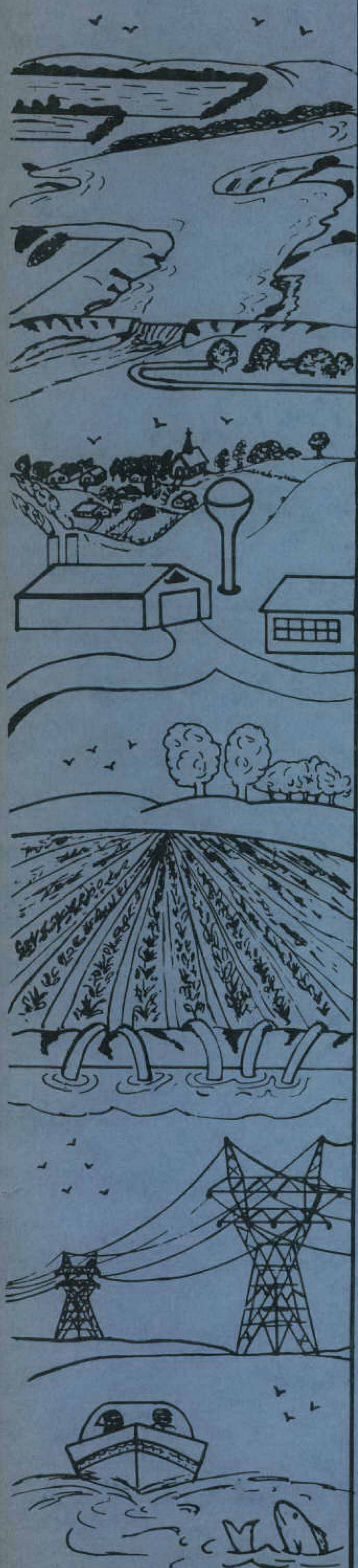
GROUND-WATER SURVEY OF THE SURREY AREA

WARD COUNTY, NORTH DAKOTA
N.D.S.W.C.C. PROJECT NO. 992

by

Larry L. Froelich, Geologist

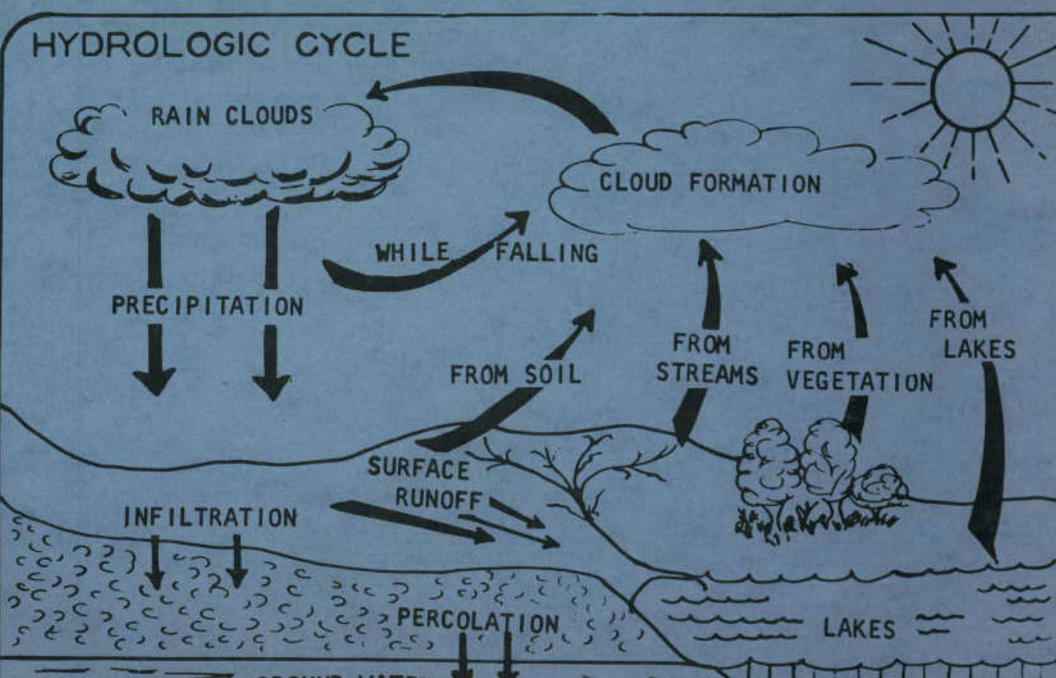


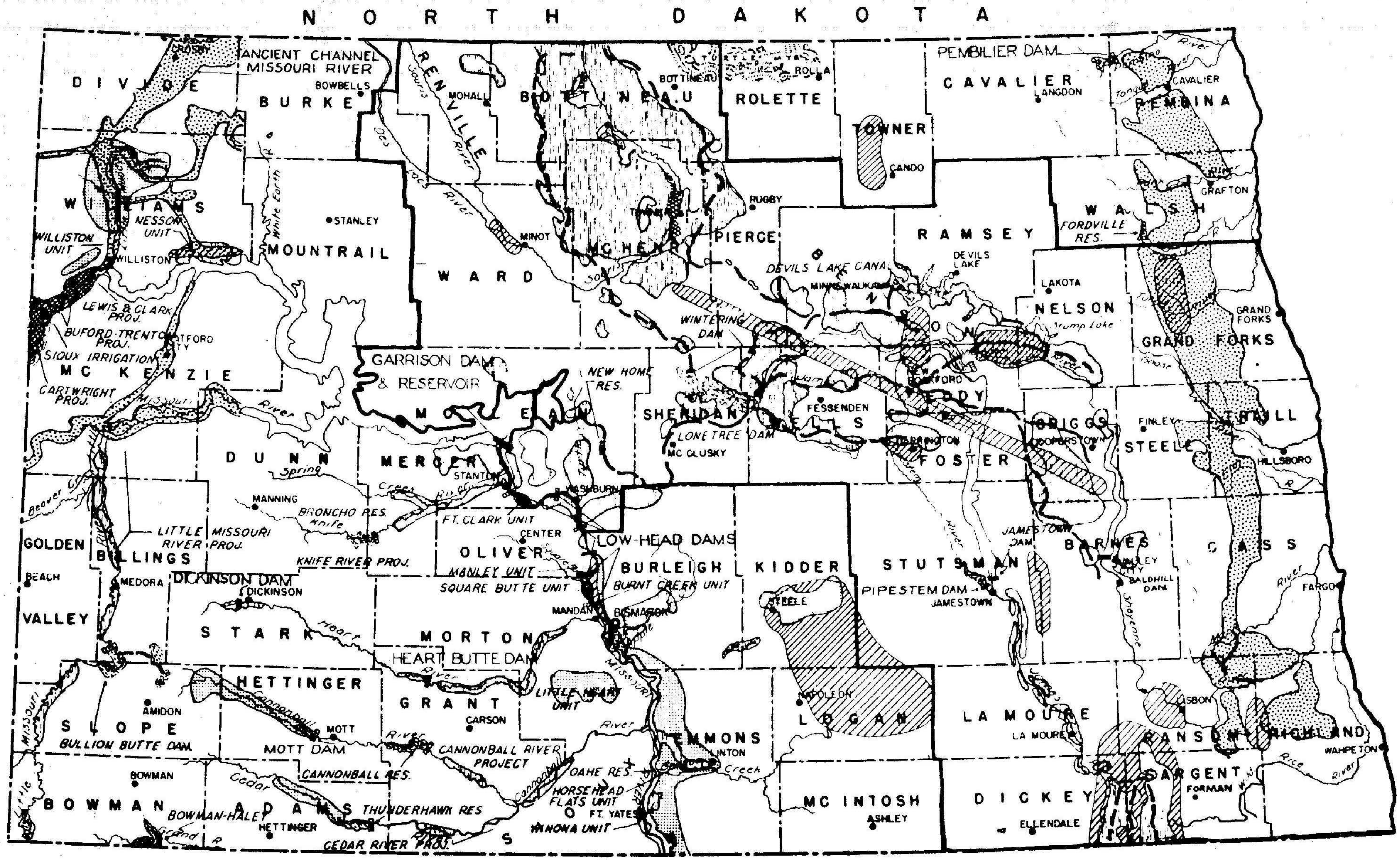
NORTH DAKOTA GROUND WATER STUDIES

NO. 58

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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NORTH DAKOTA STATE WATER COMMISSION
NEWS RELEASE

July 1, 1964

Groundwater Report of Surrey Area Released by Water Commission

Installation of wells in an aquifer near Surrey would provide adequate water supplies for that city according to a report released by the State Water Commission today.

Quality of the water is fair for most purposes, and is suitable for a municipal supply. Chemical analyses were made by the State Laboratories Department and State Health Department in Bismarck.

Locations and logs of the test holes drilled, well inventory, quality analyses, along with a map of the area are included in the report.

The State Water Commission cooperated with the City of Surrey in making the survey. Larry L. Froelich, Commission Groundwater Geologist, is author of the report, copies of which are available at the Water Commission office in Bismarck.

North Dakota State Water Commission

1301 State Capitol 223-8000 Ext 41

Bismarck, North Dakota 58501

LETTER OF TRANSMITTAL

RE: Groundwater Study Reports

We are enclosing a copy of a groundwater study report published by the State Water Conservation Commission because of your interest in such reports released by this office.

Should you desire further information regarding this report, feel free to contact the State Water Conservation Commission office in Bismarck.

Sincerely yours,

Milo W. Hoisveen

Milo W. Hoisveen

Engineer-Secretary

MWH:hs

Mimeo #160

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Larry L. Froelich, Geologist
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GROUND-WATER SURVEY OF THE SURREY AREA

WARD COUNTY, NORTH DAKOTA

North Dakota Ground-Water Study #58
North Dakota State Water Commission #992

INTRODUCTION

Scope and Purpose of the Survey

On January 12, 1963, a resolution by the Village of Surrey requesting the North Dakota State Water Commission to perform a ground-water survey for the village was received in the office of the Water Commission. On January 28, 1963 the Water Commission entered into an agreement with board members of Surrey to perform the ground-water survey and preliminary research were initiated.

During the month of April, field work and test drilling was accomplished in an effort to determine the availability of ground water for a village supply. The field work consisted of a reconnaissance of the area, a partial well inventory, collection of water samples for chemical analyses, and acquisition of pre-existing data.

On November 4 and 5, 1963, two more test holes were drilled and a preliminary pumping test on Reinhold Elker's well was completed. A total of 21 test holes were drilled with the State-owned rotary drilling rig. The project was under the direct supervision of the writer. Test drilling was done by Lewis and Lanny Knutson. Chemical analyses were performed by the North Dakota State Laboratories, Bismarck.

Special thanks are due to Mr. Tom Zook, Mr. Bonaventure Kraft and Mr. Reinhold Elker for their assistance during the survey. Their interest and complete willingness to cooperate is greatly appreciated. Mr. W. F. Arksey of the Great Northern Railway Company was very helpful in providing drill logs and comments pertinent to the Surrey study.

Previous Investigations

A general study of the geology and ground-water resources of Ward County was made by Simpson (1929, pp. 250-262, 304-305) in which he discussed the water-bearing strata of the county and included a compilation of numerous wells and chemical analyses.

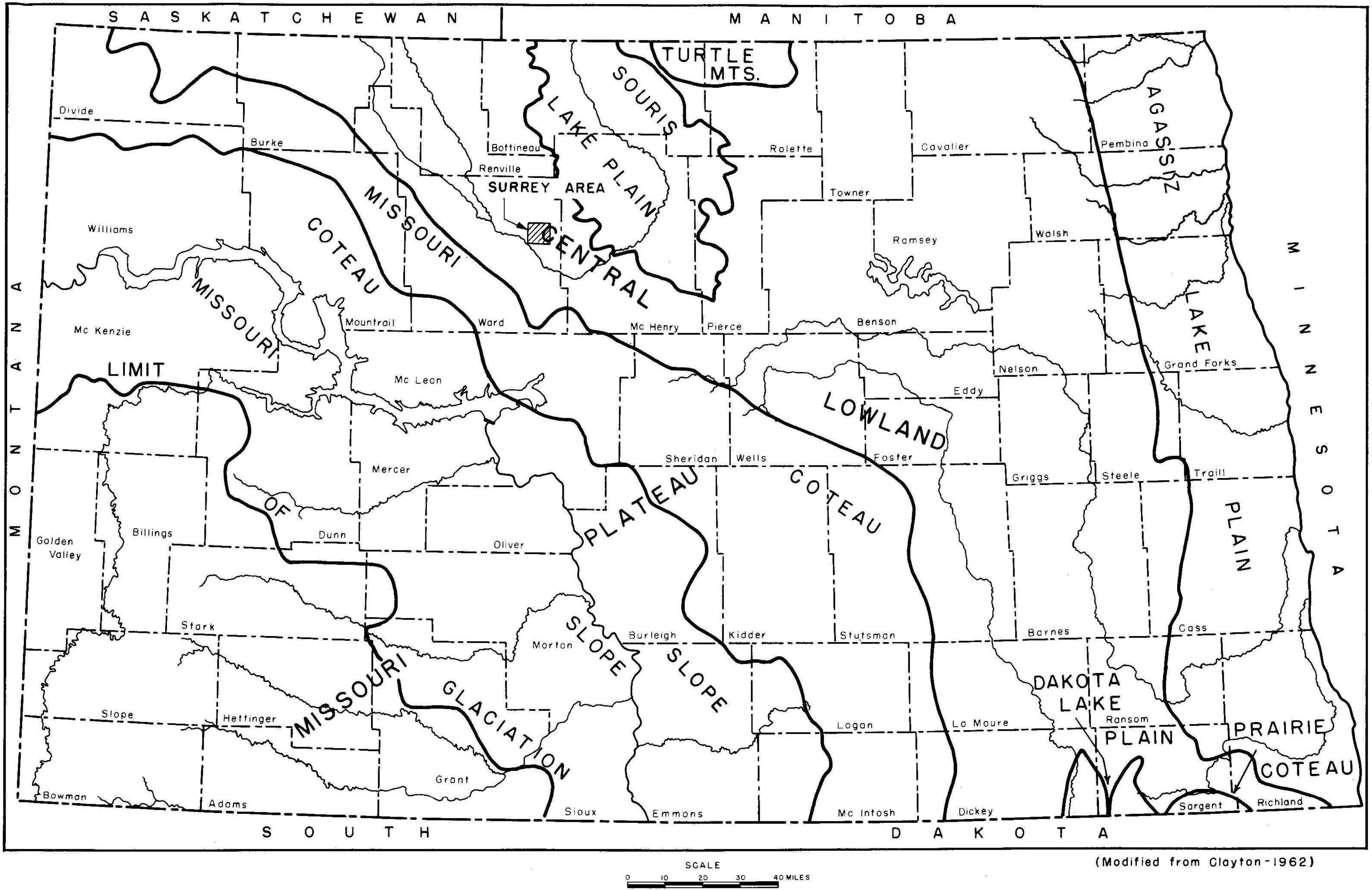
Beginning in midsummer of 1945 the United States Geological Survey (Lemke, 1960) began an investigation of a 5,500 square mile area in the Souris River drainage basin to supply basic geologic data to Federal agencies engaged in the Missouri River Development Program. Mapping was completed in the fall of 1949 and the final interpretative report was published in 1960.

Concurrent with the geologic study of the Souris Basin, the United States Geological Survey was also conducting a hydrologic study of a 4,300 square mile area within the drainage basin of the Souris River. The interpretative report (LaRocque, Swenson, and Greenman, 1963a) was published as a North Dakota Ground-Water Study. An open-file report (LaRocque, Swenson, and Greenman, 1963b) containing tables of data collected during the study is available for consultation at the United States Geological Survey or North Dakota State Water Commission offices in Bismarck, North Dakota.

Between October 1954 and October 1955, Mr. W. F. Arksey, fuel and water engineer for the Great Northern Railway Company, supervised the drilling of 20 test holes in and adjacent to the Surrey area. The purpose of the test drilling was to find a water supply for the railroad retarder yard located between Surrey and Minot.

Location and General Features of the Area

The Surrey area, as described in this report, is 6 by 6 miles in size and includes the west half of Twp. 155 N., Rge. 81 W. and the east half of Twp. 155 N., Rge. 82 W. in eastern Ward County. It is included in the Central Lowland



(Modified from Clayton-1962)

FIGURE 1--MAP SHOWING PHYSIOGRAPHIC PROVINCES OF NORTH DAKOTA AND LOCATION OF THE SURREY AREA

physiographic province of North Dakota as shown in Figure 1. Simpson (1929, p. 5) would place the Surrey area in the Souris River Valley division of the Drift Prairie physiographic province.

Topographically the Surrey area is gently to moderately undulating with a range in elevation from 1693 feet in Section 27 in the southwestern part of the area to 1543 feet in the extreme northeast corner of the area, a difference of 150 feet. Although not always apparent to the casual observer, the area is unusual in that it contains a maze of bifurcating channels (Fig. 2) which have been entrenched from 10 to 30 feet into the surface of the land.

Even though the area is criss-crossed with channels, an integrated drainage pattern has not developed. The divides between the channel are pock-marked with numerous potholes, and sloughs are common in lower portions of the channels. There are no perennial streams in the area.

Dryland farming is the major occupation in the Surrey area. The general soil type is the Barnes Loam (Holowaychuk and Boatright, 1938) which is moderately sandy and has a tendancy to 'blow' or drift when it is dry and in unprotected or cultivated areas.

Surrey, population 309 in 1960, is the only town in the area. It is located on U. S. Highway 2 and is served by the Great Northern Railway. Climatological data from the U. S. Weather Bureau at the Minot airport, located 7 miles west and 1½ miles north of Surrey, show the long-term mean temperature to be 39.5°F, based on a 57 year mean. Long-term mean precipitation at the same station, based on a 57 year mean, is 15.62 inches per annum (Personal communication, U. S. Weather Bureau, Bismarck).

Present Water Supply

At the present time (1964) the Village of Surrey has no public waterworks or sewage facilities. Approximately 30 private wells supply the needs of the village residents. The wells range in depth from about 20 feet to over 500 feet. Buildings with indoor plumbing have private cesspools or septic tanks. Several of the villagers purchase bottled water for drinking from Granite Springs Water and Ice Company of Minot.

The village has three public supply wells. Two shallow wells are equipped with hand pumps. A 135 foot well is electrically powered and is equipped with a coin meter for dispensing water.

Well-numbering System

The well-numbering system used in this report, illustrated in Figure 3, is based on the location of the well in the Federal system of rectangular surveys of public lands. The first number denotes the township north and the second number denotes the range west, both referred to the Fifth principal meridian and base line; the third number denotes the section in which the well is located. The letters a, b, c, and d designate respectively the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections and quarter-quarter-quarter sections (10-acre tracts). Consecutive terminal numbers are added if more than one well is located in a 10-acre tract. Thus well 155-82-15daa would be located in the NE$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$ Sec. 15, Twp. 155 N., Rge. 82 W.

GEOLOGY AND OCCURRENCE OF GROUND WATER

Introduction

Contrary to the popular belief that underground water occurs in 'veins' or buried rivers or lakes, scientific investigations have proven that nearly everywhere, at varying depths, the rock material composing the earth's crust is saturated with water. It is the geologic structure and the composition of the rock

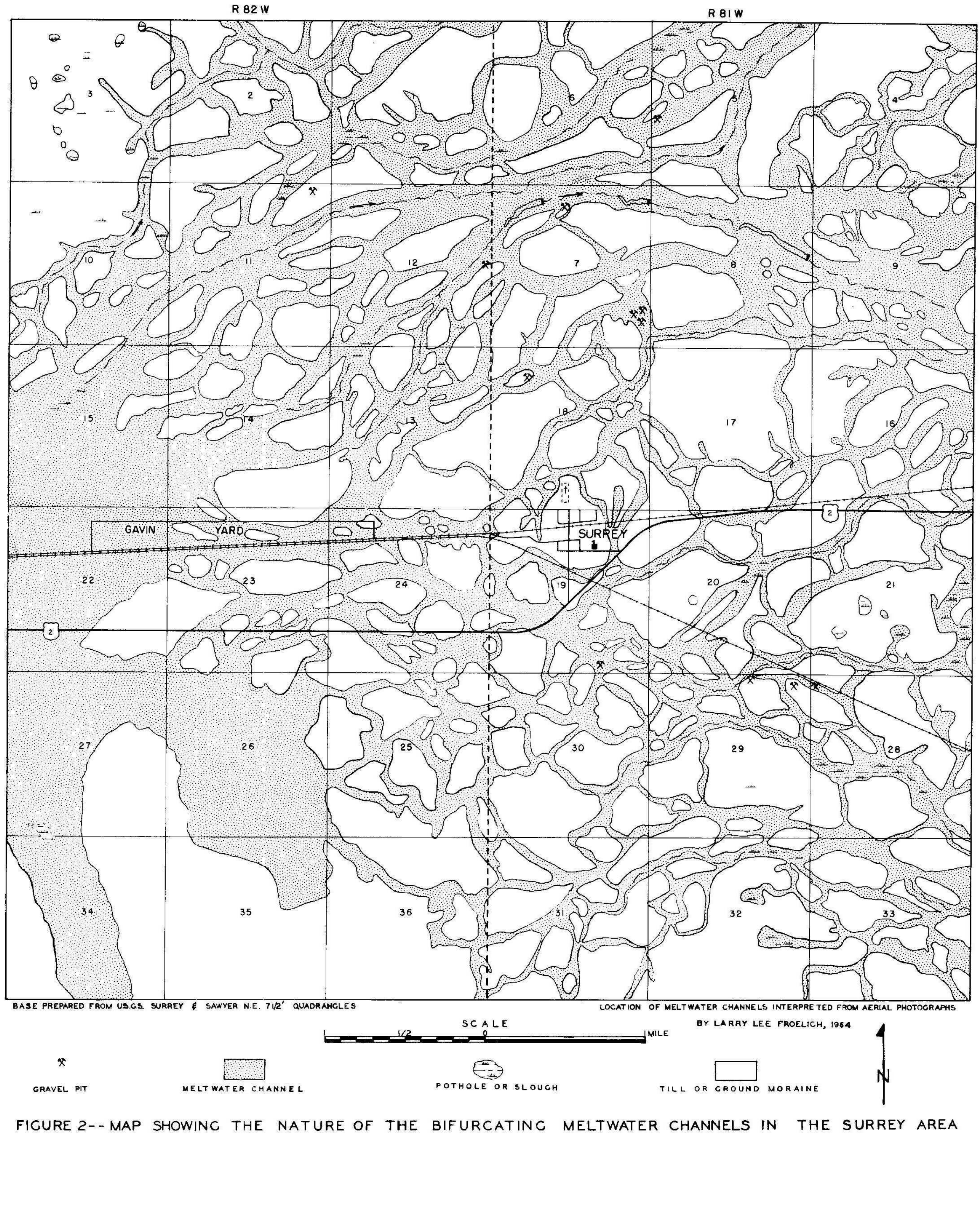


FIGURE 2--MAP SHOWING THE NATURE OF THE BIFURCATING MELTWATER CHANNELS IN THE SURREY AREA

materials that determine whether water can be withdrawn in sufficient quantities for an intended purpose from a well penetrating these materials. Since the occurrence of ground water is dependent upon geological relationships the two must be examined contemporaneously to determine the availability of ground water in any given area.

In the Surrey area there are present two major geologic units--namely bedrock and the overlying glacial drift. However, before the occurrence of water in the two major units is discussed, certain basic hydrologic concepts are presented as a means of introducing to the reader terminology and general ground-water conditions which exist in the area.

Hydrologic Concepts

Essentially all ground water of economic importance is meteoric, or that water derived from precipitation. After soil and vegetation requirements have been satisfied, excess precipitation either runs off the land surface to lower elevations or percolates through the ground to where the earth material is saturated with water. The upper surface of this zone of saturation, which generally conforms with the earth's surface, is called the water table. Water also reaches the water table, in certainareas, by percolation from streams, ponds, and lakes. Some areas, because of the composition of the surficial material, allow water to enter the ground and reach the water table more readily than other areas and these are called recharge areas.

Practically all ground water is in the process of movement from the recharge area to a place of disposal or a discharge area. Discharge areas are the result of lateral movement of ground water after the downward movement of precipitation has raised the water table sufficiently to intercept the land surface. Hence, discharge areas are visible at the land surface and occur as springs and lakes or rivers which retain surface water throughout the year. Natural discharge of

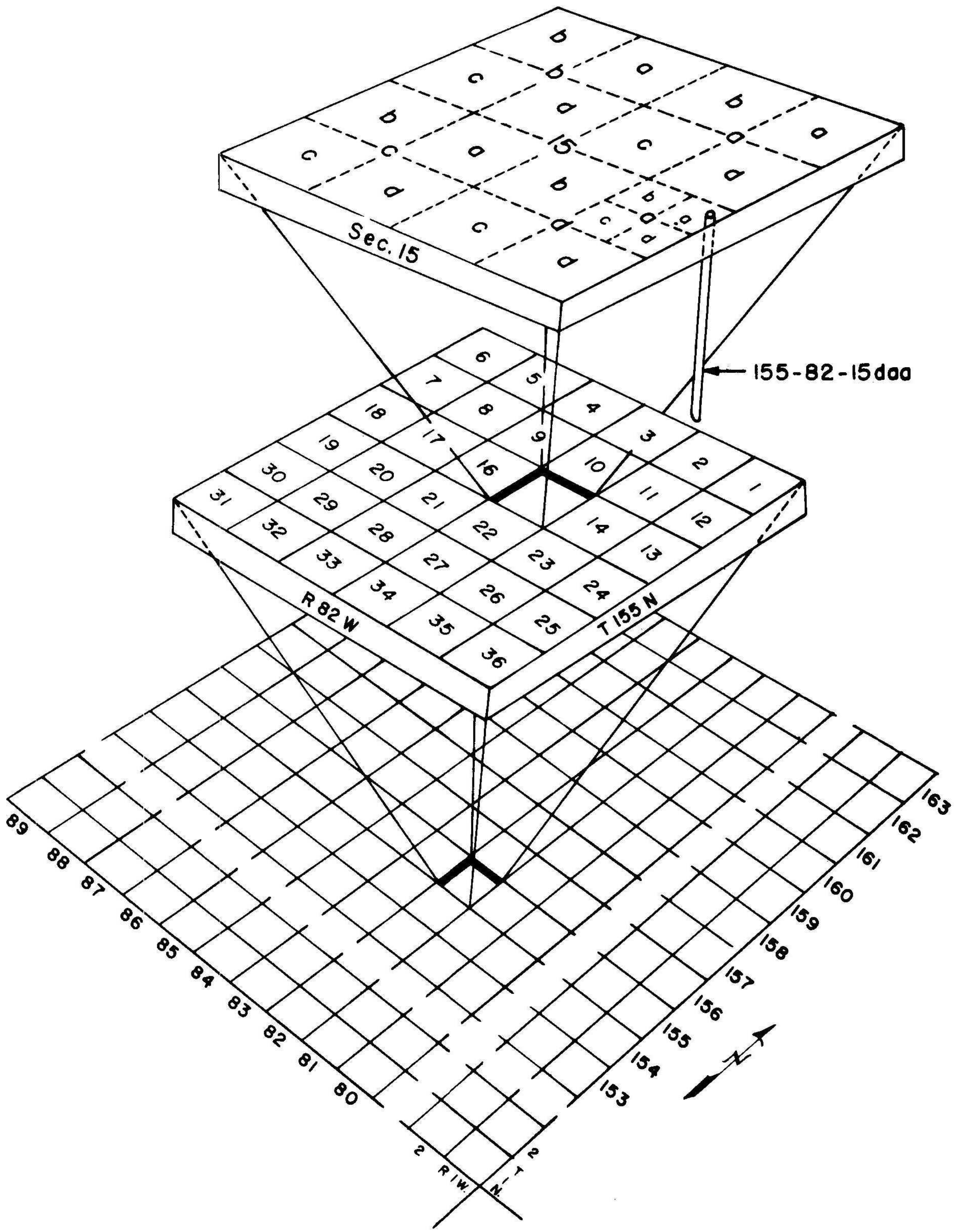


FIGURE 3--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

ground water also occurs as direct evaporation from the soil surface and bodies of open water, and as transpiration from plants. Ground water may also discharge directly from one ground-water reservoir to another, or by slow percolation from one reservoir to another through a separating formation.

Any formation or stratum that will yield water in sufficient quantity to be of importance as a source of supply is called an 'aquifer'. The water moving through the aquifer from recharge areas to discharge areas is considered as water in 'transient storage'. The amount of water that can be stored in an aquifer depends upon the amount of open space in the material, or its porosity, and upon the dimensions of the entire aquifer.

The capacity of an aquifer to yield water is less than the porosity would indicate because part of the water will be retained in pore spaces by molecular attraction, much as a sponge or wet towel after it has stoppped dripping. The amount of water which is free to drain out of an aquifer under natural conditions and expressed in percentage of the total volume of the aquifer is called the 'specific yield'. 'Specific retention' refers to that part of water which will be retained, hence, porosity (water holding capacity) = specific yield + specific retention.

If the pore spaces are large and interconnected, as they commonly are in sand and gravel, the water movement is less restricted and is transmitted more or less freely, and the material is considered permeable. If the pore spaces are very small or not connected, as they are in clay or silt, the water is transmitted very slowly and the material is said to be impermeable. Unconsolidated material such as sand and gravel is generally more permeable than consolidated rocks such as shale, sandstone, and limestone and, therefore, are considered more important as ground-water reservoirs.

If the water in an aquifer is not confined by impermeable strata, the water is considered to occur under water table conditions. If the aquifer is separated from the main ground-water reservoirs by impermeable strata above the water table, a perched water table condition may develop. In either case, water may be obtained from storage in the aquifer by lowering the water level, as in the vicinity of a well being pumped, which results in gravity drainage. However, if water is confined in the aquifer by an overlying impermeable stratum, so that the water in a well rises above the top of the aquifer under hydrostatic pressure, the water is said to occur under artesian conditions. In this case, if ideal artesian conditions prevail, water is yielded as the water level in the well is lowered, but the aquifer remains saturated and the water is yielded because of its own expansion and the compression of the aquifer due to lowered pressure rather than by gravity drainage. The water yielding capacity is called the 'coefficient of storage' and is very much smaller than the specific yield of the same material when drained by gravity. The coefficient of storage is defined as the volume of water that will be released from storage in each vertical column of the aquifer having a base one foot square, when the artesian level falls one foot.

Bedrock

Geologic information on bedrock formations in the Surrey area was gained essentially from one deep hole drilled in connection with the Surrey study and from 4 oil test logs (Fig. 4, Tables 4 and 5). Bedrock formations below and including the Pierre Shale are not and should not be considered possible sources for a municipal water supply for economic reasons. The log of one oil test drilled near the Surrey area (Hunt Oil Co.-Joe Wald No. 1, 155-81-23cd) indicates the presence of formations below the Pierre Shale from the following geologic systems - Cretaceous, Jurassic, Triassic, Mississippian, Devonian, Silurian, and

Ordovician. Precambrian granite was encountered at a depth of 8,617 feet.

Fox Hills Formation - The Fox Hills Formation overlies the Pierre Shale in the Surrey area. As evidenced from the cross-section in Figure 4, the Fox Hills Formation rises and thins towards the east. Westward from Surrey the Fox Hills Formation dips into the Williston Basin and continues on into Montana.

Fifty-three feet of what is believed to be Fox Hills sediments were penetrated in the Surrey area. The material consisted of sand, sandstone, lignite, and silty to sandy clay which in some places was highly organic. The formation top was picked at a depth of 435 feet from the electric log of Test Hole 1 (155-81-19abb, Fig. 5, Table 4). The electric log indicates that a highly porous condition prevails throughout the section penetrated. Correlation between the two nearest oil tests indicates approximately 50 feet more of Fox Hills sediments can be expected below the total depth of 588 feet drilled in Test Hole 1.

The presence of lignite and organic matter in the sediments possibly suggests a marine shallow water depositional environment. A large inland sea is believed to have existed in North Dakota in Late Cretaceous time and the Fox Hills sediments in the Surrey area are probably shoreline or near-shore depositional features.

Little is known concerning the occurrence of water in this formation in the Surrey area. Only one known well (Mike Burckhard, 155-81-19aba, Table 4) obtains a domestic supply from the Fox Hills Formation, the supply was reported adequate. The water level in this well could not be measured, so therefore, it is not known whether artesian conditions are present. The Fox Hills Formation does yield water under hydrostatic pressure in central and south-central North Dakota, so artesian conditions may be assumed also in the Surrey area.

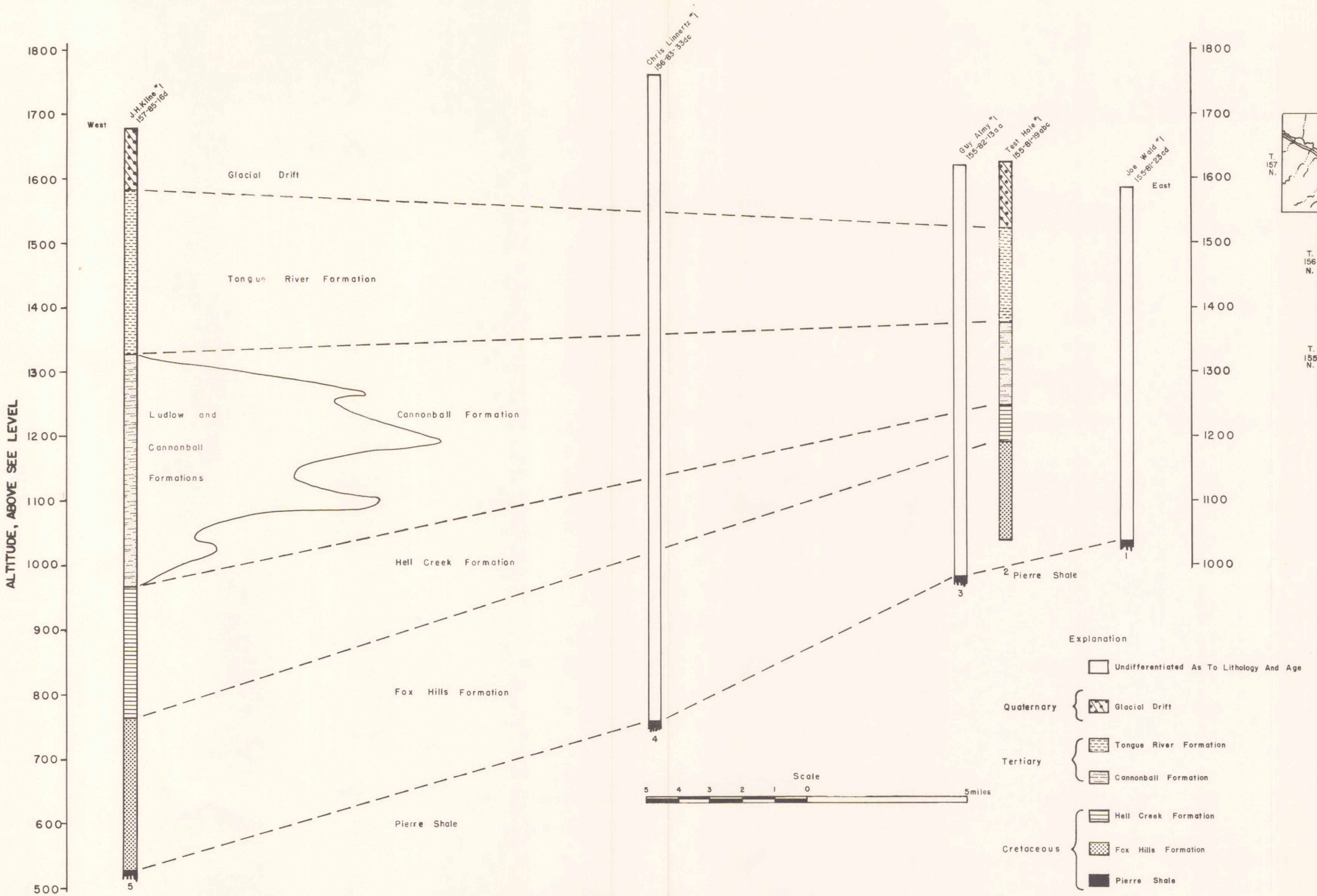
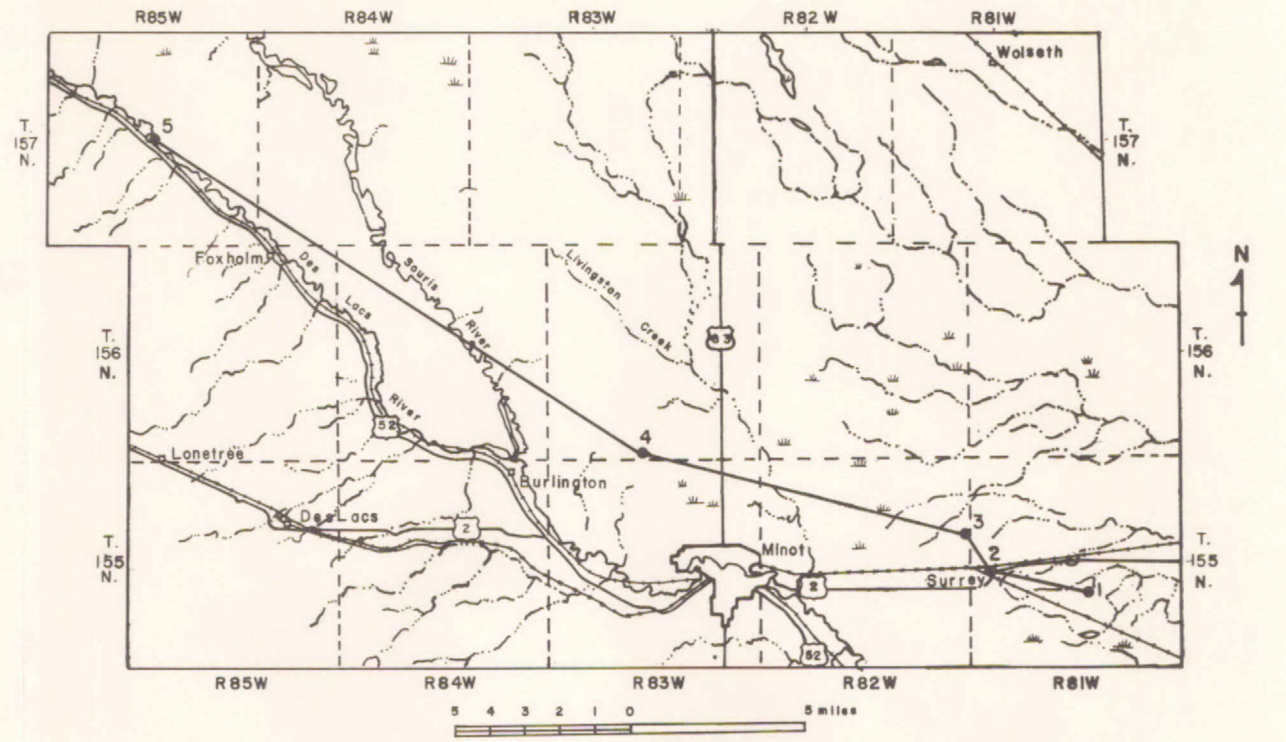


FIGURE 4--CROSS SECTION OF DEEP WELL LOGS.



SKETCH MAP SHOWING LOCATION OF DEEP WELLS AND TEST HOLES

Apparently the formation is fairly permeable in the area and it is estimated that a well which completely penetrates the aquifer and is properly developed should be capable of producing 100 gallons per minute or more. An aquifer test by qualified personnel would be required before a safe yield could be determined however.

Hell Creek Formation - Fifty-eight feet of bluish gray, silty to sandy clay believed to represent the Hell Creek Formation were penetrated in Test Hole 1. As shown in Figure 4, it is thinning more rapidly to the east than the underlying Fox Hills Formation.

The formation top was picked at a depth of 377 feet from the electric log of Test Hole 1. The electric log indicates water development much less favorable than in the underlying Fox Hills Formation but possibly slightly better than the majority of the overlying bedrock formations. No wells are known to tap the Hell Creek Formation in the Surrey area. Because the formation does not appear to be significant as a major aquifer in western North Dakota, it should not be considered as a possible source of supply other than for small domestic or stock demands in the Surrey area.

Cannonball Formation - The Cannonball Formation and the overlying Tongue River Formation are treated as the Cannonball and Tongue River Members of the Fort Union Formation by Lemke (1960) and LaRocque, et al (1963a & b). Because the two units contain separate physical, lithologic, and hydrologic characteristics and can be differentiated in the subsurface as well as at the surface in areas where they outcrop, they are treated as separate formations of the Fort Union Group in this report.

At the close of Cretaceous time which witnessed the deposition of the Hell Creek Formation, there followed a period characterized by erosion rather than deposition in North Dakota. At the beginning of Tertiary time, a large

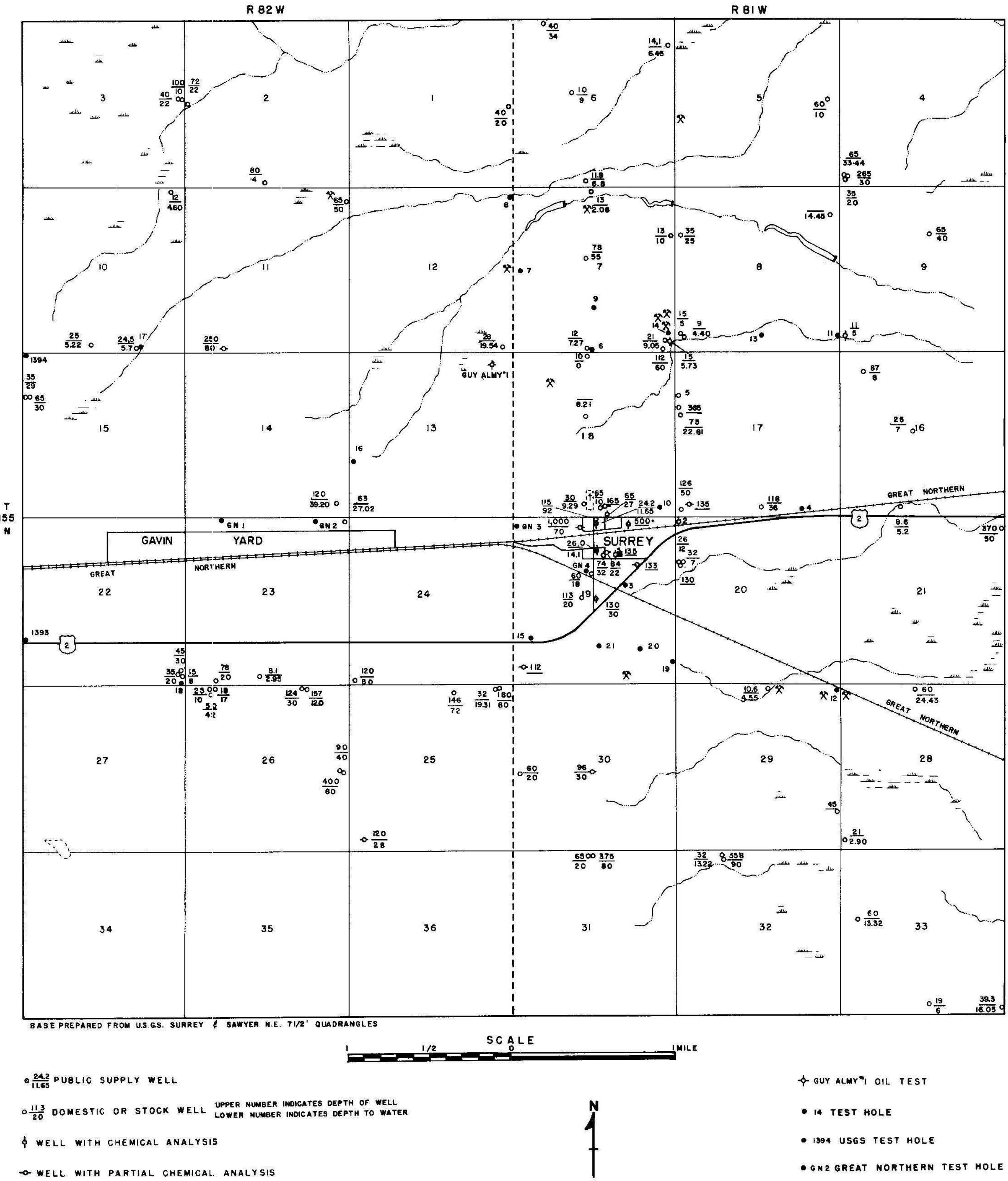


FIGURE 5--MAP OF THE SURREY AREA SHOWING THE LOCATION OF WELLS AND TEST HOLES

inland sea, somewhat similar to that of Fox Hills time, covered central and western North Dakota and adjacent areas and deposited the sediments of the Cannonball Formation. LaRocque, et al (1963a, p. 17) believes the westernmost advance of the Cannonball sea was a line almost coinciding with the course of the DesLacs River.

In conjunction with the shallow Cannonball sea, streams and rivers were transporting debris from a part of the Rocky Mountain regions and depositing it on the broad plain bordering the sea. These deposits are collectively known as the Ludlow Formation. Because of fluctuations of sea level and the variation in deposition, the sediments of the Cannonball and Ludlow Formations intertongue and are extremely difficult to differentiate in western North Dakota. Lemke (1960) includes both in the measured section of the J. H. Kline #1 (Fig. 4), but only Cannonball deposits are believed by the writer to be present in the Surrey area.

The top of the Cannonball Formation in the Surrey area was picked at a depth of 249 feet from the electric log of Test Hole 1. The formation is composed, for the most part, of silty and sandy clay but includes shale, sandstone, lignite and silt strata. The electric log indicates only the sandstone is capable of yielding water to wells and these yields can be expected to be low.

Several wells have been developed in the Cannonball Formation and produce sufficient water for ordinary domestic and stock demands. The water level may vary from 30 to 90 feet below land surface and should fluctuate only slightly because artesian conditions are present. Recharge areas to the Cannonball Formation (and presumably to the underlying Hell Creek and Fox Hills Formations) is for the most part from the south and southwest where the formation crops out. LaRocque, et al state,

> "The Cannonball 'Member' is exposed on the walls of the Souris River from a point about midway between Minot and Velva to a point about 9 miles downstream from Velva." (1963a, p. 17)

Although the supply to wells penetrating sand or sandstone strata in the Cannonball Formation is adequate and reliable, it is doubtful if a sufficient quantity could be obtained to support a small municipal water supply in the Surrey area.

Tongue River Formation - After the final retreat of the Cannonball sea, deposition of continental deposits extended over the entire area and continued uninterupted throughout Tongue River time, which lasted to the end of the Paleocene Epoch. The Tongue River thickens west of the Surrey area and in the unglaciated portion of southwestern North Dakota occurs at the surface throughout the majority of the region.

All test holes drilled in connection with the Surrey study encountered the Tongue River Formation at variable depths. The deepest it was found was 103 feet in Test Hole 1. The formation consists largely of light-colored interbedded clay, sandy clay, sand, sandstone, shale and silt. The sediments were deposited, for the most part, in swamps and shallow lakes and shifting of the water bodies during accumulation caused the resulting layers to be disconnected and uneven in thickness.

The majority of wells in the Surrey area, which do not obtain their supply from the overlying glacial drift, tap sandy parts of the Tongue River. Due to the sporadic nature of the sandy strata, wells in the area are variable in depth and show a marked variance in water levels. Water in nearly all of the wells is under hydrostatic pressure but yields are low. The largest known yield from a well developed in Tongue River sediments in the Surrey area is reported to be 11 gallons per minute (Donald Erck-Minot well driller, oral communication, April 1963).

Because of the fine-grained nature of the sediments and poor hydrologic connections it is very doubtful if any one well penetrating the Tongue River

Formation would be capable of supplying the demand of a municipal supply in the Surrey area. It does yield small but adequate and reliable quantities for ordinary domestic and stock-watering purposes, however.

Glacial Drift

Glacial drift refers to all stratified or unstratified materials deposited directly or indirectly by glacial action. It occurs at the surface and immediately underlying the entire Surrey area. The average thickness of drift in the Surrey area is approximately 62 feet and varies from 36 to 103 feet.

Glaciers, heavily laden with bedrock materials and glacial debris which had been picked up and transported by the ice, moved southward across the area during the Pleistocene Epoch. As the margins of the glaciers melted back to the north, the rock material carried within the glacier was left as a mantle on the surface overridden by the ice. Streams of meltwater flowing from the ice deposited sorted materials in mounds and ridges and cut a network of meltwater channels in the surface throughout the majority of the area. The present surface is essentially as the ice and meltwater left it.

Till - Till is the part of the glacial drift characterized by an unstratified mixture of clay, silt, sand, pebbles, and cobbles which was deposited directly by the glacier with little or no transportation by water. Two tills, representing two separate glacial advances, were noted during test drilling. The lower till is a tightly compacted, olive gray clay; the upper till is less compacted, yellowish brown to olive gray, sandy clay. Both tills contain variable amounts of silt, sandy, and pebbles. Cobbles and small boulders are included in either till, but are not common.

During the waning stages of the last glaciation, the surface of the Surrey area consisted of a gently undulating till plain or ground moraine. Numerous saucer-shaped depressions, called kettles or potholes, dotted the entire area. These potholes are the result of the melting of ice blocks which had been deposited with the till by the glacier as it retreated. Many of the potholes were later eroded by a complex of meltwater channels, but the original pock-marked surface is still visible on the divides between the channels.

Till is essentially impervious and does not readily yield water to wells. In general, wells recovering water from the glacial drift, tap outwash sand and/or gravel deposits at the surface or included in the till. It is possible to obtain variable amounts of water from a well dug or bored into the till, if the till contains cracks called fractures or joints. Aerial photographs indicate a predominant fracture pattern may exist in the Surrey area. Numerous northwest-southeast striking linear traces were identified on the photos. The traces are not affected by changes in topography and range from several tens to several hundreds of feet in length. Providing these traces are fractures, and if they continue on below the water table, small or possibly moderate supplies of water might be recovered from a well dug directly over the fracture. The yield naturally will be determined by the size, width, and depth of the fracture and its degree of hydraulic connections. The traces are nearly indiscernable on the ground but quite evident on aerial photographs because of the linearity which is almost perpendicular to the general topographic dip to the northeast.

Most of the recharge to the till is due directly to precipitation which accumulates in the potholes and surficial materials and gradually percolates downward. It is doubtful if the till or any part of the glacial drift in the Surrey area recharges the underlying bedrock and, in fact, because hydrostatic pressure exists, the bedrock may actually be recharging the immediately overlying glacial drift.

Outwash - Outwash refers to all detrital material swept out of the melting glacier by meltwater streams. Outwash is irregularly distributed throughout the Surrey area at the surface, included within the till, and within the confines of the meltwater channels. It varies in thickness from inches to over 40 feet and in degree of sorting from poorly sorted to well sorted.

Outwash deposits at the surface are difficult to distinguish topographically because of the erosion by the meltwater channels. They can be observed, however, in exposed areas such as roadcuts and gravel pits. Aerial photographs are especially helpful in locating surficial outwash in that it shows up as a white to medium-light gray tone. Also there is a definite lack of potholes and recent erosion because of the high degree of permeability, and the channel bottoms in outwash are flat whereas those cut through till are U-shaped. The largest concentration of surficial outwash is in the northern half of the Surrey area. Test Hole 7 (155-81-7cbb, Table 5) encountered 44 feet of outwash material, the upper 16 feet of which consisted of poorly sorted gravel. Test Hole 14 (155-81-7dda, Table 5) encountered at least 33 feet of outwash material, the majority of which was gravel. Both Test Holes 7 and 14 are near gravel pits.

Nearly all test holes encountered variable amounts of outwash within the till. These deposits cannot be foretold by surface expression and must be located by test drilling or geophysical exploration. In general, these deposits are restricted in lateral extent and occur as small lenses and stringers, however, concentrated test drilling or geophysical exploration may prove some to be fairly extensive. The shallow aquifer supplying village wells numbers 1 and 2 (Table 4) apparently exists throughout the northern portion of the village. A U. S. Geological Survey test hole drilled in the NE¼ Sec. 13, Twp. 155 N., Rge. 81 W., located 6 miles east of Surrey, indicates a potential aquifer. The log of the test hole (Table 6) shows 9 feet of sand and gravel from 27 to 36 feet and 44 feet of coarse sand and gravel from 43 to 87 feet. This area definitely holds a possibility for the development of a moderately large water supply.

Outwash deposits associated with the meltwater channels are largely the result of reworking and redeposition of previously deposited surficial outwash by the meltwater which carved the network of channels in the area. They will be discussed more fully in the following section on meltwater channel deposits.

Outwash deposits consist of clay, silt, sand, and gravel. The clay and silt are essentially impermeable and do not readily yield water to wells. The sand and gravel deposits on the other hand are quite permeable and supply the majority of water to glacial drift wells. Small domestic and stock wells encountering as much as one or two feet of saturated sand and gravel are reported as supplying adequate quantities of water for those purposes. The yield of such wells would be approximately 1 to 3 gallons per minute. Larger yields can be expected from greater thickness of saturated sand and gravel; long-term, higher pumping rates will depend on the degree of hydrologic connections in the sand and gravel and the aerial extent of the recharge area.

Hydrologic connections in surficial sand and gravel are usually very good and a well penetrating the deposits will draw water from the majority of the deposit. If a well is intended to produce for any purpose other than domestic or stock uses, a pumping test should be performed to determine a safe yield. Recharge to surficial outwash sand and gravel is dependent on precipitation. Discharge through surficial sand and gravel to nearby meltwater channels is probably quite rapid and should be taken into consideration before developing a well any distance from the channel.

The simplest and most economical means of determining the availability of water in buried outwash associated with the till is a pumping test. If a well penetrating buried sand or gravel deposits can be pumped dry in a short period of time, a lenticular condition exists in the sand or gravel and it is probably completely surrounded by nearly impervious till with no recharge area to draw from except the till. If the well can be pumped at a steady rate with no serious drawdown of the water level, good hydraulic connections are present and a safe pumping rate can be determined by careful analyses of the pump test data. This data along with records of water level measurements of nearby observation wells will indicate recharge and discharge characteristics of the aquifer.

The outwash deposits associated with certain meltwater channels are perhaps the best suited for development of a municipal water supply in the Surrey area. The occurrence of water in these deposits will be discussed in the following section on meltwater channel deposits.

Meltwater channel deposits - During the final phase of glaciation as the wasting glacier was retreating to the north, a large mass of ice blocked the Souris River Valley south of Minot causing meltwater to spill to the east through the Surrey area. Lemke offers the following explanation for the present day surface

> "In the complex braided network of outwash channels in the vicinity of Surrey, in the eastern part of Ward County, it appears that several channels may have carried meltwaters simultaneously and that the melt waters flowed between many blocks of ice. If blocks of ice had not been present, probably only a few large channels would have formed at successive positions marginal to the ice because of the northeast slope of the ground surface" (Lemke, 1960, p. 88).

Eventually as the mass of ice south of Minot melted, meltwater was diverted south but a portion of the history of the Souris River was recorded on the surface in the Surrey area.

Meltwater channel deposits range from a thin veneer of silt and clay with local patches of sand and gravel in the gently rounded channel bottoms eroded into till, to 30 or 40 feet of sand, gravel, silt, and clay in the wider flat-bottomed channels. Minor amounts of recent alluvium and slopewash consisting of clay, silt, and fine sand overlie outwash deposits in the larger channels, but they are thin and do not constitute a significant source of water supply in the area.

Test drilling indicates that strata of relatively clean, sorted sand and gravel occur as discontinuous lenses along portions of the meltwater channels and that they are probably separated by less permeable materials such as silty or clayey sand, clayey silt, or even reworked till. The lack of continuity in the sands and gravels is primarily due to varying conditions of sedimentation caused by meltwaters which were forced to flow among stagnant blocks of ice rather than in continuous defined channels. The supply of meltwater, the amount and size of material being transported, and the presence or absence of an unobstructed course are conditions which determined whether the meltwater was eroding a channel or depositing material in it. Frequent channel changes contributed to the discontinuity of the meltwater channel deposits by eroding, reworking, and redepositing parts of the pre-existing deposits. The thicker sand and gravel beds are the best potential aquifers. In much of the area, however, meltwater channel deposits do not have sufficient thickness to be important as a source of ground water for a municipal supply.

Although generally thin and apparently discontinuous in part, certain meltwater channel deposits, namely sand and gravel, are moderately to highly permeable and are known to yield sufficient water for stock and domestic purposes in the Surrey area. The municipal supply wells of Mohall and Glenburn, North Dakota, tap meltwater channel deposits. Because little was known regarding the yield potential of meltwater channel deposits in the Surrey area, a preliminary pumping test was performed on Reinhold Elker's stock well (155-81-7ddd$_3$, Fig. 5, Table 4).

The stock well, 18 inches in diameter and 21 feet deep, consists of four 4-foot concrete culverts and one 5-foot galvanized steel culvert. The steel culvert, perforated in several places to allow water to enter the well as it is pumped, was set at the bottom of the bored hole. The well was not gravel-packed or developed. On November 5, 1963, as part of this study, the well was pumped for a period of 8 hours at a rate of 60 gpm (gallons per minute). Accurate drawdown measurements could not be obtained from the well because of its construction, however, the water level surprisingly was never lowered sufficiently to affect the rate of 60 gpm. An old stock well (155-81-7ddd$_2$, Table 4), located 142 feet east of the pumped well, was used as an observation well. Periodic measurements were taken on this well during pumping to determine the influence of the pumped well. The observation well was lowered .09 foot after 5 hours of pumping and remained static for the next three hours.

Accurate predictions regarding a municipal supply well at this location cannot be made since data collected was incomplete. However, because the pumped well was not designed to produce 60 gpm, the belief that the well does not penetrate the entire thickness of saturated gravel, and that the apparent recharge area is fairly extensive; it can be safely assumed that a properly developed municipal supply well at this location will be capable of producing at least 60 gpm for a period of at least 8 hours. A well pumping 60 gpm for 8 hours will yield 28,800 gallons of water. It is estimated that a supply of 25,000 to 28,000 gallons of water per day would be sufficient to supply all residents of the village of Surrey under average conditions.

Significant amounts of recharge to the meltwater channel deposits occur through direct penetration of rainfall and also by lateral movement of ground water into the channels from the till or outwash deposits. However, the most important source of recharge to the channel deposits occurs during the spring runoff when substantial surface flows result from the melting of accumulated snow. During the spring runoff generally much more water is available than can be absorbed by the deposits and the surface runoff may be thought of as 'rejected recharge', or water that would have been absorbed by the deposits had they not been saturated. A dam across the meltwater channel will help to retain the majority of the rejected recharge.

Although some of the water in the meltwater channel deposits may seep into underlying or adjacent deposits, the greater part moves down the long axes of the channels. Water in the channels not withdrawn through wells, consumed by vegetation, or evaporated, is discharged into a surface drainage course, a lake, or a marsh. A subsurface dam or clay core will prevent the subsurface drainage down the channel and retain large quantities of water that otherwise would be lost.

QUALITY OF WATER

Ground water in the Surrey area is primarily of meteoric origin. Meteroic water, or water precipitated as rain or snow, contains only small amounts of dissolved mineral matter. As soon as it reaches the earth, however, it begins to react with the minerals of the soil and rocks with which it comes in contact. The amount and character of the mineral matter dissolved by meteoric waters depend upon the chemical composition and physical structure of the rocks with which they have been in contact, the temperature, the pressure, the duration of contact, and the material already in solution. The solvent action of the water is assisted by carbon dioxide in solution which is derived from the atmosphere and organic processes in the soil through which the water passes.

Quality of shallow ground water, in general, varies inversely with the quantity; where abundant, it is commonly potable; where sparse, it is commonly highly mineralized. Extent of mineralization, in general, varies directly with depth; deeper bedrock waters being usually more highly mineralized than shallow waters. Deep artesian water is usually highly mineralized. Shallow water is, however, more likely to be polluted from surface sources.

The purity of water as regards the sanitary conditions must be determined by inspection of the source and its surroundings and by bacteriological examination of the water. The condition of a water as regards pollution may change so quickly that the results of an examination at one time do not necessarily bear any relation to the purity of the water at another time. The mineral constituents, on the other hand, are fairly constant in water from a given source unless the source is a stream or river that carries different quantities of dissolved material at different stages.

The quality of water for public supply and domestic use commonly is evaluated in relation to standards of the United States Public Health Service for drinking water. The standards, adopted in 1914 to protect the health of the traveling public, were revised several timesin subsequent years. The latestrevision by the U. S. Public Health Service (1963), approved by the Secretary of Health, Education and Welfare, is, in part, as follows:

Table I -- Geologic Formations

Era	Period	Epoch	Formation		Lithologic Character
CENOZOIC	QUATERNARY	Recent	Alluvium		Clay, silt, and fine sand
		Pleistocene	Glacial Drift	Meltwater channel deposits	Clay, silt, and fine to coarse sand and gravel
				Outwash	Clay, silt, and fine to coarse sand and gravel
				Till	Clay and sandy clay, yellowish brown to olive gray; limestone and granitic pebbles
	TERTIARY	Paleocene	Tongue River Formation		Light-colored interbedded clay, sandy clay, sand, sandstone, shale and silt; some lignite
			Cannonball Formation		Silty and sandy clay, shale, sand, sandstone, silt and lignite
MESOZOIC	CRETACEOUS	Upper Cretaceous	Hell Creek Formation		Bluish-gray silty to sandy clay
			Fox Hills Formation		Greenish-gray sand, sandstone, and silty to sandy clay; lignitic
			Pierre Shale		Gray shale and clay; lumpy, bentonitic

and their water-bearing characteristics

Maximum thickness (feet)	Water-bearing characteristics
2	Too thin to constitute a source of water supply
44±	Sand and gravel generally well-sorted, moderately to highly permeable; in places may yield enough water for small or medium municipal, industrial, or irrigation developments
19±	Sand and gravel poorly-to moderately -sorted, moderately permeable; in places may yield enough water for small municipal or industrial development
90±	Relatively impermeable; may yield sufficient supply for small domestic or stock demands
146±	Slightly permeable, poor hydrologic connections; may yield up to 11 gpm
128	Slightly permeable; sand or sandstone strata may yield 10-15 gpm
58	Not known to be a source of supply for other than domestic or stock wells
203±	Permeable; may yield 100 gpm (estimated)
1292±	Impermeable; not usually a source of supply

Table 2 - Drinking water standards of the U. S. Public Health Service

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

Seventeen complete and partial chemical analyses of well water in the Surrey area are shown in Table 3. The partial analyses were taken from the tables of LaRocque, et al.(1963b). The complete analyses were performed by the State Laboratories in connection with this study.

The Fox Hills Formation contains highly mineralized sodium chloride water in the Surrey area (155-81-19aba, Table 3). The water, similar to sea water but in lesser concentrations, acquires its poor quality from water and minerals trapped in the sediments as they were deposited. The water is soft and preferred for laundering but the high concentration of boron, sodium, and total dissolved solids make the water unsuitable for watering plants, lawns and gardens. Because treatment of this water is difficult and expensive, the Fox Hills Formation should not be considered as a source for a municipal supply of water.

Waters of the Cannonball Formation are of the sodium chloride or sodium bicarbonate type, slightly saline, soft, and unsuitable for gardening. The water is similar to that from the Fox Hills, but apparently less alkaline. Alkalinity can be judged in the pH column (Table 4). The range of pH is from 0 to 14. A solution with a pH of 7 is said to be neutral. Progressive values below 7 denote increasing acidity, those above 7 denote increasing alkalinity.

Tongue River Formation waters are characterized by the sodium bicarbonate type. The waters are very soft averaging about 16 ppm, but quite alkaline with an average pH of 8.3. The average sodium concentration is less than waters of the Fox Hills or Cannonball Formations but the average of 98% sodium is the same, making the water unfit for irrigation. Chloride content of the Fox Hills and Cannonball average 1,000 ppm while those of the Tongue River average 53 ppm. This difference is because of marine deposition of the Fox Hills and Cannonball sediments and the continental deposition of the Tongue River sediments. If the chloride concentration is much over 400 ppm, water will have a salty taste. Tongue River waters contain the highest iron concentration in the area and average about 2.5 ppm. Although the U. S. Public Health Service recommends .3 ppm, up to 1 ppm is acceptable; 1 to 3 ppm is fair and over 3 ppm objectionable. Staining of plumbing fixtures and clothing may occur if the iron concentration is over 1 ppm.

Glacial drift waters are generally of the calcium sulfate type although deeper drift wells may contain sodium sulfate waters due in part to contamination by infiltrating bedrock waters. The major differences between drift and bedrock waters, other than the type, is the hardness and % sodium. Glacial drift waters are very hard averaging about 820 ppm. The North Dakota State Department of Health recommends a maximum hardness of 140 ppm for municipal supplies. Hardness can be easily and economically removed by water softeners. The % sodium is usually very low in drift waters, unless contaminated by bedrock waters, and suitable for all types of irrigation, making it more desirable than bedrock waters for a municipal supply. The sulfate content of drift waters, as well as those from the Tongue River Formation, generally exceed the limit of 250 ppm. Excess sulfate will cause a laxative effect, but concentrations up to 600 ppm can be used without any noticeable adverse effects. Drift waters are only slightly alkaline, the pH averaging approximately 7.5.

Neither bedrock nor drift waters contain excessive amounts of flouride or nitrates in the Surrey area. Fluoride in concentrations from .08 to 1.5 ppm in water drunk by children is generally believed to be beneficial in the reduction of tooth decay. The presence of nitrates of more than 10 ppm indicate contamination by sewage or other organic matter. Studies indicate that nitrate in excess of about 45 ppm in drinking water may be a contributing factor or the cause of a condition in infants known as methemoglobinemia or "blue babies" (Lohr and Love, 1954).

SYNTHESIS OF DATA

The village of Surrey, contemplating the installation of a municipal water-works to supply the 310 residents, requested the North Dakota State Water Commission to study the area in and around the village and report on the availability of water. Field work was carried out in April and November, 1963, to locate a favorable area for the development of a well to supply adequate water of good quality for village use. All geologic units above the Pierre Shale in the Surrey area were considered.

Bedrock aquifers include the Fox Hills, the Cannonball, and Tongue River Formations. The Fox Hills Formation is permeable and a well penetrating the entire thickness may yield 100 gpm, however, the water is highly mineralized, salty, and unfit for watering plants, lawns, and gardens. The Cannonball and Tongue River Formations are slighly permeable and yield small quantities of water. Waters from these formations also contain high sodium concentrations making them unfit for watering plants, lawns, and gardens. Treatment of bedrock waters would be difficult and expensive.

Glacial drift aquifers include the outwash and meltwater channel deposits. Large diameter wells penetrating saturated sand and gravel deposits over 10

TABLE 3 ----------

(analytical results in

Location	Depth of well (feet)	Aquifer	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarb-onate (HCO_3)
155-81-7dda	15	Qd	4-18-63	17	.44	100	88	70	8.4	327
155-81-9ccc	11	Qd	4-17-63	10	.32	86	45	65	5.6	254
155-81-17cc	135	Qd(?)	6-17-47	--	--	--	--	--	--	990
155-81-18dcc	65	Qd	4-2-63	20	3.4	122	57	420	20	610
155-81-18dc2	365	Tc	6-17-47	--	--	--	--	--	--	850
155-81-19aba	500+	Kfh	4-2-63	6.8	1.6	5.6	7.3	1,125	13	835
155-81-19abb1	24.2	Qd	4-2-63	21	1.24	273	173	205	28	649
155-81-19abc1	26.0	Qd	4-2-63	19	.76	273	146	55	9.6	446
155-81-19aca1	135	Ttr	4-2-63	22	2.8	8.0	0	580	6.6	864
155-81-19aca2	84	--	7-19-61	--	3.8	--	--	--	--	632
155-81-19acb	174	Ttr	4-2-63	9.5	3.08	4.8	0	596	2.7	1,147
155-81-19acc	130	Ttr	4-2-63	9.5	1.68	6.4	0	657	9.3	883
155-81-19ad1	133	Ttr	6-17-47	--	--	--	--	--	--	1,040
155-81-19ba1	1,000	--	6-17-47	--	--	--	--	--	--	850
155-81-19cc	112	Ttr	6-17-47	--	--	--	--	--	--	940
155-81-20bbb	38	Qd	4-9-63	21	1.2	132	92	64	14	400
155-82-11ccd	250	Tc	9-11-47	6.0	.47	7.5	3.9	980	7.2	1,030

Aquifer:
- Qd- Glacial Drift
- Ttr- Tongue River Formation
- Tc- Cannonball Formation
- Kfh- Fox Hills Formation

CHEMICAL ANALYSES

parts per million except as indicated)

Carbon-ate (CO3)	Sulfate (SO4)	Chloride (Cl)	Flouride (F)	Nitrate (NO3)	Boron (B)	Total dissolved solids	Total hardness as $CaCO_3$	Total hardness non-carbonate	% Sodium	Sodium Absorption Ratio SAR	Specific conductance mmhos/cm	pH
0	415	54	.5	10	.12	1,014	610	342	19	1.2	1,566	7.6
0	270	40	.3	5	0	699	400	190	26	1.5	1,080	7.7
--	--	70	--	--	--	--	--	--	--	--	2,500	--*
0	905	34	.6	2	.58	1,918	540	0	62	8.0	2,749	7.4
--	--	1,060	--	--	--	--	--	--	--	--	4,350	--*
0	11	1,300	.5	0	2.82	3,095	44	0	98	70.0	5,498	8.1
0	1,200	70	1.0	6.0	4.72	2,484	1,390	859	24	2.5	3,071	7.5
0	950	50	.7	10	.10	1,924	1,280	921	9	.7	2,374	7.3
48	450	32	.7	1.0	1.13	1,716	20	0	98	50.7	2,610	8.3
0	1,011	56	--	trace	--	2,119	372	--	75	--	2,972	7.7
0	254	82	.6	1.5	1.3	1,628	12	0	99	90.0	2,610	8.2
58	550	44	.6	1.0	.60	1,932	16	0	98	73.3	2,901	8.3
--	--	38	--	--	--	--	--	--	--	--	2,310	--*
--	--	1,000	--	--	--	--	--	--	--	--	4,190	--*
--	--	33	--	--	--	--	--	--	--	--	2,310	--*
0	500	10	.6	0	.20	1,130	710	380	16	1.1	1,740	7.5
0	.8	940	.5	1.2	2.4	2,450	34	0	98	--	4,340	7.6*

*LaRocque, G. A., Jr., Swenson, H.A., and Greenman, D. W., 1963b, Tables of hydrologic data, Crosby-Mohall area, North Dakota, U.S. Geol. Survey open-file report, 508 p.

feet thick may produce sufficient water for a municipal supply depending on the grain size, the degree of sorting, the hydrologic connections and the recharge area available. These conditions can be determined by test drilling and pumping tests on small diameter pilot wells. Generally glacial drift waters are chemically suitable for a municipal supply but are very hard. Hardness can easily and economically be reduced by a water softener.

RECOMMENDATIONS

On the basis of information gained during the survey, the meltwater channel in the extreme SE$\frac{1}{4}$ Section 7, Township 155 North, Range 81 West apparently contains a potential aquifer near the village of Surrey. The site was chosen for several reasons, some of which are:

1) Test Hole 14 penetrated at least 23 feet of well-sorted, clean, highly permeable gravel.
2) Gravel pits and aerial photographs indicate that sand and gravel deposits extend, perhaps somewhat discontinuously, at least one mile to the northwest. These permeable deposits allow for immediate infiltration and downward percolation of precipitation to recharge the aquifer.
3) Several bifurcating meltwater channels converging toward the site are capable of carrying excess runoff water and perhaps significant amounts of ground water to the immediate area from as far away as Gavin Yard, the Great Northern retarder yard located between Minot and Surrey.
4) The preliminary pumping test on Reinhold Elker's stock well indicates at least 60 gpm can be produced for at least 8 hours. A properly developed well penetrating the entire thickness of saturated gravel will undoubtedly produce a larger quantity of water. A pumping test will determine the length of time the well could produce a specific rate.

5) The meltwater channel narrows considerably as it enters Section 8 to the east. By excavating the permeable deposits in the channel, perhaps along the section line road, and replacing the deposits with a clay core, ground water moving down the axis of the channel can be retained and stored in a natural underground reservoir.

6) The quality of water, with the exception of the hardness is suitable for a municipal supply.

Disadvantages of a municipal supply well at this site are:

1) The distance from the well to the village requiring over one mile of pipeline.

2) The danger of contamination from surface sources.

3) Extended periods of drouth may sufficiently lower the water table to restrict the rate of pumping.

If the village of Surrey proposes to install a well in the SE$\frac{1}{4}$ of Section 7 or any other location in the area, it is recommended the State Water Commission be notified so observation well installation and collection of pumping test data may be made. Pumping test data will permit personnel of the Water Commission to analyze hydrologic characteristics of the aquifer and determine a safe yield of the well.

After the well is completed and producing, a water right should be acquired to protect the supply. Daily records of water level measurements, pumping rates, and pumping time should be registered for future reference. The North Dakota State Health Department, Bismarck, requires all towns or cities with a municipal supply to send in periodic water samples for bacteriological and chemical analyses.

TABLE 4 -- RECORDS OF WELLS AND TEST HOLES

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

Type of well: Dr.,drilled; Du, dug; Dv, driven; Bo, bored; g.p.m., gallons per minute

*LaRocque, G.A., Jr., Swenson, H.A., and Greenman, D. W., 1963b, Tables of hydrologic data, Crosby-Mohall area, North Dakota, U. S. Geol. Survey open-file report, 508 p.

Elevations considered correct to within 5 feet

Aquifer:
- Qd - Glacial Drift
- Ttr- Tongue River Formation
- Tc - Cannonball Formation
- Kfh- Fox Hills Formation

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

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

Note: Wells in Section 19 located to the nearest 40 acres (e.g. 155-81-19ac$_1$) are not shown on Figure 5 unless a partial chemical analyses was made of the water.

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
155-81-4cc$_1$	Harold Dickinson	65	22	Du		33.44	5-26-47	D,S	Qd	1589.0	*
155-81-4cc$_2$	Harold Dickinson	265	4	Dr		30		D,S	Tc	1590	
155-81-4cc$_3$	Harold Dickinson	35	36	-		20		D,S	Qd	1590	
155-81-5ad	D.E. McAllister	60	24	Bo		10	5-26-47	S	Qd	1593	*
155-81-6aa	Unknown	14.1	14	Bo		6.45	10-16-45	S,O	Qd	1563.0	*
155-81-6ba	Lena VonBerg	40	24	Bo		34	5-26-47	S	Qd	1597	*
155-81-6bd	Lena VonBerg	10	36	Du		9	5-26-47	S	Qd	1579	*
155-81-6cd	John Kauffman	11.9	30	Du		6.8	10-16-45	S,O	Qd	1565.0	*
155-81-7ad	S. M. Sheets	13	42	Du		10	5-27-47	D,S	Qd	1581	*
155-81-7ba	A. Korgel	13	16	Bo		2.08	5-29-47	D,S	Qd	1587.0	*
155-81-7bd	J. Korgel	78	16	Bo		55	5-29-47	D,S	-	1602	*
155-81-7cad	Test Hole 9	63	4 3/4	Dr	4-15-63	6.64	4-19-63	T	Qd	1578	See log
155-81-7cbb	Test Hole 7	84	4 3/4	Dr	4-15-63	14.32	4-17-63	T	Qd	1595	See log
155-81-7cdd$_1$	George Luchsinger	12	24	Bo		7.27	4-15-63	S	Qd	1586	Hard
155-81-7cdd$_2$	Test Hole 6	63	4 3/4	Dr	4-15-63	14.8	4-19-63	T	Qd	1598	See log
155-81-7dda	Test Hole 14	63	4 3/4	Dr	4-18-63	1.0	4-19-63	T	Qd	1578	See log
155-81-7ddd$_1$	Reinhold Elker	112	6	Dr		60		D,S	Ttr	1600	

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
155-81-7ddd$_2$	Reinhold Elker	15	60	Du		5.73	11-5-63	S,O	Qd	1578	Chem.analysis
155-81-7ddd$_3$	Reinhold Elker	21	18	Bo		9.05	11-5-63	S	Qd	1581	Pumping test - 60 gpm for 8 hours
155-81-8aa	Unknown			Bo		14.45	10-16-45	U		1588.0	*
155-81-8bcb	L. Curtis Luchsinger	35	24	Bo		25		D,S	Qd	1581	
155-81-8ccc$_1$	Sophionia Erb	15	48	Du		5		S	Qd	1572	
155-81-8ccc$_2$	Sophionia Erb	9	6	Du		4.40	5-27-47	D,S	Qd	1572.0	*
155-81-8dcc	Test Hole 13	63	4 3/4	Dr	4-17-63	-	-	T	-	1560	See log
155-81-8ddd	Test Hole 11	63	4 3/4	Dr	4-17-63	3.4	4-19-63	T	Qd	1563	See log
155-81-9abc	Eugene Dickinson	65	24	Bo		40		D,S	Qd	1582	
155-81-9ac	Harold Dickinson	100	24	Bo		50	5-26-47	D,S	-	1584	*
155-81-9ccc	Leonard Elker	11	48	Du		5		D,S	Qd	1588	Chem. analysis
155-81-16bb	J. Erb	67	24	Bo		8	6-4-47	D,S	Qd	1591	*
155-81-16bd	J. Erb	25	36	Du		7	6-4-47	S	Qd	1590	Unsuitable for domestic use *
155-81-16cd	Unknown	8.6	48	Du		5.20	10-17-45	O	Qd	1595.0	*
155-81-17bcb	Test Hole 5	84	4 3/4	Dr	4-8-63	17.2	4-19-63	T	Qd	1615	See log
155-81-17bcc	Keith Burns	365	4	Dr		-	-	D	-	1612	
155-81-17bc	O. Herbroson	75	18	Bo		22.81	5-29-47	S	Qd	1614.0	*
155-81-17ccc	Lawrence Unrah	126	6	Dr		50	-	D,S	Ttr	1620	
155-81-17cc	L. Andre	135	4	Dr		-	-	D,S	Qd(?)	1614	Partial chem. analysis *
155-81-17dc	T. Elsberry	118	4	Dr		36	5-29-47	D,S	-	1605	*
155-81-17ddc	Test Hole 4	74	4 3/4	Dr	4-8-63	3.0	4-19-63	T	Qd	1583	See log
155-81-18ba	Greslivold	10	7	Du		0	5-29-47	D,S	Qd	1588	*
155-81-18bd	Greslivold	-	48	Du		8.21	5-29-47	S	Qd	1624.0	*
155-81-18cd	G. Heger	30	24	Bo		9.29	6-12-47	U	Qd	1621.0	*
155-81-18dcc	Chester L. Keith	65	4	Dr		27		D	Qd	1625	Chem.analysis
155-81-18dc$_1$	D. E. Benell	65	20	Bo		10	6-4-47	D	Qd	1626	*
155-81-18dc$_2$	D. E. Benell	365	4	Dr				D,S	-	1626	Partial chem. analysis *

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
155-81-18ddd	Test Hole 10	84	4 3/4	Dr	4-15-63	14.23	4-19-63	T	Qd	1615	See log
155-81-19aa	P. A. Yoder	25	14	Bo		15	6-6-47	D	Qd	1621	*
155-81-19ab$_1$	Surrey Township	40	48	Du		20	6-6-47	D	Qd	1630	*
155-81-19ab$_2$	G. B. Hardy	23	24	Du		8	6-6-47	D	Qd	1630	*
155-81-19ab$_3$	Lewis Cook	55	18	Bo		25.78	6-6-47	D	Qd	1630	*
155-81-19ab$_4$	Wayne Grabow	75	4	Dr		25	-	D	Qd	1625	26 grains hardness
155-81-19aba	Mike Burckhard	500+	-	Dr		-	-	D	Gfh	1625	Chem.analysis
155-81-19abb$_1$	Village well #1	24.2	-	--		11.65	4-2-63	PS	Qd	1625	Chem.analysis
155-81-19abb$_2$	Earl Hall	115	4	Dr		92	-	D	Ttr	1627	
155-81-19abc$_1$	Village well #2	26.0	-	--		14.1	4-2-63	PS	Qd	1630	Chem.analysis
155-81-19abc$_2$	Test Hole 1	588	4 3/4	Dr	3-4-63	10.65	4-10-63	T	--	1625	See log
155-81-19aca$_1$	Surrey School	135	2	Dr		-	-	D	Ttr	1633	Chem.analysis
155-81-19aca$_2$	O. J. Hunter	84	4	Dr		22	-	D	--	1628	Partial chem. analysis
155-81-19acb	Tom Zook	174	4	Dr		32	-	D	Ttr	1628	Chem.analysis
155-81-19acc	Village well #3	130	4	Dr		30	-	PS	Ttr	1625	Chem.analysis
155-81-19acd	Test Hole 3	84	4 3/4	Dr	4-8-63	12.9	4-10-63	T	Qd	1614	See log
155-81-19ac$_1$	Unknown	10.0	48	Du		7.55	10-27-45	S	Qd	1630	*
155-81-19ac$_2$	A. C. Withun	55	--	Bo		20	6-6-47	D	Qd	1630	*
155-81-19ac$_3$	Stake	--	6	Du		14.12	6-6-47	U	Qd	1630.5	Unsuitable for domestic use *
155-81-19ac$_4$	Tom Zook	--	16	Bo		13.12	6-6-47	D	--	1630	*
155-81-19ad$_1$	Surrey School Dist.	133	2 1/2	Dr		--	-	D	Ttr	1617	Partial chem. analysis *
155-81-19ad$_2$	T. Stein	24	36	Bo		4.22	6-10-47	D,S	Qd	1617	*
155-81-19ad$_3$	J. Styer	50	18	Bo		22.06	6-10-47	S	Qd	1617	*
155-81-19ad$_4$	A. L. Dompkin	20	6	Bo		12	6-6-47	D	Qd	1617	*
155-81-19ad$_5$	W. J. Conners	60	18	Bo		29.18	6-6-47	D	Qd	1617.1	*
155-81-19ba$_1$	P. W. Thom	1,000	4	Dr		70	6-6-47	D	--	1623	Partial chem. analysis *

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
155-81-19ba$_2$	Great Northern Railway	20	12	Bo		16	6-6-47	D,S	Qd	1623	*
155-81-19ba$_3$	Unknown	20	36	Du		16	6-6-47	U	Qd	1623	*
155-81-19bbb	Great Northern test 3	180	--	Dr	4-6-55	--	-	T	--	1628	See log
155-81-19bda$_1$	Wm. H. Linnertz	60	12	Bo		18	-	D	Qd	1620	Hard
155-81-19bda$_2$	Great Northern test 4	180	--	Dr	4-28-55	--	-	T	--	1625	See log
155-81-19bdd	Bonaventure Kraft	113	4	Dr		20	-	D	Ttr	1625	Soft
155-81-19bd$_1$	R. Brey	30	6	Dr		13.81	6-6-47	U	Qd	1630	*
155-81-19bd$_2$	S. Dugle	60	24	Bo		16	6-6-47	S	Qd	1630	Unsuitable for domestic use *
155-81-19ca	Great Northern Railway	60	6	Bo,Dr		--	-	D	Qd	1630	*
155-81-19cbc	Test Hole 15	84	4 3/4	Dr	4-18-63	16.29	4-19-63	T	Qd	1615	See log
155-81-19cc	Floyd Kauffman	112	3	Dr		--	-	D,S	Ttr	1636	Partial chem. analysis *
155-81-19cd	S. N. Yoder	40	18	Bo		20	6-10-47	D,S	Qd	1622	*
155-81-19da	Steward Dugle	20	24	Bo		5.86	6-6-47	S	Qd	1636	*
155-81-19dc	S. Yoder	60	12	Bo		32	6-6-47	D	Qd	1622	*
155-81-19dcb	Test Hole 21	73½	4 3/4	Dr	11-4-63	--	-	T	--	1610	See log
155-81-19ddb	Test Hole 20	84	4 3/4	Dr	11-4-63	--	-	T	Qd	1608	See log
155-81-19ddd	Test Hole 19	84	4 3/4	Dr	4-19-63	10.0	4-19-63	T	Qd	1605	See log
155-81-20bbb	Test Hole 2	84	4 3/4	Dr	4-6-63	10.15	4-19-63	T	Qd	1615	See log, chem.analysis
155-81-20bcb$_1$	John Luchsinger	130	4	Dr		--	-	D, S	--	1615	
155-81-20bcb$_2$	John Luchsinger	32	18	Bo		7	-	D, S	Qd	1610	
155-81-20bc	John Luchsinger	26	24	Bo		12	6-10-47	D, S	Qd	1615	*
155-81-21aaa	John Stip	370	4	Dr		50	-	D, S	--	1580	
155-81-28ba	J. Hauptmann	60	14	Bo		24.43	6-10-47	D, S	Qd	1607	*
155-81-28cc	John Luchsinger	21	18	Bo		2.90	6-5-47	D, S	Qd	1606	*
155-81-28dd	T. Aberle	--	12	Bo		--	-	U	Qd	1605	*
155-81-29aaa	Test Hole 12	84	4 3/4	Dr	4-17-63	9.19	4-19-63	T	Qd	1603	See log
155-81-29ab	Unknown	10.6	48	Du		4.55	10-17-45	O	Qd	1600	*
155-81-29da	L. Guthrie	45	12	Bo		20	6-10-47	D, S	Qd	1616	*

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
155-81-29dda	Howard Guthrie	45	16	Bo		-	-	D,S	-	1616	
155-81-30ca	J. V. Thompkins	96	4	Dr		30	6-12-47	D,S	Ttr	1631	Partial chem. analysis *
155-81-30cb	Floyd Kauffman	60	12	Bo		20	6-10-47	D,S	Qd	1620	*
155-81-31baa	John Wald	375	4	Dr		80	-	D,S	-	1625	Soft
155-81-31ba	T. C. Anderson	65	18	Bo		20	6-10-47	S	Qd	1626	*
155-81-32bab	Marcus Effertz	358	4¼	Dr		90	-	D	-	1621	
155-81-32ba$_1$	Marcus Effertz	358	4	Dr		60	6-10-47	D,S	-	1621	*
155-81-32ba$_2$	Marcus Effertz	72	18	Bo		13.22	6-10-47	S	-	1621	*
155-81-32cb$_1$	T. C. Anderson	40	20	Bo		13.58	6-10-47	S	Qd	1626	*
155-81-32cb$_2$	T. C. Anderson	15	36	Du		5.42	6-10-47	S	Qd	1626	*
155-81-33bc	T. Aberle	60	18	Bo		13.32	6-5-47	U	Qd	1614	*
155-81-33dc	Edith Luchsinger	19	6-1½	Du,Dr		6	6-5-47	S	Qd	1621	*
155-81-33dd	Unknown	39.3	24	Du		16.05	10-18-45	D,S,O	Qd	1609	*
155-82-1daa	Donald Poltry	40	18	Bo		20	6-11-47	D,S	-	1608	
155-82-2cb	G. V. Furnam	72	18	Bo		22	6-11-47	S	Qd	1626	*
155-82-2cdd	Chas. Abernathy	80	18	Bo		4	-	D,S	Qd	1608	Hard
155-82-2dc	C. Hamback	82.5	24	Bo		26.05	10-16-45	U	Qd	1608	*
155-82-3ad	G. V. Furnam	40	18	Bo		22	6-11-47	U	Qd	1626	*
155-82-3add	Gene F. Furnam	100	4	Dr		10	-	D,S	Ttr	1628	
155-82-10aa	Frank Hrdlicka	12	48	Du		4.60	10-16-45	D,O	Qd	1632	*
155-82-10cd	E. Foley	25	18	Bo		5.22	6-12-47	S	Qd	1630	*
155-82-10dcd$_1$	Unknown	24.5	12	Bo		5.7	4-3-63	U	Qd	1595	
155-82-10dcd$_2$	Test Hole 17	63	4 3/4	Dr	4-19-63	10.0	4-19-63	T	Qd	1590	See log
155-82-11aa	C. Abernathy	65	24-18	Bo		50	6-11-47	D,S	Qd	1612	*
155-82-11ccd	Marion Swanson	250	3	Dr		80	6-12-47	D,S	Tc	1632	Chem.analysis *
155-82-12aaa	Test Hole 8	47	4 3/4	Dr	4-15-63	6.38	4-19-63	T	Qd	1575	See log
155-82-12dd	Lloyd Elsberry	28	18	Bo		19.54	6-12-47	S	Qd	1616	*
155-82-13aa	Wm. H. Hunt-Guy Almy Oil test #1	7300	10 3/4 to 7	Dr	7-20-54	-	-	OT	-	1632	See log

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
155-82-13cbc	Test Hole 16	84	4 3/4	Dr	4-18-63	6.05	4-19-63	T	Qd	1603	See log
155-82-14dd	John Balarud	120	4	Dr		39.20	10-17-45	O	-	1638	*
155-82-15bbb	USGS Test 1394	94½	4 3/4	Dr	9-17-58	-	-	T	-	1641	See log
155-82-15bc$_1$	T. Thompson	35	18	Bo		29	6-12-47	S	Qd	1611	*
155-82-15bc$_2$	T. Thompson	65	24	Bo		30	6-12-47	S	Qd	1611	*
155-82-22ccb	USGS Test 1393	105	4 3/4	Dr	9-17-58	-	-	T	-	1625	See log
155-82-22ddd$_1$	Wooledge	15	36	Du		8	10-17-45	D,S	Qd	1634	*
155-82-22ddd$_2$	Wooledge	45	24	Bo		30	-	D,S	Qd	1635	Hard, good
155-82-22ddd$_3$	Wooledge	35	24	Bo		20	-	D,S	Qd	1635	Hard, good
155-82-22ddd$_4$	Test Hole 18	84	4 3/4	Dr	4-19-63	7.42	4-19-63	T	Qd	1629	See log
155-82-23aab	Great Northern Test #2	410	12-10	Dr	3- -55	-	-	T	-	1640	See log
155-82-23aa	W. W. Perry	63	18	Bo		27.02	6-12-47	D,S	-	1634	*
155-82-23bba	Great Northern Test #1	390	8-6	Dr	11- 54	-	-	T	-	1640	See log
155-82-23cc	B. Mormon	78	24	Bo		20	6-12-47	D,S	-	1650	*
155-82-23cd	Unknown	8.1	36	Du		2.95	10-17-45	O	Qd	1641	*
155-82-24ccc	Harold Kauffman	120	3	Dr		80	-	D,S	Ttr	1637	Soft, no good
155-82-25aa$_1$	Unknown	180	3½	Dr		80	10-17-45	D,S	-	1628	*
155-82-25aa$_2$	Evert Ehr	32.0	21	Bo		19.31	8-9-50	S	Qd	1628	*
155-82-25ab	Evert Ehr	146	6	Dr		72	8-9-50	S	-	1638	*
155-82-25cc	D. G. Kauffman	120	3	Dr		28	6-12-47	D,S	Qd	1636	Partial chem. analysis *
155-82-26aba	A. C. Glick	157	4	Dr		120	-	D,S	Ttr	1652	Soft, poor
155-82-26ab	A. F. Glick	124	4	Dr		30	6-12-47	D,S	-	1652	*
155-82-26bbb$_1$	Roy Martin	18	24	Bo		10	-	D,S	Qd	1640	Hard,good
155-82-26bbb$_2$	Roy Martin	25	24	Bo		17	-	D,S	Qd	1640	Hard, good
155-82-26bbb$_3$	Roy Martin	50	24	Bo		42	-	D,S	Qd	1640	30 grains hardness
155-82-26daa	Earl Martin	400	6	Dr		80	-	D,S	-	1633	Soft, no good
155-82-26da	Earl L. Martin	90	6	Dr		40	10-18-45	D,S	-	1631	*

TABLE 5--Logs of Test Holes

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-7cad **Test Hole 9** **Elevation 1,578 feet**			
Glacial Drift:				
	Clay,silty and sandy, dusky yellow to moderate olive brown, very poorly consolidated, soft, calcareous...............	5	0	5
	Gravel, fine to medium, sandy, moderately sorted, subangular to subrounded, oxidized........	4	5	9
	Clay, silty to sandy, pebbles, moderate olive brown, tightly consolidated, very cohesive, plastic, oxidized (till).......	3	9	12
	Clay, as above, but olive gray and unoxidized.................	7	12	19
	Sand, fine to coarse, moderately well-sorted, subrounded, saturated......................	6	19	25
	Clay, silty to sandy, olive gray, tightly consolidated (till)....	20	25	45
Tongue River Formation:				
	Sand, fine to medium, light greenish gray, moderately consolidated, noncalcareous....	9	45	54
	Clay, dark yellowish brown, tightly consolidated, non-calcareous.....................	9	54	63
	Electric Log			
	155-81-7cbb **Test Hole 7** **Elevation 1,595 feet**			
Glacial Drift:				
	Gravel, fine to coarse with coarse and very coarse sand, poorly sorted, subrounded, occasional clayey spots, oxidized.......................	16	0	16
	Clay, silty, olive gray,tightly consolidated, cohesive,plastic, calcareous.....................	3	16	19
	Sand, coarse, well-sorted, subrounded to rounded,saturated...	2	19	21
	Clay, silty, olive gray, tightly consolidated,very cohesive, plastic, calcareous............	14	21	35

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	155-81-7cbb Test Hole 7 Elevation 1,595 feet (continued)			
	Sand, fine to coarse, subangular to subrounded, unoxidized, saturated; contains thin clayey layers.................	5	35	40
	Gravel, fine and medium, sandy...	4	40	44
	Clay, silty, sandy and pebbly, olive gray, moderately soft and consolidated, cohesive, plastic (till); gravelly in spots........................	17	44	61
Tongue River Formation:				
	Sand, fine and medium, greenish gray, moderately consolidated, noncalcareous................	23	61	84
	Electric Log			
	155-81-7cdd Test Hole 6 Elevation 1,598 feet			
Glacial Drift:				
	Clay, sandy, yellowish gray, soft, oxidized, leached.......	4	0	4
	Clay, sandy with pebbles, moderate olive brown, soft to moderately soft, moderately consolidated, cohesive, oxidized (till).....	21	4	25
	Clay, silty, slightly sandy, olive gray, tightly consolidated, cohesive, plastic (till)......	33	25	58
Tongue River Formation:				
	Sand, fine to medium, greenish gray, well-sorted, subangular to subrounded, moderately consolidated, noncalcareous...	5	58	63

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-7dda **Test Hole 14** **Elevation 1,578 feet**			
Glacial Drift:				
	Clay and silt, yellowish gray to dusky yellow to olive brown, soft, loosely consolidated, calcareous, oxidized...........	4	0	4
	Gravel, fine and medium with medium to very coarse sand, moderately sorted, generally subrounded, saturated..........	14	4	18
	Gravel, medium, well-sorted, very permeable, clean. Used 100 lbs. of drilling mud................	7	18	25
	Clay, silty with sand and gravel, olive gray, moderately soft, tight, cohesive, plastic, unoxidized (till?).............	4	25	29
	Gravel, fine to medium, sandy....	4	29	33
	Clay (till?) as above the gravel, some cobbles..................	5	33	38
Tongue River Formation:				
	Sand, fine to medium, greenish gray, moderately consolidated, noncalcareous.................	25	38	63
	Electric Log			
	155-81-8ddc **Test Hole 13** **Elevation 1,560 feet**			
Glacial Drift:				
	Clay, silty, yellowish gray, soft, loosely consolidated; contains light gray marly clay and highly oxidized sandy layers.........	7	0	7
	Clay, silty to sandy with pebbles, olive gray, moderately soft, tightly consolidated, cohesive, plastic (till)................	32	7	39
Tongue River Formation:				
	Sand, fine to medium, greenish gray, moderately consolidated, noncalcareous................	24	39	63
	Electric Log			

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	155-81-8ddd **Test Hole 11** **Elevation 1,563 feet**			
Glacial Drift:				
	Clay, silty, dark brownish black, loosely consolidated, very high organic content..........	5	0	5
	Gravel, fine to coarse with coarse and very coarse sand, moderately sorted, generally subrounded, clean, saturated...	9	5	14
	Clay, silty to sandy, olive gray, cohesive, plastic(till).	4	14	18
	Sand, fine to medium, well-sorted, subrounded to rounded.	1	18	19
	Clay (till) as above the sand, occasional cobbles............	17	19	36
Tongue River Formation:				
	Sand, fine to medium, dark greenish gray, well-sorted, generally subrounded, moderately consolidated, noncalcareous.................	27	36	63
	155-81-17bbc **Test Hole 5** **Elevation 1,615 feet**			
Glacial Drift:				
	Clay, silty, yellowish gray to dusky yellow, very soft, loosely consolidated, very sandy, oxidized (till)........	4	0	4
	Clay, sandy, moderate olive brown, moderately soft and consolidated, cohesive, plastic, oxidized (till)...............	21	4	25
	Clay (till) as above, but olive gray and unoxidized...........	29	25	54
	Clay, silty, olive gray, tight, very cohesive; interbedded with sandy layers which become more common with depth (till).	25	54	79
Tongue River Formation:				
	Sand, fine to medium, greenish gray, moderately consolidated, noncalcareous.................	5	79	84

Electric Log

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-17ddc Test Hole 4 Elevation 1,583 feet			
Glacial Drift:				
	Clay, silty and sandy with pebbles, yellowish gray to dusky yellow, very soft to moderately soft, moderately consolidated, cohesive, plastic, oxidized (till).........	10	0	10
	Till, as above, moderate olive brown, with thin sandy layers, partially oxidized...............	8	10	18
	Sand, medium and coarse, well-sorted, subrounded, clean, saturated, slightly calcareous; clayey horizon at 22 feet...............	13	18	31
	Clay, silty and sandy, olive gray, tightly consolidated, cohesive, unoxidized (till)................	9	31	40
	Till, as above, interbedded with sand and gravel layers...........	19	40	59
Tongue River Formation:				
	Sand, fine to medium, greenish gray, clayey (?), moderately consolidated, very slightly cohesive, nonplastic, noncalcareous....................	15	59	74
	Electric Log			
	155-81-18ddd Test Hole 10 Elevation 1,615 feet			
Glacial Drift:				
	Clay, silty and sandy, very soft, poorly consolidated, leached, oxidized.........................	4	0	4
	Clay, silty to sandy with pebbles and cobbles, moderate olive brown, moderately soft, tightly consolidated, cohesive, plastic, partially oxidized (till)..................	19	4	23
	Till, as above, light olive gray, cobbles common....................	7	23	30
	Till, as above, olive gray, unoxidized.......................	8	30	38
	Sand, fine to medium, well-sorted, subrounded, slightly calcareous, saturated.......................	9	38	47
	Clay, silty to sandy with pebbles, cobbles and boulders, olive gray, moderately soft, tightly consolidated, plastic, cohesive (till).........	29	47	76

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-18ddd Test Hole 10 Elevation 1,615 feet (continued)			
Tongue River Formation:				
	Sand, fine to medium, greenish gray, moderately consolidated, well-sorted, noncalcareous.......	8	76	84
	Electric Log			
	155-81-19abb Test Hole 1 Elevation 1,625 feet			
Glacial Drift:				
	Clay, very sandy, yellowish gray, slightly cohesive and plastic, oxidized, highly calcareous......	4	0	4
	Clay, very sandy, yellowish gray to moderate olive brown, loosely to moderately consolidated, oxidized (till).................	16	4	20
	Clay, very sandy, moderate olive brown to light olive gray, very tightly consolidated, partially oxidized, slightly calcareous....	9	20	29
	Gravel, fine, and coarse sand, poorly sorted, angular to subrounded, oxidized, saturated.....	5	29	34
	Clay with silt and fine sand, olive gray, tightly consolidated, slightly plastic, moderately calcareous (till)................	26	34	60
	Clay, silty with pebbles, olive gray, very tightly consolidated, cohesive, plastic (till).........	14	60	74
	Till, as above, but very sandy, and contains unconsolidated sand and gravel layers...................	29	74	103
Tongue River Formation:				
	Clay, sandy, greenish gray, tight, organic material in spots, calcareous.....................	21	103	124
	Clay, silty to sandy, greenish gray to light olive gray, tightly consolidated, moderately soft, plastic, cohesive, smooth to slightly gritty, noncalcareous..	86	124	210

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-19abb Test Hole 1 Elevation 1,625 feet (continued)			
	Clay, silty, light olive gray, moderately soft, plastic..........	13	210	223
	Shale, olive black, indurated, contains stringers of calcite, highly calcareous................	2	223	225
	Silt, clayey, olive gray, uniform texture, crumbles easily, nonplastic, noncalcareous........	7½	225	232½
	Sandstone, bluish green, indurated.	1½	232½	234
	Silt, clayey, olive gray, nonplastic, noncalcareous....................	15	234	249
Cannonball Formation:				
	Shale, sandy, greenish gray, slightly indurated to highly indurated....	7	249	256
	Clay, silty, olive gray with brownish black organic areas, smooth, plastic.........................	5	256	261
	Sandstone, fine-grained, light bluish green, indurated, calcareous.......................	19	261	280
	Silt, clayey, light bluish gray to brownish black, moderately plastic, moderately cohesive, occasional thin sandstone strata............	20	280	300
	Clay, silty to sandy, olive gray to brownish black, thinly bedded....	27	300	327
	Clay, silty, light olive gray, soft, smooth, cohesive, slightly sticky, calcareous.......................	8	327	335
	Lignite, black, fissile............	1	335	336
	Clay, silty, light olive gray, soft, calcareous......................	4	336	340
	Clay, sandy, tan, gritty, tight....	6	340	346
	Clay, silty, light olive gray, smooth, slippery, slightly sticky, interbedded lignite seams.........	31	346	377
Hell Creek Formation:				
	Clay, silty to sandy, light bluish gray to brownish gray, occasional limestone strata, calcareous......	21	377	398
	Clay, silty to sandy, medium bluish gray, moderately to tightly consolidated....................	26	398	424

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-19abb Test Hole 1 Elevation 1,625 feet (continued)			
	Clay, silty to sandy, light olive gray to greenish gray to brownish gray, lignitic.........	11	424	435
Fox Hills Sandstone:				
	Clay, sandy, brownish black, slightly cohesive, fairly plastic, tight, noncalcareous..................	5	435	440
	Sand, fine to medium clayey, light greenish gray, subangular to subrounded, well-sorted, noncalcareous, indurated sandstone strata very common........................	18	440	458
	Lignite, black, fissile...........	3	458	461
	Clay, silty, brownish gray, soft, sticky, tight.................	17	461	478
	Clay, silty to sandy, grayish red purple, hematitic, tightly consolidated..................	14	478	492
	Clay, silty to sandy, varigated, possibly bentonitic, noncalcareous.........................	31	492	523
	Clay, silty and sandy, greenish gray, fairly tight, occasional sandstone strata................	45	523	568
	Clay, silty, greenish gray, soft, tight........................	20	568	588
	Electric and Gamma Ray Logs			
	155-81-19aca Test Hole 3 Elevation 1,614 feet			
Glacial Drift:				
	Clay, sandy with pebbles, dusky yellow to moderate olive brown, soft, cohesive, plastic, oxidized (till).................	16	0	16
	Sand, coarse, with fine gravel, moderately sorted, subangular to subrounded, oxidized.........	4	16	20
	Clay, very sandy, olive gray, soft to moderately soft, tightly consolidated, cohesive, unoxidized (till).......................	12	20	32

TABLE 5--Logs of Test Holes--Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	155-81-19aca Test Hole 3 Elevation 1,614 feet (continued)			
	Sand, fine to medium, unconsolidated, well-sorted, subrounded, calcareous, saturated	8	32	40
	Clay, silty to sandy, olive gray, moderately soft, tightly consolidated, cohesive (till)	18	40	58
	Sand, medium and coarse, moderately well-sorted, subrounded to rounded, slightly calcareous, saturated	8	58	66
	Clay, sandy, olive gray, moderately soft, tightly consolidated, cohesive (till)	4	66	70
Tongue River Formation:				
	Sand, fine and medium, greenish gray, moderately consolidated, noncalcareous	14	70	84
	Electric Log			
	155-81-19bbb Great Northern Test Hole #3 Elevation 1,628 feet			
Glacial Drift:				
	Clay, with sand and rock	35	0	35
	Clay, sand and gravel	25	35	60
	Gravel, sand and a little clay	7	60	67
	Sandy clay	13	67	80
	Clay	3	80	83
	Quicksand	32	83	115
Tongue River Formation (?):				
	Clay with streaks of sand and rock	7	115	122
	Clay and rock, with a little sand, very hard	3	122	125
	Clay, with sand and rock	15	125	140
	Clay and sand	5	140	145
	Clay with some rock	10	145	155
	Clay	25	155	180

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-19bda Great Northern Test Hole #4 Elevation 1,625 feet			
Glacial Drift:				
	Clay	15	0	15
	Sandy	5	15	20
	Clay with sand	5	20	25
	Sand with clay	10	25	35
	Clay	10	35	45
	Clay, rock and a little sand	5	45	50
	Clay, with sand and rock	10	50	60
	Sand with very little water	4	60	64
	Clay and rock	2	64	66
	Clay, sand and rock	9	66	75
	Clay, sand and rock	5	75	80
	Sandy clay	7	80	87
	Clay, sand and rock	8	87	95
Tongue River Formation (?):				
	Mostly rock with some clay, very hard	2	95	97
	Sand and clay	8	97	105
	Clay with some rock	5	105	110
	Clay with little rock	7	110	117
	Clay and sand	8	117	125
	Sand and clay, mostly coal	2	125	127
	Clay	8	127	135
	Clay	6	135	141
	Fine sand with a little water	2	141	143
	Clay with sand	7	143	150
	Sand and clay	30	150	180
	155-81-19cbc Test Hole 15 Elevation 1,615 feet			
Glacial Drift:				
	Clay, silty to sandy, yellowish gray to dusky yellow, soft, loosely consolidated, weathered, oxidized (till)	4	0	4
	Clay, silty, sand and pebbles, moderate olive brown, moderately soft, tight, cohesive, plastic, oxidized (till)	11	4	15
	Clay, silty to sandy, olive gray, moderately soft, tightly consolidated, cohesive, unoxidized (till); occasional cobbles and boulders.	35	15	50

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	155-81-19cbc Test Hole 15 Elevation 1,615 feet (continued)			
	Till, as above, with interbedded gravel stringers................	11	50	61
Tongue River Formation:				
	Sand, medium, greenish gray, loosely to moderately consolidated, well-sorted, subangular to subrounded, lignitic, noncalcareous..........	23	61	84
	Electric Log			
	155-81-19dcb Test Hole 21 Elevation 1,610 feet			
Glacial Drift:				
	Clay, silty to sandy with pebbles, dusky yellow, poorly consolidated	7	0	7
	Clay, silty to sandy with pebbles, moderate olive brown, moderately compacted, cohesive, oxidized (till).........................	4	7	11
	Clay, sandy, olive gray, pebbly to rocky, fairly tight, cohesive, unoxidized, calcareous (till)...	8	11	19
	Clay, very sandy with much unconsolidated loose sand, olive gray, some loose gravel....................	15	19	34
	Gravel, fine to medium, moderately sorted, subrounded.............	4	34	38
	Clay, sandy to gravelly with occasional cobbles, olive gray, moderately compacted, calcareous (till).........................	7	38	45
	Clay, silty to sandy with pebbles, olive gray, tight, cohesive, calcareous (till)...............	12	45	57
Tongue River Formation:				
	Sand, fine to medium, clayey, light greenish gray, tightly consolidated, slightly calcareous	16½	57	73½
	Electric Log			

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	155-81-19ddb Test Hole 20 Elevation 1,608 feet			
Glacial Drift:				
	Clay, silty and sandy, yellowish gray, poorly consolidated.........	8	0	8
	Clay, sandy with pebbles, dusky yellow to moderate olive brown, tightly compacted, cohesive, fairly plastic, oxidized, calcareous (till).................	7	8	15
	Clay, silty to sandy, olive gray, moderately compacted, occasional rocks, unoxidized (till)..........	4	15	19
	Sand, medium to coarse and gravel, fine and medium, gray, subrounded, sorted, mainly limestone and granitic particles................	10	19	29
	Clay, silty, olive gray, occasional pebbles and cobbles, fairly tight, cohesive, calcareous (till).......	17	29	46
	Sand, fine to coarse, gray, well-sorted, rounded, clean............	6	46	52
	Clay, silty with sand, pebbles and cobbles, olive gray, tightly compacted, cohesive, moderately plastic (till)..................	10	52	62
Tongue River Formation:				
	Sand, fine and medium, clayey, light greenish gray, fairly tight, slightly calcareous...............	10	62	72
	Sandstone, light greenish gray, indurated, $CaCO_3$ cement...........	2	72	74
	Sand, fine and medium, clayey, greenish gray...................	10	74	84

Electric and Gamma Ray Logs

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-19ddd **Test Hole 19-992** **Elevation 1,605 feet**			
Glacial Drift:				
	Silt, sandy, yellowish gray to moderate olive brown, soft, loosely to moderately consolidated, very sandy in spots................	8	0	8
	Sand, fine to coarse, unconsolidated, moderately sorted, subangular to subrounded, partially oxidized.....	3	8	11
	Sand, very clayey in spots, moderate olive brown, loosely to moderately consolidated; clayey areas tight and cohesive, partially oxidized...	5	11	16
	Clay, very sandy, olive gray, moderately consolidated, friable in places, unoxidized.............	5	16	21
	Sand, fine to medium, unconsolidated, well-sorted, subrounded, slightly calcareous, unoxidized............	14	21	35
	Gravel, fine to medium, well-sorted, subrounded, fairly clean, saturated	6	35	41
	Clay, sandy with pebbles, olive gray, moderately soft, tight cohesive (till)...........................	2	41	43
	Sand, medium, well-sorted, subrounded, saturated.........................	7	43	50
	Clay, sandy with pebbles and cobbles, olive gray, moderately soft, tight, cohesive, plastic, gravelly in spots (till).......................	12	50	62
Tongue River Formation:				
	Sand, fine to medium, greenish gray to dark greenish gray to olive black, moderately consolidated, well-sorted, noncalcareous, highly organic; contains indurated sandstone strata......................	22	62	84

Electric log

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-20bbb Test Hole 2 Elevation 1,615 feet			
Glacial Drift:				
	Clay, silty and sandy, yellowish gray, soft, poorly consolidated.....	4	0	4
	Clay, silty and sandy, dusky yellow to moderate olive brown, soft, moderately compacted, slightly plastic,moderately calcareous, oxidized (till).........	18	4	22
	Sand, fine to medium, well-sorted, subrounded to rounded, slightly oxidized, slightly calcareous, clean, saturated	2	22	24
	Gravel, fine and medium, sandy, subrounded........................	2	24	26
	Sand, very fine to fine, clayey and silty, olive gray, cohesive, plastic, moderately calcareous...............	3	26	29
	Gravel, fine to coarse, sandy, heavily iron-stained limestone particles, saturated........................	12	29	41
	Clay, silty and sandy with pebbles and cobbles, olive gray, moderately soft, tightly compacted, contains thin sandy and gravelly layers (till)..........	32	41	73
Tongue River Formation:				
	Sandstone, light greenish gray, indurated, $CaCO_3$ cement..................	1	73	74
	Sand, fine to medium, clayey, dark greenish gray, moderately well-sorted, subangular to subrounded, slightly friable, moderately consolidated, noncalcareous.....................	10	74	84
	155-81-29aaa Test Hole 12 Elevation 1,603 feet			
Glacial Drift:				
	Clay,sandy, yellowish gray, soft, loose and poorly consolidated, oxidized........................	7	0	7
	Clay, silty to sandy with pebbles and cobbles, dusky yellow, moderately soft, cohesive, slightly plastic, oxidized, calcareous (till).........	16	7	23

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	155-81-29aaa Test Hole 12 Elevation 1,603 feet (continued)			
	Till, as above, moderate olive brown to light olive gray, partially oxidized........................	8	23	31
	Clay, silty to sandy with pebbles, cobbles, and gravel stringers, olive gray, moderately soft, cohesive, unoxidized (till).......	22	31	53
	Sand, fine to medium, olive gray, well-sorted, generarlly subrounded, slightly calcareous...............	2	53	55
	Clay, silty with sand, pebbles, and cobbles, olive gray, moderately soft, tight, calcareous (till)....	14	55	69
	Sand, fine to coarse, olive gray, moderately sorted, generally subrounded, slightly calcareous...	3	69	72
Tongue River Formation:				
	Sandstone, fine-grained, light greenish gray, indurated, highly calcareous.......................	$2\frac{1}{2}$	72	$74\frac{1}{2}$
	Sand, fine to medium, greenish gray, moderately consolidated, non-calcareous.......................	$9\frac{1}{2}$	$74\frac{1}{2}$	84
	155-82-10dcd Test Hole 17 Elevation 1,590 feet			
Glacial Drift:				
	Clay, silt to sandy with pebbles, dusky yellow to moderate olive brown, soft, loosely consolidated, oxidized (till)..................	6	0	6
	Sand, fine to medium, subrounded, oxidized.........................	3	6	9
	Clay, silty to sandy with pebbles, moderate olive brown, soft, slightly sticky (till)...........	3	9	12
	Sand, fine to coarse, gray, moderately sorted, subangular to subrounded..	2	12	14
	Clay, silty with sand, pebbles and cobbles, olive gray, moderately soft, cohesive, unoxidized (till).......	9	14	23

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	155-82-10dcd Test Hole 17 Elevation 1,590 feet (continued)			
	Clay, silty, olive gray, contains pebbles and sandy and gravelly layers, moderately soft, tight (till)........................	15	23	38
Tongue River Formation:				
	Clay, silty, light gray to dusky brown, smooth to slightly gritty, moderately soft, cohesive, plastic, noncalcareous..................	2	38	40
	Lignite, black, fissile...........	4	40	44
	Sand, medium, clayey, grayish brown, moderately consolidated, well-sorted, noncalcareous......	9	44	53
	Sand, as above, light greenish gray.........................	10	53	63
	Electric Log			
	155-82-12aaa Test Hole 8 Elevation 1,575 feet			
Glacial Drift:				
	Clay, silty and sandy, yellowish gray to dusky yellow, soft,poorly consolidated, oxidized, contains thin gravelly layers............	18	0	18
	Clay, silty, moderate olive brown to light olive gray, tightly compacted, cohesive, partially oxidized, calcareous (till)..............	5	18	23
	Clay, silty to sandy with pebbles, olive gray, moderately soft, tight, cohesive, plastic, unoxidized, calcareous (till)...	14	23	37
Tongue River Formation:				
	Sand, fine to medium, clayey, greenish gray, moderately consolidated, well-sorted, subangular to subrounded, noncalcareous.........	10	37	47

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-82-13aa Wm. H. Hunt -Guy Almy #1 Elevation 1,620 feet			
	(MISSING)	350	0	350
Bedrock, undifferentiated				
	Sandstone, very light gray, fine to medium, subangular grains, calcareous; shale, light gray and pale brown, silty, micaceous, bentonitic........................	50	350	400
	Shale, as above, with a little sandstone as above................	50	400	450
	Sandstone, very light gray, fine to medium, subangular grains, calcareous; some shale as above.........	20	450	470
	Shale, light gray and pale brown, micaceous, silty and bentonitic...	30	470	500
	Shale, as above; a little sandstone, light gray, fine to medium, subangular grains, calcareous........	180	500	680

Pierre Shale contact picked at 638' (Carlson, 1957)

Partial log - total depth 7,300 feet (found dry and plugged 8-17-54)

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-82-13cbc Test Hole 16 Elevation 1,603 feet			
Glacial Drift:				
	Silty loam, underlain by several inches of coarse sand.............	1½	0	1½
	Clay, sandy, moderate olive brown, moderately soft, tight, cohesive, plastic, calcareous, oxidized (till)...........................	7½	1½	9
	Clay, silty to sandy with pebbles, olive gray, tight, cohesive, unoxidized (till); contains loose sandy and gravelly layers..............	29	9	38
	Sand, medium, greenish gray, well-sorted, subrounded, saturated.....	2	38	40
	Clay, silty to sandy with numerous pebbles and cobbles, olive gray, moderately soft, tight, cohesive, plastic (till); contains numerous sandy and gravelly layers.........	21	40	61

TABLE 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-82-13cbc Test Hole 16 Elevation 1,603 feet (continued)			
Tongue River Formation:				
	Sand, fine to medium, clayey, greenish gray, moderately consolidated, well-sorted, noncalcareous........................	23	61	84
	155-82-15bbb USGS Test #1394 Elevation 1,641 feet			
Glacial Drift:				
	Topsoil, black......................	3	0	3
	Clay, yellow, and fine gravel.......	19	3	22
	Clay, gray, contains fine gravel and shale pebbles (till)..........	63	22	85
Tongue River Formation:				
	Clay, sandy, gray...................	9½	85	94½
	155-82-22ccb USGS Test #1393 Elevation 1,625 feet			
Glacial Drift:				
	Topsoil, black......................	4	0	4
	Clay, yellow, and fine gravel.......	9	4	15
	Clay, gray, with fine to medium gravel and shale pebbles (till)...	49	15	64
	Sand, fine, dirty...................	9	64	73
	Clay, gray, with fine gravel, shale pebbles, cobble stones, and lignite (till)....................	15	73	88
Tongue River Formation:				
	Clay, sandy, gray...................	17	88	105

Table 5--Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-82-22ddd Test Hole 18 Elevation 1,629 feet			
Glacial Drift:				
	Marl, sandy, light gray, soft, very highly calcareous............	3	0	3
	Sand, fine, light tan, well-sorted, subrounded, slightly calcareous, mixed with clay.................	6	3	9
	Clay, sandy, moderate olive brown to medium gray, soft, cohesive, calcareous........................	3	9	12
	Clay, silty to sandy with pebbles, olive gray, moderately soft, cohesive (till)..................	7	12	19
	Clay, sandy, olive gray, moderately soft, tight, cohesive, plastic; numerous pebbles and cobbles and several sandy and gravelly layers (till).........................	35	19	54
	Gravel, fine to coarse, with coarse sand, moderately sorted, subangular to subrounded, saturated..........	7	54	61
	Till, as above the gravel...........	11	61	72
Tongue River Formation:				
	Sand, medium, clayey, dusky brown, moderately consolidated, noncalcareous, highly organic...........	6	72	78
	Sand, fine to medium, clayey, greenish gray, well-sorted, moderately consolidated..................	6	78	84

Electric Log

TABLE 6--Logs of Test Holes Used In Report But Located Outside Report Area

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-13aa USGS Test Hole (from LaRocque, et al., 1963b, p.241, table 3) Elevation 1,574 feet			
Glacial Drift:				
	Soil	1	0	1
	Silt, fine, and sandy clay	5	1	6
	Clay, yellow, with some gravel	21	6	27
	Sand and gravel	9	27	36
	Clay, sandy, gray	7	36	43
	Sand, coarse, and gravel, coarse	44	43	87
	Boulder, granite	2	87	89
Fort Union Formation: (Tongue River Formation of this report)				
	Clay, gray	17	89	106

Water level 19.09 (8-12-47)
Hole filled

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	155-81-23cd Wm. H. Hunt - Joe Wald #1 Elevation 1,586.5 feet			
	(MISSING)	400	0	400
Bedrock, undifferentiated:				
	Shale, light gray, tan siltstone, and a little light brown sandstone	50	400	450
	Shale, one piece of very light olive gray; and one piece of light gray, dense limestone	10	450	460
	Shale, light olive gray, silty	110	460	570

Pierre Shale contact picked at 550 feet (Anderson, S. B., 1963, personal communication)

Partial log - total depth 8,652 feet

Well abandoned

TABLE 6--Logs of Test Holes Used in Report But Located Outside of Report Area --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	156-83-33dc Quintana Producation Co.-Chris Linnertz #1 Elevation 1,760 feet			
Glacial Drift:				
	Silt and gravel....................	42	0	42
	Poorly sorted sand and gravel.......	354	42	396
Bedrock, undifferentiated:				
	Bentonitic shale; medium gray, lumpy, slightly silty, traces of sand and gravel..................	152	396	548
	Shale; medium gray, lumpy with much poorly sorted sand and gravel.....	181	548	729
	Shale; medium gray, lumpy, silty; some poorly sorted sand................	31	729	760
	Shale; medium gray, lumpy, silty and sandy............................	55	760	815
	(MISSING)	5	815	820
	Sand; fine to medium, rounded; traces of limestone and pyrite...........	10	820	830
	Missing samples.....................	420	830	1250
	Pierre Shale contact picked at 1,002 feet (Smith, 1953) Partial log - total depth 8,938 feet Dry hole - plugged 10-27-52			
	157-85-16d Dewey Price Co.-J. H. Kline #1 (taken from Lemke,1960, p.11-12) Elevation 1,679 feet			
Glacial Drift:				
	Sand, buff, coarse, some pebbles....	95	0	95
Fort Union Formation, Tongue River Member: (Tongue River Formation of this report)				
	Lignite, black......................	5	95	100
	(Sand and gravel, caved from above?)	33	100	133
	Sandstone and siltstone, gray, fine-grained, soft, clayey.............	10	133	143
	Lignite, black......................	6	143	149
	Siltstone and shale, gray, soft, clayey...........................	16	149	165
	Sandstone, gray, fine-grained, soft, clayey...........................	5	165	170

TABLE 6--Logs of Test Holes Used in Report But Located Outside of Report Area --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	157-85-16d Dewey Price Co.- J. H. Kline #1 (taken from Lemke, 1960, p. 11-12) Elevation 1,679 feet (continued)			
	Siltstone and shale, gray, soft, clayey; includes a little lignite..	38	170	208
	Sandstone, light gray, fine-grained..	6	208	214
	(Sand and gravel, caved from above?).	31	214	245
	Sandstone, siltstone, and shale, gray, fine-grained, soft, clayey; apparently considerably interbedded; includes a little lignite and soft plant-bearing clay............................	55	245	300
	Sandstone, medium light gray, fine-grained, hard, calcareous..........	50	300	350
Fort Union Formation, Ludlow and Cannonball Members: (Cannonball Formation of this report)				
	Shale, medium gray, soft, silty; includes a little sandstone and foraminifera identified by S.F. Fox as of Cannonball age..............	85	350	435
	Sandstone, medium gray, very fine-grained, calcareous...............	35	435	470
	Siltstone and shale, medium gray,soft, sandy...........................	40	470	510
	Sandstone, light- to medium gray, fine- to medium grained.................	20	510	530
	Shale, medium gray, soft, silty......	57	530	587
	Sandstone, siltstone, and shale, medium gray, soft, clayey..........	83	587	670
	Sandstone, light-medium gray, fine-grained, calcareous, hard..........	10	670	680
	Silstone and shale, medium gray, soft; contains some carbonaceous partings and a little light gray sandstone, and some gray silty bentonite at 700-705 feet........................	30	680	710
Hell Creek Formation:				
	Sandstone, light-medium gray, fine-grained, fairly soft; contains abundant silt cement...............	10	710	720
	Sandstone, medium gray, fine-grained, soft, clayey; contains partings of medium gray siltstone..............	80	720	800
	Sandstone, siltstone, and mudstone, medium gray, soft.................	20	800	820

TABLE 6--Logs of Test Holes Used In Report But Located Outside of Report Area --Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	157-85-16d Dewey Price Co.-J. H. Kline #1 (taken from Lemke, 1960, p. 11-12) Elevation 1,679 feet (continued)			
	Siltstone, medium gray, soft..........	35	820	855
	Bentonite, greenish gray, silty.......	5	855	860
	(Sample missing)......................	45	860	905
	Shale, medium gray, soft, silty.......	10	905	915
Fox Hills Sandstone:				
	Sandstone, light gray, fine-grained, calcareous........................	25	915	940
	Shale, dark-medium gray, soft, silty; contains carbonaceous specks........	20	940	960
	Shale, dark-medium gray; includes some gray siltstone and clayey sandstone.	25	960	985
	Sandstone, whitish-to medium gray, fine-grained, calcareous, hard...........	10	985	995
	Siltstone, light-medium gray, soft, shaley; contains fine white mica....	35	995	1,030
	Siltstone and shale, light-medium gray, soft..............................	20	1,030	1,050
	Shale, light-medium gray, silty, soft; contains some partings of siltstone and a few shell fragments and ostracodes	100	1,050	1,150

Partial log - total depth 8,435 feet

Well abandoned

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