to grayish olive, calcareous..........................	4	51
	Silt, dark yellowish orange, to dark yellowish brown, calcareous, oxidized..	21	72
	Till, dark yellowish brown to olive gray, calcareous, partially oxidized........	44	116
	Till, olive gray, calcareous............	8	124
Tongue River Formation			
	Shale, greenish gray, calcareous.........	8	132
	Shale, grayish green to brownish black, silty, indurated, lignite..............	$4\frac{1}{2}$	$136\frac{1}{2}$
	151-86-4daa T.H. 24- 931 Elevation 2102 feet		
Glacial Drift			
	Till, dark yellowish brown, gravelly, calcareous, oxidized..................	11	11
	Till, olive gray, calcareous............	28	39
	Silt, olive gray, calcareous............	4	43
	Silt, moderate yellowish brown, calcareous, oxidized..................	2	45
	Gravel, granule to pebble, subrounded....	2	47
	Silt, moderate yellowish brown, calcareous, oxidized..................	3	50
	Till, moderate yellowish brown to dark yellowish brown, calcareous, oxidized..	25	75
	Till, moderate yellowish brown to olive gray, calcareous, partially oxidized...	10	85
	Till, olive gray, calcareous............	31	116
Tongue River Formation			
	Shale, greenish gray, indurated, calcareous...........................	10	126

TABLE 4 -- Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-4dab T.H. 26-931 Elevation 2105 feet		
Glacial Drift			
	Soil	1	1
	Till, moderate yellowish brown, calcareous, oxidized	15	16
	Till, olive gray, calcareous	1	17
	Gravel, granule to pebble	2	19
	Till, olive gray, calcareous	22	41
	Clay, olive gray, silty, calcareous	4	45
	Clay, moderate yellowish brown, calcareous, oxidized	6	51
	Sand, very fine to medium	2	53
	Till, dark yellowish orange, calcareous, oxidized	21	74
	Till, moderate yellowish brown, calcareous, oxidized	12	86
	Till, olive gray, calcareous	18	104
Tongue River Formation			
	Shale, greenish gray	11½	115½
	151-86-10aca T.H. 14-931 Elevation 2104 feet		
Glacial Drift			
	Soil	1	1
	Till, moderate yellowish brown, calcareous, oxidized	10	11
	Till, olive gray, calcareous	2	13
	Sand, very fine to very coarse, subrounded	3	16
	Till, olive gray, calcareous, with gravel, granule to pebble from 19 to 20 feet	13	29
	Till, moderate yellowish brown, calcareous, oxidized	13	42
	151-86-10acc T.H. 12 -931 Elevation 2108 feet		
Glacial Drift			
	Soil	1	1
	Till, moderate yellowish brown, calcareous, oxidized	7	8

TABLE -- Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-10acc T.H. 12-931 Elevation 2108 feet (continued)		
Glacial Drift (continued)			
	Till, dark yellowish orange,calcareous, oxidized..............................	10	18
	Gravel, granule to pebble, sandy, rounded..............................	2	20
	Till, olive gray, calcareous............	10	30
	Till, dark yellowish orange, calcareous, oxidized..............................	7	37
	Shale, grayish blue green, silty, indurated (Tongue River Formation erratic??)..............................	2	39
	Till, moderate yellowish brown, calcareous, oxidized..................	13	52
	Till, moderate yellowish brown to olive gray, calcareous, partially oxidized...	19	71
	Till, olive gray, calcareous............	10	81
Tongue River Formation			
	Shale, brownish black, silty, lignitic, indurated..............................	4	85
	Shale, olive gray, silty, indurated......	5	90
	Sandstone, very fine to fine, silty, greenish gray..........................	4½	94½
	151-86-10bbb T.H. 2-931 Elevation 2106 feet		
Glacial Drift			
	Till, moderate yellowish brown to grayish orange, calcareous, oxidized...	5	5
	Till, dark yellowish orange, calcareous, oxidized..............................	12	17
	Till, olive gray, calcareous............	7	24
	Sand, very fine to very coarse, subangular..............................	2	26
	Till, olive gray to light olive gray, calcareous..............................	16	42
	Clay, light olive ;gray, silty,calcareous	8	50
	Till, moderate yellowish brown, calcareous, oxidized..................	10	60
	Till, olive gray, calcareous............	13	73
	Gravel, granular, sandy, subangular......	10	83

TABLE 4 -- Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-10bbb T.H. 2-931 Elevation 2106 feet (continued)		
Glacial Drift (continued)			
	Till, olive gray, calcareous............	29	112
Tongue River Formation			
	Shale and Sandstone, greenish gray to light bluish gray, with lignite........	14	126
	151-86-10bbc T.H. 25-931 Elevation 2107 feet		
Glacial Drift			
	Soil................................	1	1
	Till, moderate yellowish brown, calcareous, oxidized..................	11	12
	Till, light olive gray, calcareous, with abundant gravel, granule to pebble.....	5	17
	Till, olive gray, calcareous............	26	43
	Clay, olive gray, silty, calcareous......	3	46
	Sand, very fine to medium, predominantly quartz..............................	3	49
	Gravel, granule to pebble, sandy,rounded.	1	50
	Till, dark yellowish brown, calcareous, oxidized..............................	14	64
	Till, dark yellowish brown to olive gray, calcareous, partially oxidized.........	25	89
Tongue River Formation			
	Sandstone, very fine to fine, clayey, dusky yellow, partially oxidized.......	10	99
	Shale, grayish green, silty, indurated...	6	105
	151-86-10bcd T.H. 11-931 Elevation 2110 feet		
Fill			
	Old road bed...........................	5	5
Glacial Drift			
	Till, moderate yellowish brown, calcareous, oxidized..................	9	14
	Till, olive gray, calcareous, with gravel granule to pebble from 21 to 22 feet...	27	41
	Silt, olive gray, calcareous............	5	46
	Till, dark yellowish orange, calcareous, oxidized..............................	19	65

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-10bcd **T.H. 11-931** **Elevation 2110 feet** **(continued)**		
Glacial Drift (continued)			
	Till, dark yellowish orange to olive gray, calcareous, partially oxidized..........	14	79
	Till, olive gray, calcareous..............	6	85
	Till, olive gray with some dark yellowish orange, abundant sandstone particles, calcareous, partially oxidized..........	33	118
	Sand, very fine to medium, subrounded, oxidized...............................	3	121
Tongue River Formation			
	Shale, moderate yellowish brown, sandy, slightly to non-calcareous, oxidized....	16	137
	Shale, greenish gray, silty...............	10	147
	151-86-10bdb **T.H. 22-931** **Elevation 2103 feet**		
Glacial Drift			
	Soil....................................	1	1
	Clay, light gray, silty, highly calcareous, oxidized....................	4	5
	Till, moderate yellowish brown, calcareous, oxidized....................	7	12
	Till, olive gray, calcareous..............	13	25
	Silt, olive gray, calcareous..............	4	29
	Silt, moderate yellowish brown, calcareous, oxidized....................	10	39
	Silt, moderate yellowish brown to olive gray, calcareous, partially oxidized....	2	41
	Till, moderate yellowish brown to olive gray, calcareous, partially oxidized....	40	81
Tongue River Formation			
	Shale, very silty, moderate yellowish brown to olive gray, partially oxidized.	9	90
	Shale, medium bluish gray, indurated, lignite from 91 to 92 feet.............	4½	94½

TABLE 4 -- Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	151-86-11baa **T.H. 16-931** **Elevation not determined**		
Glacial Drift			
	Soil	1	1
	Sand, very fine to medium, rounded quartz.	3	4
	Till, moderate yellowish brown, calcareous, oxidized	9	13
	Till, olive gray, calcareous	15	28
	Gravel, granule to pebble, sandy, subrounded	5	33
	Till, olive gray, calcareous	13	46
	Till, moderate yellowish brown, calcareous, oxidized	16	62
	Till, moderate yellowish brown to olive gray, calcareous, partially oxidized	9	71
Tongue River Formation			
	Shale, silty, lignitic, variegated (yellow, green, black and brown) calcareous to non-calcareous, oxidized to unoxidized	13	84
	151-86-11bcb **T.H. 13-931** **Elevation 2138 feet**		
Glacial Drift			
	Sand, fine to medium, subangular, quartz	7	7
	Clay, yellowish gray, silty, highly calcareous, oxidized	2	9
	Clay, moderate yellowish brown, silty, calcareous, oxidized	11	20
	Silt, olive gray, clayey, calcareous; gravel, granule to cobble from 29 to 31 feet	20	40
	Gravel, granule to cobble	2	42
	Till, olive gray, calcareous	10	52
	Till, moderate yellowish brown, calcareous, oxidized	12	64
	Till, moderate yellowish brown to olive gray, calcareous, partially oxidized	19	83
	Till, olive gray, calcareous	7	90
Tongue River Formation			
	Shale, moderate yellow, silty, indurated, oxidized	$4\frac{1}{2}$	$94\frac{1}{2}$

Formation	Material	Thickness (feet)	Depth (feet)
	152-86-33ddd **T.H. 9-931** **Elevation 2117 feet**		
Glacial Drift			
	Silt, dark yellowish orange to dusky yellow, clayey, highly calcareous, oxidized	11	11
	Sand, very fine to medium, quartz	3	14
	Clay, dark yellowish orange to dusky yellow, silty, laminae, calcareous, oxidized	9	23
	Clay, olive gray, silty, calcareous	7	30
	Till, olive gray, calcareous; gravel, granule to pebble, subrounded from 35 to 38 feet	29	59
	Clay, silty, olive gray to light olive gray, calcareous	12	71
	Till, dark yellowish orange to light olive brown, calcareous, oxidized	19	90
	Till, dark yellowish orange to olive gray, calcareous, partially oxidized	25	115
Tongue River Formation			
	Shale, moderate yellow, silty, indurated, oxidized	1	116
	Lignite	1	117
	Shale, grayish blue green, silty, lignitic, indurated	9	126

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