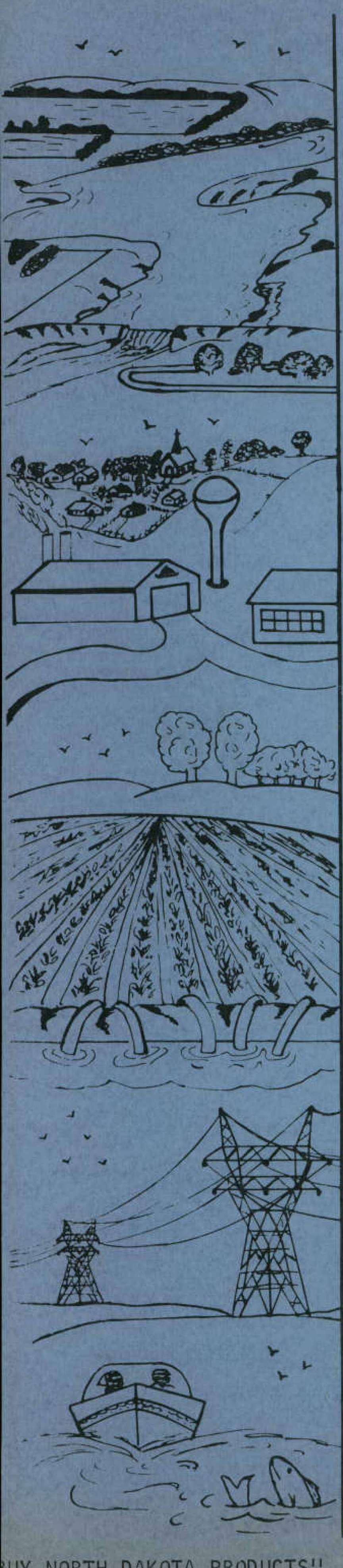

GEOLOGY AND OCCURRENCE OF GROUND WATER IN THE STANLEY AREA

MOUNTRAIL COUNTY, NORTH DAKOTA

By
Quentin F. Paulson
Geologist, Geological Survey
United States Department of the Interior

NORTH DAKOTA GROUND WATER STUDIES

NO. 23

Prepared by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission, and the North Dakota Geological Survey

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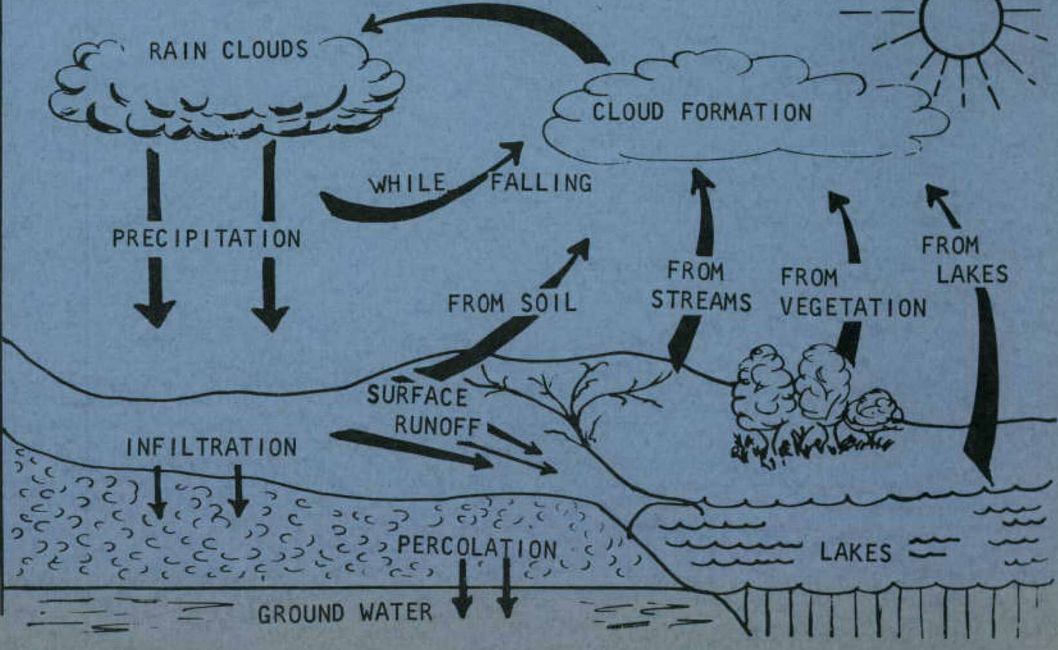
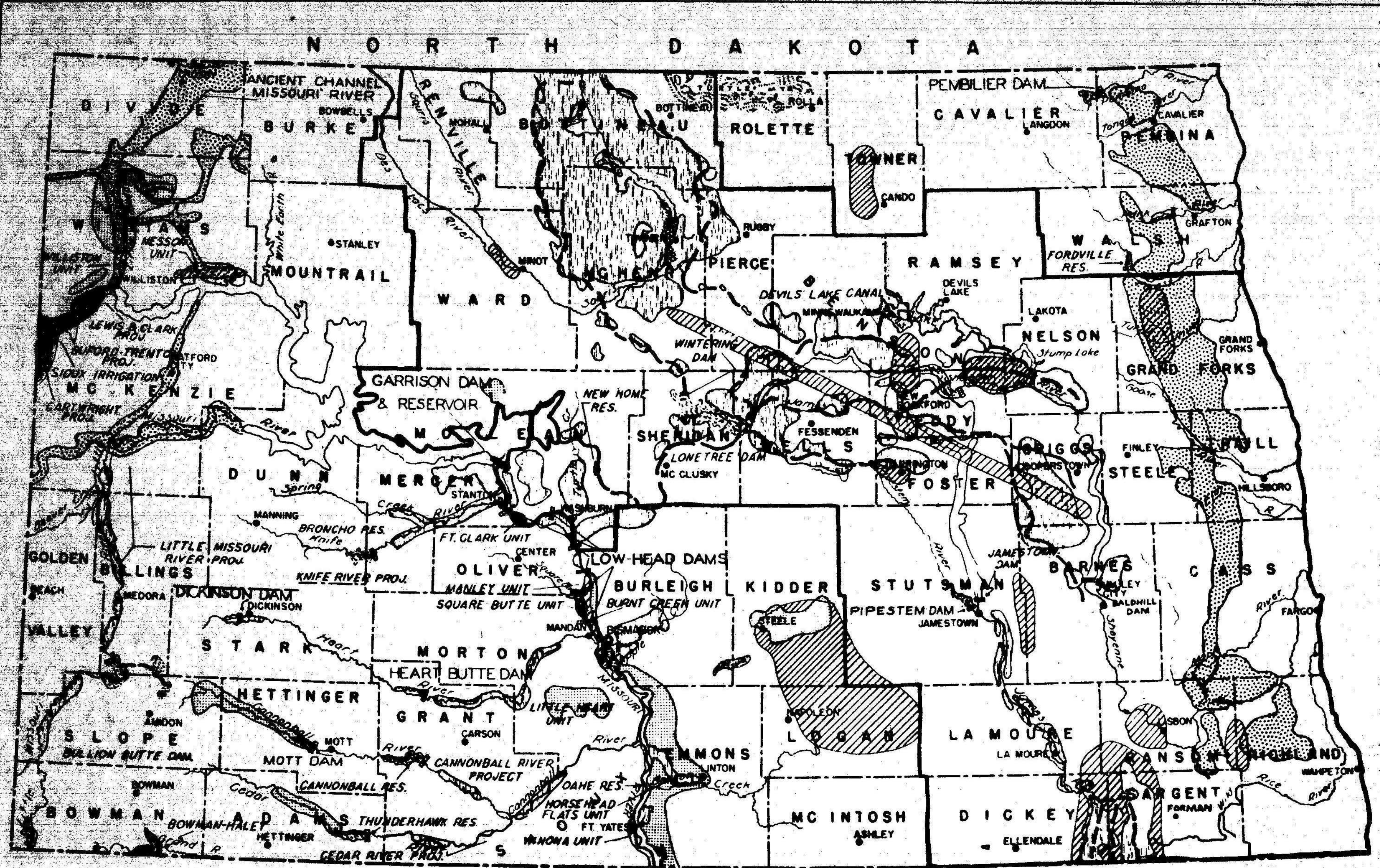
HYDROLOGIC CYCLE





NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

LANDS UNDER IRRIGATION

AREAS CONSIDERED IRRIGABLE

AREAS BEING INVESTIGATED

PROPOSED FOR INVESTIGATION

EXISTING

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ILLUSTRATIONS

GEOLOGY AND OCCURRENCE OF GROUND WATER IN THE STANLEY AREA, MOUNTRAIL COUNTY, NORTH DAKOTA

By

Quentin F. Paulson

ABSTRACT

The area described in this report consists of 72 square miles in T. 156 N., Rs. 91 and 92 W., in northwestern North Dakota. The largest community in the area, the city of Stanley, has a population of about 1,500.

The area is in the glaciated section of the Missouri Plateau. It is covered extensively with glacial materials deposited during late Wisconsin time. The glacial deposits consist largely of end moraine but include also lake-basin deposits of considerable area and small areas of ground moraine. Glacial outwash deposits of sand and gravel occur in the valley of the Little Knife River, which originates a few miles east of Stanley. Thin deposits of alluvium and slope wash of Recent age overlie the outwash deposits in places and are present also in the larger tributaries to the Little Knife River and White Lake. White Lake lies in a northwest-trending depression that reflects the presence of an underlying bedrock channel thought to be of preglacial age. The bedrock in the entire area is the Fort Union formation of Paleocene age.

Aquifers of considerable importance occur in the Fort Union formation and in the outwash deposits in the Little Knife River valley. Aquifers of lesser importance occur in the glacial drift in the moraine and lake-basin areas and possibly in bedrock formations underlying the Fort Union formation. A pumping test on a public-supply well at Stanley, penetrating the Fort Union formation, indicated a transmissibility of about 6,000 gpd per foot for the formation and a specific capacity of

2.6 gpm per foot of drawdown for the well. A pumping test on a well penetrating the outwash deposits in the Little Knife River valley indicated a coefficient of transmissibility of about 24,000 gpd per foot for these deposits. It is likely that prolonged pumping of wells constructed in the outwash deposits near the edge of a reservoir in the Little Knife River valley south of Stanley would cause infiltration of water from the reservoir to the wells.

The ground water in the Stanley area ranges from moderately mineralized and hard in the outwash deposits to highly mineralized but relatively soft in the Fort Union Formation. Water of intermediate quality occurs in the glacial deposits in the moraine and lake-basin areas.

INTRODUCTION

General studies of the geology and ground-water resources of different counties in North Dakota are being made by the United States Geological Survey in cooperation with the State Water Conservation Commission and the State Geological Survey. These studies are made to determine the occurrence, movement, discharge, and recharge of the ground water and the quantity and quality of such water available for all purposes, including municipal, domestic, irrigation, and industrial. However, the most critical need at present is for adequate and perennial water supplies for numerous towns and small cities that are constructing municipal water-supply systems for the first time or are expanding present facilities. For this reason, the county studies are being started in the vicinity of those towns that have requested the help of the State Water Conservation Commission and the State Geologist, in connection with water-supply problems. Progress reports are being released as soon as possible in order that the preliminary data may be available for use in the solution of water-supply problems, as well as for general reference, before the general studies can be completed.

Purpose, Scope, and Nature of the Investigation

The study described in this report relates chiefly to that part of Mountrail County that may be of interest to the city of Stanley, North Dakota and surrounding area as a source of water supply. The investigation was made under the general supervision of A. N. Sayre, Chief of the Ground Water Branch, of the U. S. Geological Survey. The field work and test drilling with a State-owned rig were done under the direct supervision of P. D. Akin, district engineer.

Fieldwork in the area was done chiefly in July, August, and September, 1952. It consisted of the following: (1) mapping geologic features on aerial photographs, (2) gathering information on many of the existing wells, including, where possible, measurements of depths and depths to water levels, (3) drilling 46 test holes ranging in depth from 20 to 350 feet, for a total of 5,059 feet, and taking ditch samples and cores of the earth materials, (4) collecting and submitting for chemical analysis samples of water from water-bearing beds penetrated by test holes and existing wells, and (5) obtaining data from aquifer tests.

Laboratory and office work in connection with the investigation was done chiefly during the winters of 1952-53 and 1953-54. It included the following: (1) examination and analysis of the cuttings and cores from the test holes, (2) correlation of well logs, (3)interpretation of the chemical analyses of the water, (4) compilation of well, test-hole, and other data, (5) analysis ofaquifer test data, and (6) preparing illustrations and writing this report on the investigation.

Previous Investigations and Acknowledgments

The geology and ground-water resources of Mountrail County have been described generally by Simpson (1929, p. 174-177) and Alpha (1935). These reports, however, do not contain sufficient detail to be of more than general use in evaluating the water resources of the area.

The present study was facilitated by the ready cooperation of the townspeople and farmers. Thanks especially are due those who permitted measurements of water levels in their wells and test drilling on their land.

The assistance of the North Dakota State Department of Health in making chemical analyses of samples of ground water from the area is gratefully acknowledged.

Location and General Features of the Area

The Stanley area (see fig. 1) consists of 72 square miles in T. 156 N., Rs. 91 and 92 W., in the northwestern part of North Dakota. The city of Stanley, the largest community in the area, is in the eastern part of the area. The small community of Ross is about 7 miles west of Stanley. The area is served by the main line of the Great Northern Railway, U. S. Highway 2, and State Highway 8, all of which pass through Stanley (see pl. 1). The population of Stanley is 1,486 (1950 census).

The area is in the glaciated section of the Missouri Plateau (Fenneman, 1931, p. 72-79). The topography is primarily glacial, being composed for the most part of rolling knob-and-kettle tracts, interspersed with large glacial-lake basins.

The valley of the Little Knife River extends southwestward across the southeastern corner of the area. It heads near the eastern margin of the area and increases very rapidly in width and depth downstream so that at the southern edge of the area it is nearly half a mile wide and is incised to a depth of about 200 feet.

Present Water Supply and Future Needs

Ground water is the chief source of water in the area. In addition, water from the Little Knife River and prairie potholes is used to some extent for stock. A dam constructed by the Great Northern Railway across the Little Knife River south of Stanley impounds water which is piped via several substage reservoirs to a storage tank,at the north edge of Stanley, for use in steam locomotives.

Stanley has a municipal water-distribution system. The system is presently supplied with water from 3 wells, all of which are within the city limits. The wells are designated in the tables and are shown on plate 1 as Stanley No. 1, 2, and 3. They are 188, 200, and 180 feet deep,respectively. All the wells obtain water from very fine sand or sandstone in the Fort Union formation.

Owing to the relatively large areal extent and thickness of the water-bearing beds it is likely that the potential quantity of water available from the Fort Union formation will be adequate for the present and forseeable future needs of the city. However, the chemical quality of the water is poor and it would be desirable to obtain water of better quality for municipal purposes, even though the development of a more satisfactory supply might entail considerable financial expense.

Well-Numbering System

The well-numbering system used in this report is based upon the location of the well with respect to the land-survey divisions used in North Dakota. The first number is that of the township north of the base line which extends laterally across the middle of Arkansas. The second number is the range west of the 5th principal meridian. The third number is the section within the designated township. The letters, a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, the quarter-quarter sections, and the quarter-quarter-quarter sections (10-acre tracts). If more than one well within a 10-acre tract is listed, consecutive numbers are given to the wells as they are scheduled. This number follows the letters. Thus well 156-91-34aaa (see pl. 1) is in T. 156 N., R. 91 W., sec. 34. It is in the northeast quarter of the northeast quarter of the northeast quarter of the section. Similarly, well 156-91-25bcc1 is in T. 156 N., R. 91 W., sec. 25. It is in the southwest quarter of the southwest quarter of the northwest quarter of the section and is the first of a number of wells scheduled in that 10-acre tract. Numbers for wells not accurately located within the section may

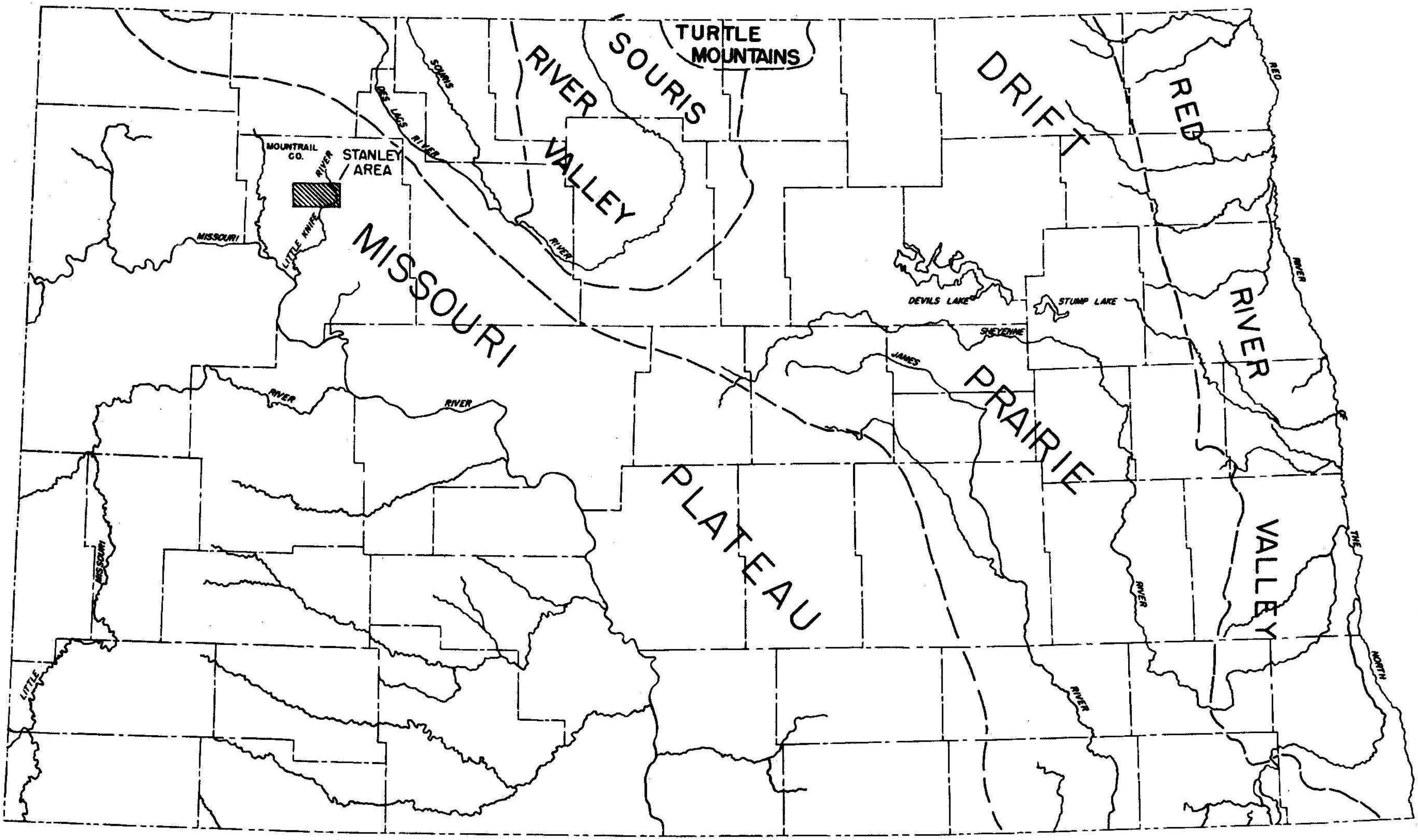


FIGURE I.- MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC DIVISIONS, AS MODIFIED FROM SIMPSON, AND LOCATION OF THE STANLEY AREA.

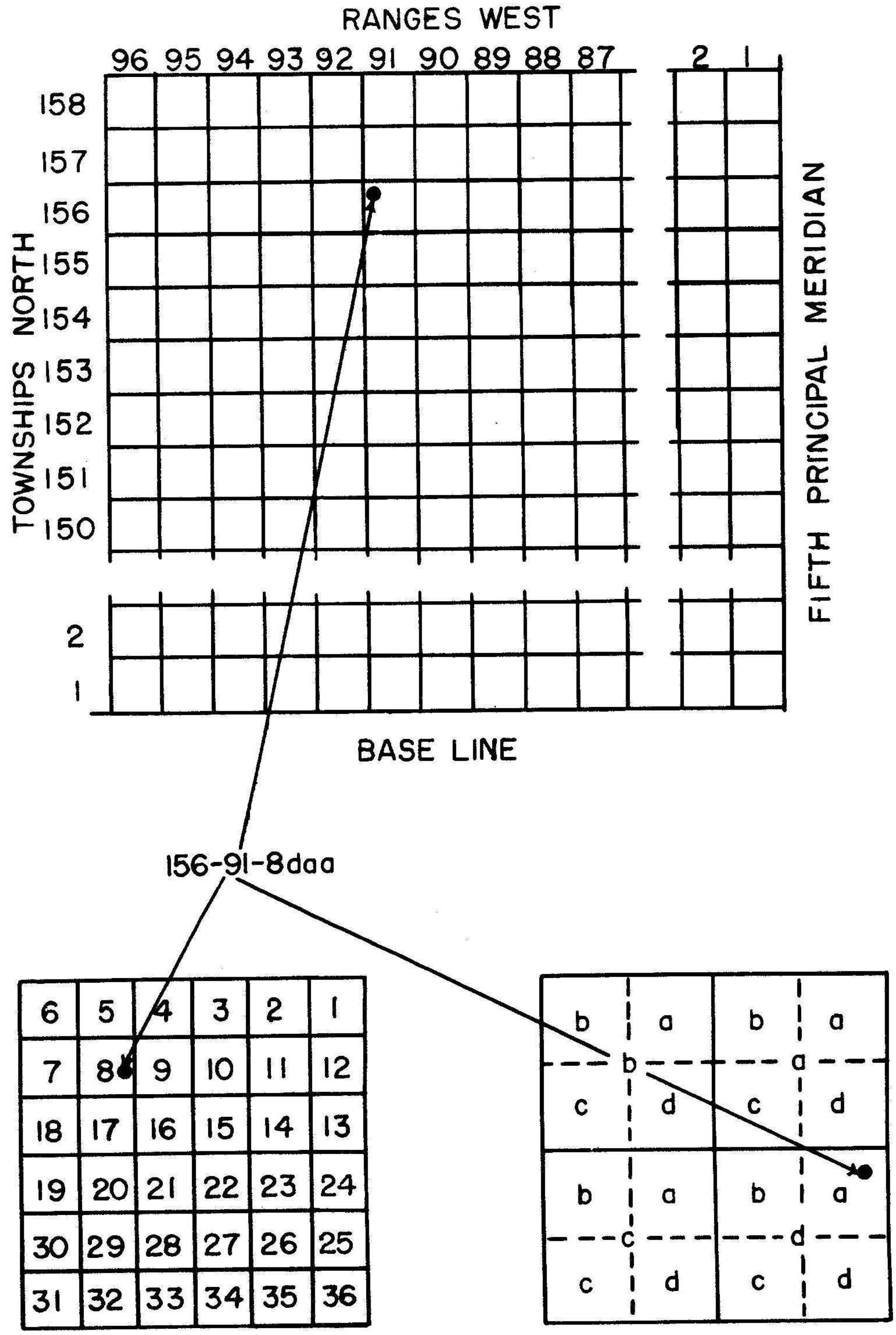


FIGURE 2.– SKETCH ILLUSTRATING WELL-NUMBERING SYSTEM

contain only one or two letters after the section number, indicating that the location of such wells is accurate only to the quarter or quarter-quarter section, respectively.

Figure 2 illustrates how the numbering system is applied.

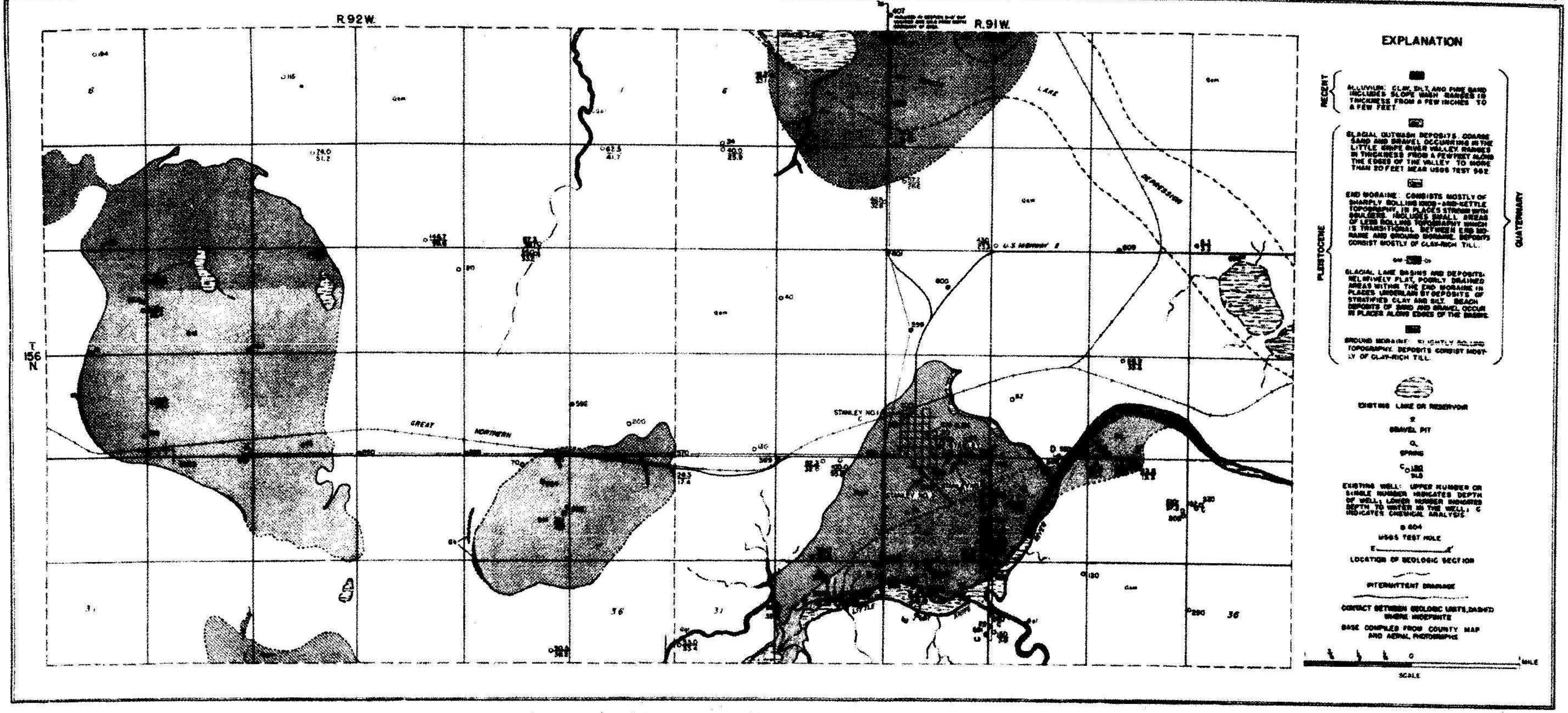
The test holes drilled by the U. S. Geological Survey with the State-owned rig were given serial numbers in the field. These serial numbers have been retained in the report for purposes of reference and for ease of recognition by the local people.

GEOLOGY

The occurrence of ground water in any area is controlled foremost by the geology of the area. Consequently, an understanding of the geology of the area is necessary before an effective evaluation of the ground-water resources can be made. The geologic investigation of the Stanley area involved both surface and subsurface methods.

A geologic map of the area (pl. 1) was prepared, with the aid of aerial photographs, on which were drawn the boundaries between the various geologic features or types of deposits as they were distinguished in the field. It is hoped that the reader may follow the geologic descriptions more easily, by referring to the geologic map, especially as references are made to the water-bearing characteristics of the various types of deposits.

In conjunction with and as a supplement to the geologic mapping of the area, 46 test holes, ranging in depth from 20 to 350 feet, were drilled with a hydraulic-rotary drilling rig owned by the State of North Dakota. Descriptive logs of the geologic materials penetrated in each of the test holes were made by the head driller and samples were taken at 5-foot intervals. The samples were examined later by the writer and composite logs were compiled which included the information given by the driller and also the writer's interpretations. These logs are given on pages 31 to 49. Using the logs of the test holes, correlations of similar



MAP OF STANLEY AREA SHOWING GEOLOGY AND LOCATIONS OF WELLS AND TEST HOLES geologic deposits and formations were made, and the correlations are shown graphically in the geologic sections (pls. 2 and 3).

The youngest deposits in the area consist of alluvium and slope wash, which are found mainly in the valley of the Little Knife River and in some of the larger gullies tributary to it. Except for places where alluvium and slope wash are present, the surface formation over the entire area is glacial drift. The glacial drift has been subdivided, as to land forms and types of rock material, into end moraine, ground moraine, lake basins and deposits, and outwash. The bedrock in the entire area consists of the Fort Union formation and was reached in all the test holes. In the following sections the deposits are described from youngest to oldest, as they would be penetrated in a well drilled through them all.

Alluvium and Slope Wash

Thin deposits of alluvium and slope wash of Recent age occur in the Little Knife River valley and in the larger tributaries to it, and, also, in the larger tributaries to White Lake. The deposits consist mostly of dark gray humic clay, silt, and very fine sand. They range in thickness from a few inches to several feet and grade downward and laterally into adjacent deposits.

Glacial Drift

Glacial drift is present over the entire area. It was penetrated in all the 46 test holes and averaged about 70 feet in thickness. However, much of the test drilling was done in the valley of the Little Knife River, where the drift is comparatively thin. On a regional basis the average thickness of the drift probably is in the neighborhood of 100 feet, as indicated in the general geologic sections (pl. 2). In parts of the Little Knife River valley, less than 10 feet of drift overlies the bedrock. The maximum thickness of glacial drift penetrated was in USGS test 606, about 3 miles north of Stanley, where it was found to be 224 feet.

The unusual thickness at that location is due to the presence of a rather deep trough in the underlying Fort Union formation. This feature is discussed further in the section on the White Lake depression.

It is believed that the glacial drift exposed at the surface in the Stanley area is of a single age which, tentatively, is believed to be late Wisconsin. However, the test drilling indicated the presence of at least one older drift sheet and possibly several others, underlying the late Wisconsin drift in places. The older drift is indicated in the test-hole logs by the yellowish-gray, oxidized zones of till (indicating weathering while at or near the land surface) underlying gray, unoxidized till. Consequently, it is known that the area was periodically covered and uncovered by glaciers several times during the glacial or Pleistocene epoch.

The glacial drift in the Stanley area was differentiated by topography and lithology into the following categories: end moraine, ground moraine, lake basins and deposits, outwash deposits in the Little Knife River valley, and the White Lake depression.

End Moraine

End moraine is the most extensive surficial deposit in the Stanley area. It is characterized by rolling, knob-and-kettle topography. Undrained depressions (ranging in size from small sloughs or "potholes" a few hundred feet across to larger, more permanent, sloughs and lakes several thousand feet across) are rather common in the end-moraine areas. Local relief generally does not exceed 50 feet. However, east of Stanley the end moraine becomes more rugged, and it is likely that the local relief in that area may be 100 feet, or more.

No attempt was made to correlate the end moraine with similar deposits outside the area investigated. It is believed that the end moraine in the Stanley area represents but a very small part of a much larger, linear end moraine that extends across North Dakota from the northwestern corner of the State to approximately the middle of the southern boundary line with South Dakota. Early investigators of the geology of the State generally believed this extensive belt of end moraine to be correlative with the Altamont moraine which is prominent in South Dakota. (Todd, 1896). Consequently, the usage of the term "Altamont" for the North Dakota counterpart of the moraine has become rather well entrenched in the literature.

However, Townsend and Jenke (1951, p. 845) recently have proposed that the term "Altamont end moraine" be discontinued, at least insofar as it applies to that part of the deposits extending northwest from the latitude of Bismarck, N. Dak. In place of the term "Altamont end moraine" they introduced the new term "Max moraine," which they used because of the prominence of the morainal deposits near Max, N. Dak. Thus, they expressed doubt as to the validity of the correlation of the deposits with the Altamont moraine in South Dakota and also to the use of the term "end moraine," substituting rather the nongenetic term "moraine."

It is believed that the deposits in the Stanley area designated "end moraine" are a part of the large belt of glacial deposits in question. Because of the small area involved in this report, little additional information was gained that would help solve the correlation problem which is of regional proportion. However, the writer believes that the deposits are true end-moraine deposits formed along the margin of the late Wisconsin glacier.

The end moraine is composed predominantly of till which was deposited directly from the glacial ice along its margins with little sorting by melt water. Consequently, the till is a heterogeneous mixture of clay, silt, sand, gravel, and boulders. Clay and silt probably constitute more than 75 percent of the till so that it is very compact and relatively impermeable. In places the end moraine may include deposits of sorted sand and gravel without much clay.

Ground Moraine

Ground moraine occurs in only two small isolated areas. The larger of these areas is in the vicinity of Stanley and the other is in the lower part of secs. 32 and 33, T. 156 N., R. 92 W. The ground moraine areas are underlain by deposits of till just as are the end-moraine areas, but they can be distinguished from end moraine by their characteristically flatter topography.

The deposition of the ground moraine probably was directly from the glacial ice without any significant action of melt water.

Lake Basins and Deposits

Three basinal areas of varying sizes and shapes occur in the Stanley area. These areas are believed to be the sites of extinct glacial lakes which existed for relatively short periods during the latter stages of late Wisconsin glaciation.

The largest lake basin is in the western part of the area in the vicinity of the village of Ross. It has an area of about 7 square miles. The lake that formerly occupied the basin had a shoreline of about 15 miles. Much of the basin is underlain by stratified deposits of clay, silt, and sand resting on till. In USGS test 591, which was drilled near the southern edge of the basin, 9 feet of clay and sand were penetrated. Beach deposits consisting of well stratified and relatively well sorted sand and gravel occur northwest and southeast of Ross. The beach deposits northwest of Ross are known to be at least 15 feet thick, and a gravel pit of commercial importance has been opened in them.

A small lake basin, about 2 square miles in area, occurs in the south-central part of the Stanley area. USGS test 493 was drilled near the center of the basin and penetrated 14 feet of lake deposits, consisting mostly of clay. Low ridges of sand and gravel occur in places along the edges of the basin, and they are shown in plate 1 as beach ridges although it is likely that they are partly of ice-contact origin. That they are partly of ice-contact origin is evidenced by their discontinuity and also by the large volume of material composing the ridges in relation to the small size of the body of water that must have occupied the basins. Evidence of the proximity of active glacial ice in the area at the time of the existence of the lakes is found, also, in the relatively large thickness of the finer-grained lake deposits in the central parts of the basins.

It is believed that significant thicknesses of lake-sorted materials ordinarily would not be deposited in lake basins as small as those in the Stanley area. Instead, it seems likely that the lakes were in contact with active glacial ice along their northern shores so that consequently, large amounts of detrital material were continually dumped into the lakes and were sorted and redeposited by the lake waters.

Part of the White Lake depression in the northern part of the area is underlain by relatively thick lake deposits. In USGS test 603, 16 feet of clay was penetrated, and in USGS test 606, 66 feet of silty clay was penetrated. White Lake apparently is the remnant of a considerably larger lake that formerly occupied a large part of the White Lake depression at the close of late Wisconsin glaciation. However, its mode of origin is different from that of the lakes already described in that it was not necessarily bounded by glacial ice on the north. Although the preglacial channel in which White Lake occurs is more or less filled with glacial drift, the channel is incised so deeply into the bedrock that a considerable depression that collected and ponded glacial melt water remained in the topography after glaciation.

Outwash Deposits in the Little Knife River Valley

Glacial outwash deposits consisting of sand and gravel occur in the Little Knife River valley east and south of Stanley. They occur along the inside of the meander loops in the valley and, south of Stanley, are nearly a mile wide. Terrace deposits have been developed in places along the valley sides; but, because of the small are involved and also because of the resemblance of the deposits to ice contact deposits in places, no attempt was made to distinguish them on the map(pl.1).

The outwash deposits probably were deposited for the most part by the melt water from the late Wisconsin ice sheet. The deposits consist mostly of very coarse sand and gravel, but in the southern part of the area they are overlain by and probably grade laterally into lake clays.

A considerable number of test holes were drilled in the outwash deposits in order to determine their thickness at various locations and to aid in determining the areal extent of the deposits. Geologic sections were compiled from the logs of the test holes and are shown in plate 3. The thickest deposits appear to be in the area south of Stanley, as shown in geologic sections E-E' and G-G'. The maximum thickness of the deposits penetrated was in USGS test 562, where it was 22 feet.

White Lake Depression

A northwest-trending topographic depression averaging somewhat less than a mile in width extends across the northeastern corner of the area. It is shown on plate 1 as the White Lake depression, although only a small segment of White Lake is present in the area.

The White Lake depression is about 4 miles long in the Stanley area but it was traced northwestward for an additional 25 miles to the vicinity of the village of Powers Lake. White Lake, Cottonwood Lake, Powers Lake, and an unnamed lake of considerable size southeast of White Lake lie on the axis of the depression. All the lakes are linear, generally ranging in width from one-half to three-quarters of a mile and in length from 2 to 4 miles. The water of White Lake is highly mineralized, sodium sulfate or "Glauber's salt" being the main constituent. A sample of water taken from near the water's surface along the east shore of the lake during a survey in 1948 contained 94,300 parts per million of dissolved solids, of which, more than 90 percent was sodium sulfate (Grossman, 1949, p. 42).

It is believed that White Lake depression marks the course of a preglacial stream channel. This is strongly evidenced by the meandering course of the depres-

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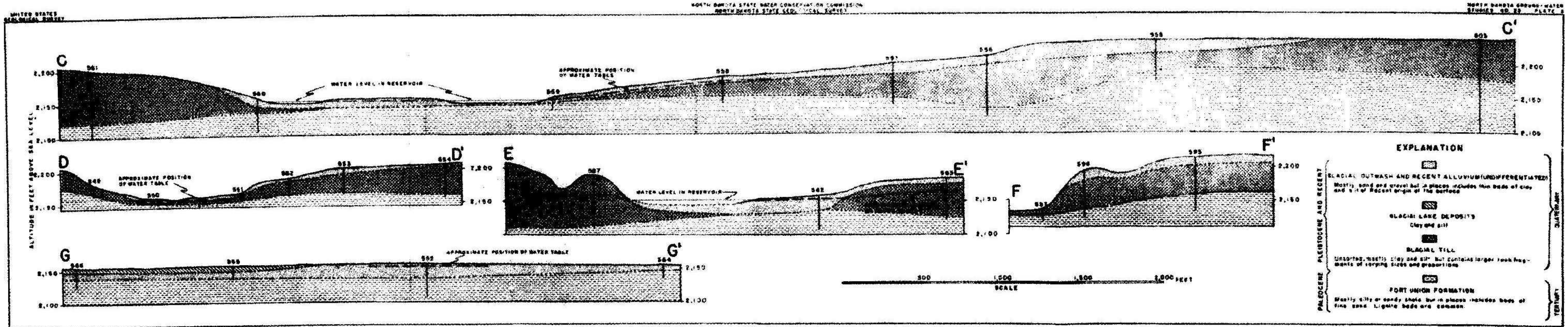
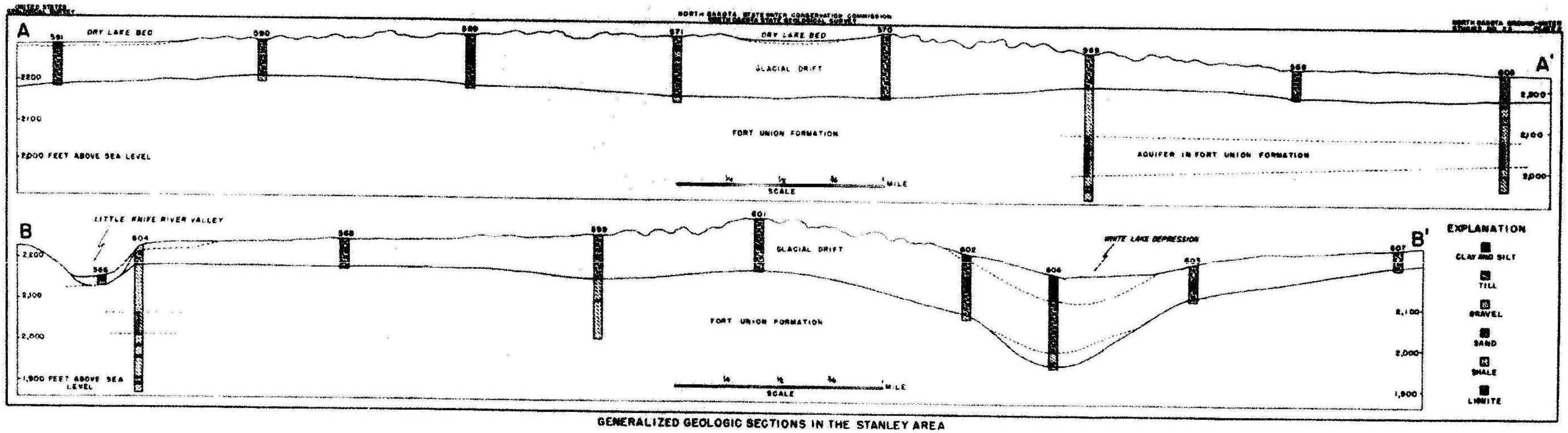
NORTH DAKOTA GROUND-WATER STUDIES NO. 23 PLATE



GEOLOGIC SECTIONS IN LITTLE KNIFE RIVER VALLEY, STANLEY AREA.



GENERALIZED GEOLOGIC SECTIONS IN THE STANLEY AREA sion and by the deep channel incised in the underlying bedrock (B-B', pl. 2).

On the basis of the test drilling it was determined that the channel is incised in the bedrock to a depth of more than 200 feet. As shown in geologic section B-B', there appears to be some evidence of terrace cutting along the sides of the channel. This is indicated by the relatively sharp breaks in slopes at the locations of USGS test 602 and 603.

It is believed that the preglacial stream which eroded the channel flowed northwestward, inasmuch as elevations obtained at the test holes drilled in the White Lake depression showed a slope of the channel floor in that direction.

That part of White Lake depression that extends through the Stanley area is largely filled with end-moraine deposits. However, the area south and east of White Lake is relatively flat and apparently is underlain by lake deposits. In USGS test 606, which was drilled about half a mile southeast of White Lake, 62 feet of uniform clay and silt, believed to be lake deposits, were penetrated. Altogether, 224 feet of glacial drift was penetrated in USGS test 606, the greatest thickness of glacial drift penetrated anywhere in the area.

The floor of the bedrock channel underlying the White Lake depression apparently is lined with deposits of sand and gravel. The deposits range in thickness from 12 feet in USGS test 608 to 24 feet in USGS test 606. Considerable carbonaceous material was found mixed with the deposits of sand and gravel, and it is possible that the deposits are preglacial alluvium.

Fort Union Formation

The Fort Union formation of Paleocene age underlies the glacial drift everywhere in the area. No exposures of the Fort Union were found in the area but in some places, especially in the Little Knife River valley, the formation lies close to the land surface.

In some of the test holes the Fort Union formation was penetrated to depths of more than 200 feet. The test-hole cuttings of the formation consist mostly of light-gray clay, sandy clay, and very fine sand. Lignite beds are rather common, at least in that part of the formation penetrated by the test drilling. The typical lignite bed is about 2 feet thick.

Insofar as is known, no test holes or wells that completely penetrate the Fort Union formation have been drilled in the Stanley area, so that the total thickness of the formation in the area is not known. However, in the Amerada-Iverson No. 1 oil well, drilled about 25 miles west of Stanley, 725 feet of the Fort Union formation is reported to have been penetrated (North Dakota Geol. Survey, 1952, p. 13). It is probable that the thickness of the formation in the Stanley area is somewhat less, probably in the neighborhood of about 600 feet, owing to the fact that the area lies east of the axis of the basin where the largest thickness would be expected.

Older Rocks

The Fort Union formation is underlain successively by rocks of Cretaceous, Jurassic, Triassic, and Paleozoic ages. The total thickness of sedimentary rocks in the area is believed to exceed 12,000 feet. However, insofar as the occurrence of relatively fresh ground water is concerned, probably only the Cretaceous formations would be of interest. The log of the Amerada-Iverson No. 1 oil well about 25 miles west of Stanley indicates a total thickness of nearly 5,000 feet of Tertiary (Fort Union formation) and Cretaceous rocks in that area. The following is a list of the formations and the depths at which they were encountered in the well, from the surface to the bottom of the Cretaceous. The brief descriptions given of each formation are those of the present writer.

Tertiary			
	Fort Union	Surface	Light-gray and buff clay, silt, very fine sand: lignite beds common throughout section. Terrestrial.
Cretaceous			
	Hell Creek	725	Dark-gray and brown clay, silt, and very fine sand. Terrestrial.
	Fox Hills	1,275	Fine sandstone. Marine.
	Pierre	1,453	Light-gray silty shale. Marine.
	Niobrara	3,475	Light-gray calcareous shale. Marine.
	Benton	3,690	Dark-gray clayey shale. Marine.
	Greenhorn	3,838	Calcareous shale. Marine.
	Muddy sandstone member (of Thermopolis shale)	4,336	Fine sandstone. Marine.
	Dakota	4,615	Fine sandstone interbedded with shale. Terrestrial and marine.

OCCURRENCE OF GROUND WATER

General Principles

Essentially all ground water is derived from precipitation. The water enters the ground by direct penetration from rain or melting snow, or by percolation from surface-water bodies such as streams and lakes where such bodies are naturally higher than the general water table. In most areas there is lateral movement of ground water from areas of recharge to lower areas of natural discharge.

The amount of water that a rock can hold is determined by its porosity. Unconsolidated material such as clay, sand, and gravel is generally more porous than consolidated rocks, such as sandstone and limestone, although in some areas the consolidated rocks are highly porous.

If the pore spaces are large and interconnected, as they commonly are in sand and gravel, the water is transmitted freely and the rock is said to be permeable.

Where the pore spaces are very small, as in clay, the water is transmitted very slowly or not at all and the rock is said to be impermeable. Furthermore, a deposit of uniformly sized, well-rounded material may be more porous and permeable than a variously sized material because in the latter the smaller particles occupy the interstices between the larger ones.

At various depths in different regions, depending on local conditions, spaces in the rocks are filled with water, and the rocks are said to be saturated. This is true of clay as well as of sand and gravel, but, because of the difference in permeability, it is possible to develop successful wells only in the coarser material.

Where some part of the water-transmitting bed (aquifer) is exposed at the surface or comes in contact with another aquifer so exposed, the water discharged naturally or through wells can be replenished periodically from precipitation or streamflow. Where the aquifer is more or less completely surrounded by clay or other relatively impermeable materials, natural recharge may be very slow, and the water taken by wells from storage in the aquifer may not be fully replenished each year. The initial yield of wells in aquifers that are virtually cut off from natural recharge may be as large as that of wells in aquifers having adequate recharge areas, thereby giving an erroneous impression that an abundant perennial water supply is available.

As ground water moves through an aquifer, it dissolves a part of the more soluble mineral constituents of the rock particles. The amount of mineral matter dissolved is determined by the amount of the soluble materials present and the length of time the water is in contact with them. Therefore, in rocks of homogeneous mineral composition, the water that has been underground longest or that has traveled the greatest distance is more highly mineralized than that which is relatively near the recharge area.

Aquifers in the End-Moraine, Ground-Moraine, and Lake-Basin Areas

Most of the wells in the Stanley area obtain water from aquifers in the glacial drift of the moraine and lake-basin areas. The wells generally are bored or dug and few are deeper than 50 feet. Most of the deeper wells are bored and are in the lake-basin area near Ross in T. 156 N, R. 92 W.

Generally, the aquifers in the moraine and lake-basin areas are of small areal extent and thickness. Many of the wells were reported to yield inadequate amounts of water. In some cases the water was reported to be of very poor quality, being very hard and containing objectionable amounts of iron.

The materials composing the aquifers in the moraine and lake-basin areas range in texture from clay or clayey till to very coarse gravel. Most of the dug and bored wells in the lake basin near Ross obtain water from till composed mostly of clay and silt. The permeability of these materials is very low and the wells that obtain water from them are capable of producing only a few gallons per minute (gpm).

Test drilling in the moraine and lake-basin areas did not indicate the presence of any aquifers of major importance. In USGS test 571, an aquifer composed of fine to medium gravel was penetrated between 35 and 52 feet and between 57 and 68 feet below the land surface. However, considerable off-set test drilling from that location failed to intercept the aquifer and, consequently, it is believed to be small. It is possible that the aquifer is linear and somewhat sinuous, so that considerable detailed test drilling would be necessary to determine its boundaries.

Thin deposits of water-bearing sand and gravel were penetrated in several other test holes drilled in the moraine and lake-basin areas (see pl. 2). Those deposits constitute aquifers of minor importance from which small supplies of ground water probably could be obtained.

Aquifers in the Outwash Deposits of the Little Knife River Valley

The outwash sand and gravel occurring in the Little Knife River valley are water bearing in part and compose an aquifer of considerable importance in the Stanley area. Generally, the water occurs under water-table conditions, but in the southern part of the area deposits of clay and silt overlie the water-bearing sand and gravel, and it is likely that artesian conditions exist in that area.

Test drilling indicated that the thickest part of the deposits occur south of Stanley in the vicinity of USGS test 562 (pl. 3). At that location 18 feet of fine to coarse gravel overlain by 3 feet of clay and sand were penetrated. At the time of the test drilling the water table was about 4 feet below the land surface, indicating a zone of saturation of about 17 feet.

It is estimated from the test-drilling data and field mapping that the aquifer has an area of about 16 million square feet and that the average saturated thickness is about 7 feet. Using these figures and assuming that a minimum of 25 percent of the volume of the aquifer is saturated with water, it is estimated that about 28 million cubic feet or 210 million gallons of water occur in the aquifer in transient storage. At the rate of 150,000 gpd (100 gpd, per capita, for a town the size of Stanley) that amount of water would not be entirely used up over a continuous period of 3 years. However, it would not be economically feasible to place such a demand on the aquifer as to nearly unwater it.

On the other hand, in most of the area in which the aquifer occurs, it is easily accessible to recharge by water percolating downward from the surface. Also, it is very likely that prolonged pumping of a well constructed in the aquifer near the edge of the surface reservoir would cause water to infiltrate laterally and downward through the bed of the reservoir and into the aquifer. In that case the well would be drawing water from both the aquifer and the reservoir. A supply of water would then be assured for as long a time as water remained in the reservoir.

The major factors upon which the amount of water stored in the reservoir depend are the amount of surface runoff and the evapotranspiration rate. It is believed that not enough basic data are available at the present time to permit evaluating the effect of these factors.

A short pumping test was made on well 156-91-33bda, which is near the edge of the north shore of the reservoir and is constructed in the outwash deposits of the Little Knife River valley. It is a dug well 11.4 feet deep and 2 feet in diameter and has a stone curbing. The well was pumped for a period of 2 hours and 9 minutes at an average rate of 30 gpm. Water-level measurements were made during the period of pumping and also for a period of several hours after pumping ceased.

The water-level data obtained during the pumping and recovery period were analyzed for the coefficients of transmissibility and storage by means of the Theis nonequilibrium formula (Theis, 1935, p. 519-524; Wenzel, 1942, p. 87-90). The coefficient of transmissibility computed from the data is about 24,000 gpd per foot and the coefficient of storage is 0.02. 1/

It is probable that a well constructed within about 200 feet from the edge of the reservoir and penetrating the entire thickness of the aquifer would yield water at a rate of about 150,000 gpd for at least as long a time as water was present in the reservoir. Larger amounts of water undoubtedly could be obtained by constructing additional wells along the trend of the aquifer and near the edge of the reservoir. However, further data obtainable by means of a comprehensive pumping test of the initial well would be necessary in order to determine the proper spacing of the additional wells, if any were proposed.

1/ As used here, the "coefficient of transmissibility" is defined as the number of gallons of water that will pass in 1 day through a vertical strip of the aquifer 1 foot wide, under a unit hydraulic gradient (1 foot per foot); or, through a cross section 1 mile wide under a gradient of 1 foot per mile, under prevailing conditions.

The "coefficient of storage" may be defined as the amount of water, expressed as a fraction of a cubic foot, that will be released from storage in each vertical column of the aquifer having a base of 1 square foot when the water level falls 1 foot.

Aquifers in the White Lake Depression

It is likely that the sand and gravel deposits penetrated in USGS tests 606 and 608 are part of a narrow, linear aquifer that follows the trend of the White Lake depression and occurs near the bottom of the glacial drift. The deposits were penetrated at depths ranging from 212 to 224 feet in USGS test 606, and from 123 to 135 feet in USGS test 608.

No further quantitative data were obtained concerning this aquifer. Apparently none of the wells inventoried in the area obtain water from it. Flows of water were obtained in both the test holes that penetrated it, indicating that the water occurs under considerable hydrostatic pressure. The pressures probably are caused by the higher head that occurs in the Fort Union formation bounding the sides of the White Lake depression.

Relatively deep aquifers associated with buried channels in the Fort Union formation have been noted in several places in northwestern North Dakota (Waring and LaRocque, 1949, p. 42; Witkind, 1952, p. 674). It seems likely that some of these aquifers, although relatively narrow, would be of considerable length, perhaps several miles or more. The aquifers generally are composed of gravel and probably have higher transmissibilities than most aquifers in the Fort Union formation. However, they probably are recharged by water moving through the Fort Union formation so that the quality of the water may be similar.

Aquifers in the Fort Union Formation

The Stanley municipal-supply wells and several farm wells southwest of Stanley obtain water from aquifers in the Fort Union formation. The wells range in depth from 180 to 290 feet and are reported to obtain water from fine sand and sandy clay.

Four test holes (USGS test 569, 598, 599 and 604) were drilled to depths of 350 feet, and one test hole (USGS test 605) was drilled to a depth of 280 feet, in order to obtain some knowledge of the areal extent and thickness of the water-bearing deposits in the Fort Union. The locations of the test holes are shown on plate 1 and the logs are given on pages 31-49. Where found in the test holes the aquifer ranged in thickness from 52 feet in USGS test 604 to 119 feet in USGS test 598. The aquifer was not penetrated in USGS test 599 about three-quarters of a mile north of Stanley, and it possibly "pinches out" in that vicinity. It was penetrated in USGS test 604 about a mile south of Stanley and, as indicated by the well inventory, the aquifer probably is extensive over the entire part of the area southeast of Stanley. In USGS test 569, drilled 1 mile west of Stanley, nearly 100 feet of very clayey sand was penetrated; but, because of the high clay content, the aquifer there would not be very permeable, although it probably would yield some water. The absence of deep wells in the area west of Stanley probably is due to the high clay content of the aquifer in that area.

In USGS test 598, in which the greatest thickness of the aquifer was found, the water-bearing materials, as observed in the samples, consisted of alternating layers of very fine sand, sandstone, and sandy clay from 117 to 236 feet. The samples contained less clay than those from any of the other test holes that penetrated the aquifer.

Since the time of the test drilling in the Stanley area, a new city supply well, shown on plate 1 as Stanley No. 3, was drilled near the location of USGS Test 598 and was finished at a depth of 185 feet. The log of the well is given on page 40. The diameter of the well is 8 inches and a gravel pack was placed around the outside of the casing. The casing is perforated from 121 to 185 feet. A deep-well turbine pump was installed in the well and it is presently being pumped in service at the rate of about 70 gpm.

A pumping test was made on Stanley No. 3 supply well during the period August 27 to 29, 1953. The well was pumped at an average rate of 100 gpm for a continuous period of 24 hours. Measurements of the water level in the well were made at intervals during the time of pumping and for a period of about 24 hours after the pump was shut off.

The data obtained were analyzed by means of the Theis recovery formula (Theis, 1935, p. 522) to determine the coefficient of transmissibility. The value of the coefficient determined by this method is about 6,000 gpd per foot.

The water level before the pump was turned on was about 86 feet below the measuring point, and after 24 hours of pumping it was about 124 feet below the measuring point. The 1-day specific capacity of the well (gpm per foot of drawdown) is approximately $\frac{100}{38} = 2.6$.

Aquifers in Older Rocks

No definite information is available concerning the lithology or water-bearing properties of rocks underlying the Fort Union formation in the Stanley area. Of the formations listed on page 14, probably the Hell Creek formation, Fox Hills sandstone, Muddy sandstone member, and Dakota formation would be of interest as possible aquifers. All these strata have a large areal extent and probably contain very large amounts of water in storage. However, it is believed that they are fine grained and possibly clayey or silty so that their transmissibilities may be relatively low. Thus no single well constructed in them would have a very large yield. Also, it is very likely that the water would be highly mineralized, probably containing 3,000 ppm or more of dissolved solids. Consequently, the purposes for which the waters could be used satisfactorily would be limited.

QUALITY OF WATER AND CHEMICAL ANALYSES

In order that the reader may understand the significance of the chemical analyses, following is a partial list of chemical standards required by the U. S. Public Health Service for drinking water on interstate carriers:

Chemical substance	Concentration (parts per million)
Chloride (Cl)	250
Sulfate (SO_4)	250
Magnesium (Mg)	125
Fluoride (F)	1.5
Iron and Manganese (Fe + Mn) together	0.3

Dissolved solids should not exceed 500 ppm, but, if water of such quality is not available, a content of 1,000 ppm may be permitted.

The presence of excessive amounts of nitrate in ground water may indicate organic contamination. Water containing more than about 10 parts per million (ppm) of nitrate nitrogen (about 44 ppm of NO_3 as listed in the table of chemical analyses) should not be used for feeding infants, because of the danger of contributing to infant cyanosis, or the condition commonly known as "blue baby" (Comly, 1945; Silverman, 1949). The presence of fluoride in drinking water in excess of 1.5 ppm may cause permanent mottling of the enamel of the teeth when the water is used by children during the period of calcification of the teeth. Contents up to 1 ppm, however, may increase resistance to tooth decay.

Soft water is desirable for washing clothes or for any washing operation where soap is used. Practically all natural water contains calcium and magnesium, which cause hardness in water. Water having a hardness of about 100 ppm as $CaCO_3$ is generally considered to be moderately hard.

For general irrigation of crops or for watering lawns, trees, and gardens, water having a high percent sodium - that is, a high proportion of sodium among the total cation concentration - is undesirable because it causes the soil to become impermeable. Water containing more than 50 to 60 percent sodium (as indicated in the table of analyses) would be harmful to the soil if applied continuously for a long time. This would be especially true if the soil were heavy and subsurface drainage poor. In a porous soil having good subsurface drainage, the effects would not be so marked.

Eaton (1950, p. 123-133) has shown that if water containing relatively large amounts of carbonate and bicarbonate, as compared to the calcium and magnesium present, is used for irrigation, a soil-water solution containing principally sodium salts may result. The danger of developing a soil solution of high sodium content is increased if the water is applied sparingly and if good soil drainage is not provided. If the soil solution contains considerable sodium carbonate or sodium bicarbonate a black-alkali soil may result.

Chemical analyses of 11 samples of water from 10 wells and test holes in the Stanley area are given on page 25. The locations of wells and test holes from which the water samples were obtained are shown on plate 1.

Four samples of water from the outwash deposits in the Little Knife River valley were taken from 1 well (156-91-33bda) and 2 test holes (USGS test 550 and 560). Two samples were taken from the well, one before the well was pumped a great deal and the other after the well had been pumped continuously for a period of slightly more than 2 hours at a rate of about 30 gpm.

The water from the outwash deposits is of the best chemical quality of any ground water so far obtained in the Stanley area. The samples from well 156-91-33bda, before and after pumping, and USGS test 550 and 560 contained 340, 450, 200, and 1,130 ppm of dissolved solids (sum of determined constituents), respectively. Hardnesses of the four samples were 300, 490, 130, and 460 ppm, respectively. Both dissolved solids and hardness increased in well 156-91-33bda after 2 hours of pumping. Iron was present in objectionable quantity, more than 0.3 ppm, in only one sample, that from USGS Test 550. The percent sodium was 50 or less in all the samples.

Four samples (156-91-21cdd, 156-91-21dcb1, 156-91-21dcb2, and 156-92-23ddd) were taken from 3 wells and 1 test hole which obtained water from glacial-drift aquifers in the moraine and lake-basin areas. Dissolved solids in the 4 samples were 1,190, 1,080, 860, and 1,370 ppm, respectively. Hardnesses of the 4 samples were 930, 670, 650, and 500 ppm, respectively. Iron was present in the samples in insignificant quantities except in that from USGS test 571 which contained 2.2 ppm. The percent sodium in all 4 samples was less than 60.

Three samples (156-91-21cba2, 156-91-25bcd, and 156-91-28aba) were taken from wells that obtain water from aquifers in the Fort Union formation. Dissolved solids in the samples were 2,970, 2,950, and 2,170 ppm, respectively. The water is relatively soft, however, the hardness of the three samples being 110, 39, and 100 ppm, respectively. The predominant cation is sodium and the predominant anions are sulfate and bicarbonate. Iron in the 3 samples was 0.4, 4.9, and 0.1 ppm, respectively. The percent sodium in the 3 samples ranged from 94 to 98.

The water in the aquifer in the deposits of the Little Knife River valley is only moderately mineralized and, except for its hardness, would be acceptable for most municipal, domestic, and industrial uses. The aquifers in the glacial drift of the moraine and lake basin areas yielded water that probably would be satisfactory insofar as dissolved solids are concerned, but the extreme hardness and sulfate content of the water undoubtedly would limit its use. Both waters because of their relatively low sodium content would be satisfactory for irrigation. The water in aquifers in the Fort Union formation is too highly mineralized for most purposes, yet it is relatively soft. The large amounts of sodium, bicarbonate, and sulfate that the water contains probably would prove to be injurious to plants if the water were used extensively for irrigation purposes.

CHEMICAL ANALYSES OF GROUND WATER
(Chemical constituents in

(Analyses by North Dakota State

Aquifer: D, glacial drift except outwash in Little Knife River valley; FU, Fort Union formation; 0, glacial outwash deposits in Little Knife River valley.

Location number		Owner or name	Aquifer	Depth of well (ft)	Date collected	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)
156-91								
21cba2		Stanley No. 1	FU	200	2-19-51	0.4	24	11
21cdd		Roy Edwards	D	48	9-10-52	0.1	195	108
21dcb1		C. E. Koesseng	D	50	9-10-52	0.3	92	106
21dcb2		Lewis Backer	D	20	9-10-52	0.2	107	94
22ddc		USGS test 550	0	10	7-19-52	0.5	39	9
25bcd		James Vachal	FU	230	1952	4.9	9	4
28aba		Stanley No. 2	FU	190	1951	0.1	9	19
33bda	1/	William Nelson	0	11.4	7- 1-52		49	44
33bda	2/	. . . . .do. . . .	0	11.4	7- 1-52	0.3	95	62
34cbb		USGS test 560	0	50	7-30-52		97	53
156-92								
23ddd		USGS test 571	D	68 3/	8- 8-52	2.2	25	107

1/ Sample obtained before pumping well very much. Well had not been pumped recently.
2/ Sample obtained after pumping well about 2 hours at a rate of about 30 gpm.
3/ Not total depth of test hole.
4/ Incomplete analysis.

IN THE STANLEY AREA, N. DAK.
parts per million)

Department of Health, Bismarck)

Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$	Sum of determined constituents	Percent sodium
1,020	1,110		1,370				110	2,970 4/	95
	100		600	60	0.2	170	930	1,190 4/	
130	150	14	660	40		65	670	1,080	29
44	380		290	50		87	650	860	13
27	220		10			2.1	130	200 4/	30
1,080	1,080		1,410	20			39	2,950	98
775	920	46	910	4		2.1	100	2,170	94
28	420		10			4.3	300	340 4/	17
	500		45	2			490	450 4/	
210	370		580	8		2.1	460	1,130	50
270	250		820	20	0.1	6.5	500	1,370	54

Depth to water: Measurements given to hundredths are measured water levels. Those given in whole numbers only are reported.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type
156-91				
4cbc	USGS test 606	230	5	Drilled
4ccc1	USGS test 602	160	5	...do...
4ccc2	Bert Straoi	20	48 by 48	Dug
4ccc3	....do....	12	48 by 48	...do...
5aaa	USGS test 603	90	5	Drilled
6add	Bert Straoi	48.9	24	Bored
6cdd	Robert Kohls	34.0	...	Dug
7baa	Nels Hemstad	40.0	...	Bored
8daa	Matt Jellsed	46.3	24	...do...
9bca	Ben J. Ingeberilson	65	24	...do...
10ccc	Tom Schjervheim	60	24	...do...
11cdc	USGS test 609	140	5	Drilled
12cc	Melvin Howell	8.3	48 by 48	Dug
13baa	USGS test 608	140	5	Drilled
16acb	USGS test 600	90	5	...do...
16bbb	USGS test 601	140	5	...do...
16cca	USGS test 599	250	5	...do...
17bcc	Sam George	40	24	Bored
18daa	Albert Massen	16.1	48 by 48	Dug
19ddc	M. Jensen	130	...	Drilled
20ddd	USGS test 568	70	5	...do...
21cba1	City of Stanley	180	5	...do...
21cba2	Stanley No. 1	200	8	...do...
21cca1	USGS test 610	70	5	...do...
21cca2	USGS test 611	60	5	...do...
21cdd	Roy Edwards	48	24	Bored

Depth of well: Measurements given to hundredths or tenths are measured well depths. Those given in whole numbers only are reported.
Use of water: D, domestic; S, stock; T, test hole; U, unused; PS, public supply.

Date completed	Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
9-20-52	.....	....	T	Hole refilled. See log.
9-11-52	.....	....	T	Do.
1905	17	....	D	Aquifer, sand and gravel. Water reported hard.
1903	10	....	S	Do.
9-11-52	.....	....	T	Hole refilled. See log.
.....	33.10	7-28-52	..	Water has strong odor.
1952	25.2	7-28-52	S	Water reported hard.
.....	25.87	8- 4-52	D,S	Easily pumped dry.
.....	32.8	7-28-52	D,S	Water reported hard.
.....	26.6	7-28-52	D,S	Water reported hard; contains excessive iron.
1915	23.3	7-26-52	S	Water reported very hard. Unfit for human consumption.
9-24-52	.....	....	T	Hole refilled. See log.
1948	3.2	7-26-52	D,S	Aquifer, coarse gravel. Water reported soft.
9-24-52	.....	....	T	Hole refilled. See log.
9-10-52	.....	....	T	Do.
9-10-52	.....	....	T	Do.
9- 9-52	.....	....	T	Do.
1940	18.0	8- 4-52	D,S	Water reported hard.
.....	10.2	8- 4-52	U	
.....	85	....	S	Water reported unfit for human consumption
8- 5-52	.....	....	T	Hole refilled. See log.
1915	.....	....	U	
1947	128.0	11-30-48	PS	Casing slotted from 172-200 feet. See log, chemical analysis.
9-25-52	.....	....	T	Hole refilled. See log.
9-25-52	.....	....	T	Do.
1927	24	....	D, PS	See chemical analysis.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type
156-91 - Cont.				
21dcb1	C. E. Koesseng	50	24	Bored
21dcb2	L. Backer	20	24	...do...
21dcd	I. Fredheim	36.0	24	...do...
21ddb	L. Backer	20	36	Dug
22bcb	M. Weisenberger	62	...	...do...
22dcd	USGS test 549	40	5	Drilled
22ddc	USGS test 550	20	5	...do...
22ddd1	USGS test 551	30	5	...do...
22ddd2	USGS test 552	50	5	...do...
23bab	Oscar Kloster	60	24	Bored
23ccc	USGS test 553	80	5	Drilled
23ccd	USGS test 554	100	5	...do...
25bcc1	James Vachal	132	24	Bored
25bcc2	....do....	230	3	Drilled
26abb1	Earl Stoner	94.7	18	Bored
26abb2	....do....	22.8	24	Dug
26bbb	Vacant	53.6	24	Bored
26daa1	R. Z. Stalnecker	205	3	Drilled
26daa2	....do....	....	24	Bored
27bbb	USGS test 605	280	5	Drilled
27bcc	USGS test 555	60	5	...do...
27bcd	Anton Peterson	40.0	24 by 18	Dug
27cbb	USGS test 556	90	5	Drilled
27ccb	USGS test 557	60	5	...do...
27ccc	USGS test 558	40	5	...do...
28aba	Stanley No. 2	190	8	...do...
28abb	Jay Smith	26.0	36 by 36	Dug
28bac1	USGS test 598	350	5	Drilled
28bac2	Stanley No. 3	185	12-8	...do...
28cba	William Nelson	73	20	Bored
28ccc	USGS test 604	350	5	Drilled
28dda	M. M. Kincanon	26.4	24 by 24	Dug

Date completed	Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
1922	.....	....	D,PS	Water sold in Stanley for drinking purposes. See chemical analysis.
1949	15	....	D,PS	Do.
1943	35	....	D	Aquifer, gravel.
....	15	....	D,PS	
....	.....	....	S	0-40 clay, 40-41 fine gray sand; 41-62 blue clay.
7-19-52	.....	....	T	Hole refilled. See log.
7-19-52	.....	....	T	Hole refilled. See log, chemical analysis.
7-21-52	.....	....	T	Hole refilled. See log.
7-21-52	.....	....	T	Do.
1933	35.5	7-26-52	D,S	
7-22-52	.....	....	T	Do.
7-25-52	.....	....	T	Do.
1907	112	....	S	
1952	140	....	D,S	Aquifer, fine sand from 216 to 230 feet. See chemical analysis.
1930	75.0	7-28-52	S	Water reported hard.
....	14.2	7-28-52	D	Do.
....	40.1	7-21-52	U	
1948	94.3	7-26-52	S	
1917	57.3	7-26-52	D	
9-17-52	.....	....	T	Hole refilled. See log.
7-25-52	.....	....	T	Do.
1948	27.2	7-25-52	D	
7-26-52	.....	....	T	Do.
7-28-52	.....	....	T	Do.
7-29-52	.....	....	T	Do.
1949	95	....	PS	Pumps 50 gpm. See log, chemical analysis.
1928	13.7	9- 9-52	D,S	
9- 5-52	.....	....	T	Hole refilled. See log.
8-53	85	....	PS	Pumps 70 gpm. See log.
1928	50	....	D,S	Aquifer, hard sand. Hardness of water reported to be more than 800 ppm.
9-15-52	.....	....	T	Hole refilled. See log.
1925	15.3	7-28-52	D	Water reported hard.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type
156-91- Cont.				
29abb	E. T. Jellesed	100+	36 by 36	Dug
29baa	Andrew Johnson	60	36 by 36	...do...
29bbb	USGS test 569	350	5	Drilled
29cdc	Vacant	70.0	30	Bored
31cbc	Nick Loman	56	20	...do...
32bad	USGS test 595	80	5	Drilled
32bcc1	Reubin Enander	22	24 by 24	Dug
32bcc2	....do....	30-40	20	Bored
32bda1	USGS test 596	70	5	Drilled
32bda2	USGS test 597	20	5	...do...
33aaa	Vacant	67.5	24	Bored
33aca	USGS test 564	20	5	Drilled
33bad	USGS test 563	60	5	...do...
33bbc	USGS test 566	30	5	...do...
33bbd	USGS test 565	20	5	...do...
33bda1	William Nelson	11.4	20 by 20	Dug
33bda2	USGS test 562	50	5	Drilled
33cab	USGS test 567	80	5	...do...
33dad	USGS test 561	140	5	...do...
34aaa	Jake Jacobs	120	18	Bored
34bbb	USGS test 559	20	5	Drilled
34cbb	USGS test 560	50	5	...do...
34cbc1	Harold Hagen	16.0	36 by 36	Dug
34cbc2	....do....	28	6	Bored
36bcc	Claver Houda	290	3-2	Drilled

Date completed	Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
1902	55.8	7-26-52	D,S	Aquifer, gray clay.
1902	32.0	7-25-52	D,S	Aquifer, gravel.
8- 6-52	.....	....	T	Hole refilled. See log.
.....	36.6	7-25-52	U	
1947	33.7	7-25-52	D,S	Aquifer, blue sand.
9- 4-52	.....	....	T	Hole refilled. See log.
1929	.....	....	D,S	Aquifer, sand. Water reported hard
.....	11.5	7-25-52	S	Water reported soft, contains excessive iron.
9- 4-52	.....	....	T	Hole refilled. See log.
9- 5-52	.....	....	T	Do.
.....	22.4	7-24-52	U	
8- 1-52	.....	....	T	Do.
7-31-52	.....	....	T	Do.
8- 1-52	.....	....	T	Do.
8- 1-52	.....	....	T	Do.
.....	3.9	8- 1-52	U	Aquifer, gravel. See chemical analysis.
7-31-52	.....	....	T	Hole refilled. See log.
8- 5-52	.....	....	T	Do.
7-30-52	.....	....	T	Do.
1913	96.8	7-26-52	D,S	Aquifer, fine gray sand. Water occasionally cloudy.
7-29-52	.....	....	T	Hole refilled. See log.
7-30-52	.....	....	T	Hole refilled, see log, chemical analysis.
1930	3.8	7-25-52	S	Aquifer, gravel. Water reported soft.
1950	10	....	D	Aquifer, gravel. Water reported hard.
1949	80	....	D,S	Water reported soft.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type
156-92				
4bbb	Vacant	.....	24	Bored
4bdc	A. Farhart	115	24	...do...
6abc	Emil Fleck	194	24	...do...
7dcc	K. Olson	135	24	...do...
9abb	Vacant	74.0	24	...do...
10dcc	Jim Horne	175	24	...do...
11dcd	Vacant	67.3	24	...do...
12bab	...do...	62.5	24	...do...
14aba	Charlie Jerma	35.0	24 by 24	Dug
15aaa	Irvin Horne	80	24	Bored
16abb	....	20.0	24	...do...
17bcb	....	28.0	24	...do...
17ddd	J. Whetlock	120	24	...do...
18add	Vacant	56.4	24	...do...
18cdd	Earl Thompson	15	8	...do...
18daa	Vacant	100+	24	...do...
19daa	M. Myers	120	24	...do...
20bcc	...do...	100+	36	...do...
20ddd	USGS test 591	102	5	Drilled
21cdd	M. Myers	14	48 by 48	Dug
22ccc	USGS test 590	100	5	Drilled
23ccc	USGS test 589	130	5	...do...
23ddd	USGS test 571	160	5	...do...
24cbb	USGS test 592	172	5	...do...
24dbc	H. Nelson	200	3	...do...
24ddd	USGS test 570	160	5	...do...

Date completed	Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
.....	55	....	S	Aquifer, 1 foot of sand.
.....	100	....	S	
1940	100+	....	D,S	
.....	100	....	D,S	Water reported hard; contains excessive iron.
.....	51.2	8- 5-52	U	
1925	99.1	7-29-52	S	Aquifer, fine sand.
.....	39.1	7-29-52	U	
.....	41.5	8- 5-52	S	
1949	33.2	7-29-52	D	Aquifer,black silt.Very inadequate.
1920	58	....	S	Aquifer,clay. Water reported hard.
.....	17.5	7-23-52	D	
1941	Dry or caved	8- 5-52	S	
.....	Dry or caved	8- 5-52	S	
.....	5	....	D,S	Water reported to be of very poor quality.
.....	55.4	8- 5-52	S	
1920	110	....	S	Water reported unfit for human consumption.
1920	98.0	8- 5-52	S	Do.
8-28-52	.....	....	T	Hole refilled. See log.
.....	8	....	D,S	Aquifer, sand and gravel.
8-28-52	.....	....	T	Hole refilled. See log.
8-22-52	.....	....	T	Do.
8- 8-52	.....	....	T	Hole refilled. See log, chemical analysis.
.....	.....	....	T	Hole refilled. See log.
.....	100+	....	S	Water reported unfit for human consumption.
.....	.....	....	T	

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type
156-92 - Continued				
25aaa	David Enander	27	...	Dug
26abb	Steve Noeachek	70	36	Bored
26aca	USGS test 594	70	5	Drilled
26add	USGS test 593	135	5	...do...
26daa	J. Severson	64	24	Bored
35ddc	Vacant	90.3	20	...do...
157-91				
32aaa	USGS test 607	50	5	Drilled

Date completed	Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
1925	17.4	7-30-52	D,S	Aquifer, coarse gravel.
1930	60	....	S	Aquifer, fine sand. Water reported inadequate; high in nitrate.
9- 3-52	.....	....	T	Hole refilled. See log.
9- 3-52	.....	....	T	Do.
1919	11.9	7-29-52	U	Inadequate.
.....	39.2	7-30-52	S	
9-22-52	.....	....	T	Hole refilled. See log.

LOGS OF WELLS AND TEST HOLES IN THE STANLEY AREA, N. DAK.

156-91-4cbc
USGS test 606

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Clay, yellowish-gray	7	7
	Clay, medium-gray, silty, uniform. Appears to be lake deposits	55	62
	Till, medium-gray, sand; few pebbles	126	188
	Gravel, fine, and very coarse sand. Hard drilling	24	212
	Till (?), samples consist mostly of very coarse sand and carbonaceous clay	12	224
Fort Union formation			
	Shale, light-gray	6	230

156-91-4ccc1
USGS test 602

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Clay, gray	3	3
	Sand	1	4
	Clay, gray, and gravel	5	9
	Till, yellowish-gray	7	16
	Till, gray	38	54
	Sand, fine, and clay, gray. About 50% sand.	28	82
	Sand and gravel, cleaner than material from 54 to 82 feet	9	91
	Till, gray	55	146
Fort Union formation			
	Lignite	1	147
	Shale, light-gray, sandy	13	160

156-91-5aaa
USGS test 603

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Clay, yellowish-gray	16	16
	Till, yellowish-gray	25	41
	Sand, fine, clayey	15	56
	Till, gray. Boulders at 72 and 78 feet.	25	81
Fort Union formation			
	Lignite	1	82
	Shale, light-gray	5	87
	Lignite	3	90

156-91-11cdc
USGS test 609

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Till, pale yellowish-brown, sandy	27	27
	Till, medium-gray	55	82
	Till, moderate yellowish-brown	6	88
	Till, light-gray	43	131
Fort Union formation			
	Clay, light-gray, sandy	9	140

156-91-13baa
USGS test 608

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown	1	1
	Clay, gray	2	3
	Clay, grayish-white. Contains alkaline salts	4	7
	Till, yellowish-gray	4	11
	Till, gray; much sand and gravel	112	123
	Sand, and gravel, hard, drills like cemented gravel	12	135
Fort Union formation			
	Shale, light-gray	4	139
	Shale, dark-brown	1	140

156-91-16acb
USGS test 600

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil	1	1
	Till, yellowish-gray	18	19
	Till, light-gray	35	54
	Till, yellowish-gray	6	60
	Till, yellowish-gray	21	81
Fort Union formation			
	Shale, gray, sandy	9	90

156-91-16bbb
USGS test 601

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Till, yellowish-gray	42	43
	Till, light-gray, sandy	21	64
	Sand, medium; much clay	5	69
	Till, light-gray, sandy	33	102
	Till, yellowish-gray	24	126
	Till, gray, hard	11	137
Fort Union formation			
	Shale, light-gray	3	140

156-91-16cca
USGS test 599

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, brown	2	2
	Till, yellowish-gray	16	18
	Sand	2	20
	Till, yellowish-gray	18	38
	Sand and gravel	10	48
	Till, yellowish-gray	29	77
	Till, gray, harder than above	29	106
Fort Union formation			
	Shale, light-gray, sandy	9	115
	Shale, light-gray, clayey	30	145
	Shale, light-gray, hard	12	157
	Lignite	2	159
	Shale, light-gray, clayey	49	208
	Indurated rock, probably concretion	1	209
	Shale, light-gray, hard	39	248
	Shale, brown	2	250

156-91-20ddd
USGS test 568

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Till, yellowish-gray	20	21
	Sand ,and gravel	6	27
	Till, yellowish-gray	33	60
	Till, light-gray	6	66
Fort Union formation			
	Shale, light-gray	4	70

156-91-21cba2
Stanley No. 1 (supply well)
Log furnished by M and W Drilling Co.

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil	1	1
	Clay with cobbles (till)	13	14
	Sand, medium to coarse	4	18
	Gravel, fine, clayey	4	22
	Sand, medium to coarse; mostly shale fragments	8	30
	Sand, medium to coarse; mostly shale fragments, clayey	8	38
	Clay and sand	27	65
Fort Union formation			
	Clay, gray, tough	49	114
	Sand, clayey	4	118
	Clay, gray	35	153
	Clay, brown	7	160
	Clay, gray, sandy	10	170
	Sand, gray, clayey; hard and soft layers	5	175
	Sandstone, gray, fine	25	200

156-91-21cca1
USGS test 610

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, black	2	2
	Till, yellowish-gray	45	47
Fort Union formation			
	Shale, yellowish-gray	11	58
	Shale, light-gray	12	70

156-91-21cca2
USGS test 611

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	2	2
	Till, yellowish-gray	2	4
	Sand	3	7
	Till, yellowish-gray	42	49
Fort Union formation			
	Shale, yellowish-gray	5	54
	Shale, light-gray	6	60

156-91-22dcd
USGS test 549

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark yellowish-brown	3	3
	Till, yellowish-gray	25	28
Fort Union formation			
	Shale, light-gray	12	40

156-91-22ddc
USGS test 550

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown	1	1
	Clay, brown	2	3
	Sand, very coarse	2	5
	Gravel, very fine to coarse; average diameter about $\frac{1}{4}$ inch	5	10
	Clay, carbonaceous, dark-brown; contains bits of vegetation	4	14
Fort Union formation			
	Shale, light-gray	6	20

156-91-22ddd1
USGS test 551

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil	1	1
	Clay	2	3
	Sand, very coarse	2	5
	Till (?), yellowish-gray, much very coarse sand	5	10
	Till, yellowish-gray	5	15
	Till or lake clay, grayish-orange, contains small amounts of pebbles or sand (could also be weathered shale, more orange than oxidized till)	7	22
Fort Union formation			
	Shale, light-gray (streak of dark-brown clay and lig. from 24-26)	8	30

156-91-22ddd2
USGS test 552

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown	1	1
	Clay, brown	2	3
	Sand, fine to medium	4	7
	Till, yellowish-gray	13	20
	Till, yellowish-gray, much sandier than above	27	47
Fort Union formation			
	Shale, light-gray, sandy	3	50

156-91-23ccc
USGS test 553

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown	1	1
	Clay, yellowish-gray	2	3
	Sand, medium to coarse	2	5
	Sand, very coarse	3	8
	Gravel, very fine to coarse; average diameter about ¼ inch	8	16
	Till, yellowish-gray	58	74
Fort Union formation			
	Shale, brown	2	76
	Shale, light-gray	1	77
	Lignite	1	78
	Shale, light-gray	2	80

156-91-23ccd
USGS test 554

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown, sandy	1	1
	Clay, gray	2	3
	Sand, and gravel	5	8
	Till, yellowish-gray, sandy	80	88
Fort Union formation			
	Lignite	1	89
	Shale, light-gray, sandy	11	100

156-91-27bbb
USGS test 605

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Clay, light-gray, and gravel	2	3
	Sand	1	4
	Till, yellowish-gray, very gravelly	16	20
	Till, yellowish-gray. Streak of carbonaceous clay from 44 to 46 feet	41	61
Fort Union formation			
	Shale, light-gray	11	72
	Lignite	2	74
	Shale, light-gray, hard	25	99
	Lignite	2	101
	Shale, light-gray, hard	12	113
	Lignite	1	114
	Shale, light-gray, hard	14	128
	Shale, light-gray, sandy	32	160
	Sandy shale or sand, light-gray (about 50% sand)	57	217
	Shale, gray, clayey	24	241
	Lignite and carbonaceous clay	2	243
	Shale, light-gray, clayey	37	280

156-91-27bcc
USGS test 555

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil	1	1
	Clay, gray	2	3
	Sand, very coarse	7	10
	Gravel, medium	7	17
	Till, light-olive gray, much gravel	28	45
Fort Union formation			
	Sandstone, very fine, very friable, yellowish-gray	12	57
	Clay, light-gray	3	60

156-91-27cbb
USGS test 556

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, brown, sandy	1	1
	Clay, brown	2	3
	Gravel	2	5
	Cobbles; average diameter 2 to 3 inches	5	10
	Sand and gravel	4	14
	Till, yellowish-gray, sandy	64	78
Fort Union formation			
	Shale, light-gray	12	90

156-91-27ccb
USGS test 557

Formation : Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift		
Soil	1	1
Clay	3	4
Sand, very coarse, and gravel	6	10
Gravel, very fine to coarse	6	16
Till, medium-gray	12	28
Till, yellow, gray, and orange (streaked); very sandy. Appears to be a weathered zone. Shows evidence of greater weathering than in the overlying till; contains limonitic nodules	21	49
Fort Union formation		
Shale, light-gray	11	60

156-91-27ccc
USGS test 558

Alluvium and glacial drift		
Sand and gravel	5	5
Gravel	4	9
Till, medium-gray	13	22
Gravel	4	26
Till, medium-gray	3	29
Fort Union formation		
Shale, light-gray. Core, about 5% recovery	11	40

156-91-28aba
Stanley No. 2 (supply well)
Samples furnished by C. A. Simpson & Son

Glacial drift		
Till, yellowish-gray	60	60
Fort Union formation		
Clay, yellowish-gray, silty	10	70
Clay, light-gray	10	80
Silt, pale brown	10	90
Silt, yellowish-gray	20	110
Silt, dark-brown, carbonaceous	10	120
Silt, light-gray	10	130
Clay, dark-brown, carbonaceous	10	140
Clay, light-gray, silty	10	150
Sand, very fine, clayey, loosely consolidated.	12	162
Sand, very fine to fine, relatively clean, loosely consolidated	11	173
Sand, very fine, clayey	27	200

156-91-28bac1
USGS test 598

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Till, yellowish-gray, sandy	71	72
Fort Union formation			
	Shale, light-gray	20	92
	Lignite	2	94
	Shale, light-gray	23	117
	Sand and sandy clay, light-gray, and thin layers of hard sandstone	73	190
	Sand, cleaner than from 117 to 190, but samples still contain much clay. Washed sample obtained from pits consisted mostly of medium grained, angular sand, about 75% or more quartz; remainder consisted mainly of basic igneous rock fragments	46	236
	Lignite	1	237
	Shale, light-gray. Core obtained from 240 to 250 feet with about 60% recovery. Consisted mostly of light-gray clay-siltstone and one foot of very fine, dirty sandstone.	37	274
	Lignite	1	275
	Shale, light-gray, with hard layers	75	350

156-91-28bac2
Stanley No. 3

(Same location as USGS test 598, log furnished by C. A. Simpson & Son, Bisbee, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Clay, yellow, sandy	76	76
Fort Union formation			
	Clay or shale, gray	32	108
	Shale, green	6	114
	Shale, gray	4	118
	Shale, gray, sandy	42	160
	Sandstone, fine	2	162
	Shale, gray, sandy	8	170
	Sandstone, fine, hard	1	171
	Shale, gray, sandy	14	185
	Sandstone, fine, hard	3	188
	Shale, gray, sandy	17	205
	Sandstone, hard	2	207
	Shale, gray, sandy	28	235
	Shale, brown, sandy	3	238
	Shale, gray	1	239

156-91-28ccc
USGS test 604

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil	1	1
	Sand, medium to coarse	12	13
	Till, yellowish-gray	32	45
Fort Union formation			
	Shale, yellowish-gray	95	140
	Shale, light-gray	20	160
	Sand, light-gray, very fine to fine, much clay	52	212
	Lignite	2	214
	Clay and sand, very fine, light-gray	23	237
	Lignite	3	240
	Clay, sandy, gray. Indurated rock at 243 feet	8	248
	Shale, light-gray, not sandy	16	264
	Lignite	3	267
	Shale, light-gray, with hard layers at 293 feet and 298 feet	44	301
	Lignite	2	303
	Shale, light-gray	12	315
	Lignite	2	317
	Shale, light-gray	11	328
	Lignite	3	331
	Shale, light-gray	19	350

156-91-29bbb
USGS test 569

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Till, yellowish-gray, sandy	45	46
	Till, grayer than above	10	56
	Till, yellowish-gray, sandy	24	80
Fort Union formation			
	Clay, yellowish-gray	5	85
	Clay, very light purplish-gray, sandy	5	90
	Clay, yellowish-gray, sandy	13	103
	Clay shale, light-gray, alternating with layers of sandy clay	92	195
	Clay, very sandy, light-gray	29	224
	Sandstone, very fine, light-gray, dirty	4	228
	Sand,very clayey, light-gray	18	246
	Sandstone, fine, dirty	3	249
	Sand, very clayey (50% or more clay)	41	290
	Clay, light-gray, sandy	5	295
	Clay, gray	21	316
	Lignite	2	318
	Clay, light-gray	9	327
	Clay, brownish-gray	8	335
	Lignite	3	338
	Clay, gray	12	350

156-91-32bad
USGS test 595

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Sand	5	5
	Sand and gravel	7	12
	Till, yellowish-gray	26	38
	Till, gray	15	53
Fort Union formation			
	Shale, light-gray, sandy	27	80

156-91-32bda1
USGS test 596

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Sand	4	4
	Gravel	10	14
	Till, yellowish-gray	14	28
	Till, medium-gray	28	56
Fort Union formation			
	Shale, light-gray	14	70

156-91-32bda2
USGS test 597

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil and slope wash, dark-brown, clayey	3	3
	Till, yellowish-gray	6	9
Fort Union formation			
	Shale, light-gray, clayey	3	12
	Shale, light-gray, sandy	8	20

156-91-33aca
USGS test 564

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown	2	2
	Clay, sand, and gravel	3	5
	Sand, very coarse	4	9
Fort Union formation			
	Shale, clayey, yellowish-gray	11	20

156-91-33bad
USGS test 563

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, brown, sandy	1	1
	Clay, light-tan	1	2
	Sand	5	7
	Till, yellowish-gray	49	56
Fort Union formation			
	Shale, light-gray	4	60

156-91-33bbc
USGS test 566

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-gray, clayey	1	1
	Clay, moderate yellow, uniform. Probably lake deposits	14	15
	Sand, medium to coarse	7	22
Fort Union formation			
	Shale, light-gray	8	30

156-91-33bbd
USGS test 565

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown, clayey	3	3
	Clay, yellowish-gray, with few pebbles	6	9
	Sand, medium to coarse	9	18
Fort Union formation			
	Shale, light-gray, sandy	2	20

156-91-33bda2
USGS test 562

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown, clayey	1	1
	Clay, sand and gravel	2	3
	Gravel, fine to coarse; average size about 3/8 inch. Consists of limestone (about $\frac{1}{2}$); granite ($\frac{1}{4}$); basic igneous, concretions, and shale ($\frac{1}{4}$)	18	21
Fort Union formation			
	Shale, light-gray, sandy	29	50

156-91-33cab
USGS test 567

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown	1	1
	Till, yellowish-gray	32	33
	Sand, fine	7	40
	Sand or sandy clay, yellowish-gray, soft	15	55
	Sand, coarser than from 40 to 55	5	60
Fort Union formation			
	Shale, dark-gray, clayey	20	80

156-91-33dad
USGS test 561

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, brown	1	1
	Till, yellowish-gray	35	36
	Till, medium-gray	3	39
	Sand and gravel	1	40
	Till, medium-gray	38	78
Fort Union formation			
	Shale, gray, sandy	32	110
	Shale, yellowish-gray	19	129
	Shale, light-gray, clayey	11	140

156-91-34bbb
USGS test 559

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil and slope wash	3	3
	Clay, tan	1	4
	Sand and gravel	4	8
Fort Union formation			
	Shale, light-gray	12	20

156-91-34cbb
USGS test 560

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift			
	Soil, dark-brown, sandy	1	1
	Clay, tan	2	3
	Sand, coarse	10	13
	Till, light-gray	9	22
Fort Union formation			
	Sand, mostly medium-grained, relatively well sorted and clean	20	42
	Shale, light-gray	8	50

156-92-20ddd
USGS test 591

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Clay, yellowish-gray	3	3
	Sand	6	9
	Till, yellowish-gray	25	34
	Till, gray	36	70
	Till, yellowish-gray	30	100
Fort Union formation			
	Shale, yellowish-gray	2	102

156-92-22ccc
USGS test 590

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Till, yellowish-gray	17	18
	Till, gray	14	32
	Sand, coarse	6	38
	Till, gray	46	84
	Till, yellowish-gray	2	86
Fort Union formation			
	Clay, light-gray	4	90
	Clay, yellowish-gray	10	100

156-92-23ccc
USGS test 589

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Till, light yellowish-gray	34	35
	Sand, fine, clayey	6	41
	Clay, gray	5	46
	Sand, clayey	4	50
	Clay, dark-gray	6	56
	Sand, clayey	8	64
	Till, gray	38	102
	Till, yellowish-gray	20	122
Fort Union formation			
	Shale, yellowish-gray, sandy	8	130

156-92-23ddd
USGS test 571

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Till, yellowish-gray	30	31
	Sand, medium to coarse	4	35
	Gravel, medium	5	40
	Gravel, fine to coarse; average diameter about ¼ inch	12	52
	Till, gray	5	57
	Gravel, medium; average diameter about 3/8 inch	11	68
	Till, gray and tan	7	75
	Sand, very fine, brown, streaked with black carbonaceous zones	5	80
	Clay, dark-brown to black (as in soil), carbonaceous. Pieces of carbonized wood	5	85
	Till, gray, very sandy	16	101
	Till, yellowish-gray	7	108
	Till, medium-dark-gray and brown	36	144
Fort Union formation			
	Clay, light-gray, sandy	16	160

156-92-24cbb
USGS test 592

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Till, yellowish-gray, sandy	18	19
	Till, medium-gray, sandy	10	29
	Sand, fine to medium	7	36
	Till, medium-gray	49	85
	Till, pale yellowish-gray	23	103
	Till, medium-gray, gravelly	22	130
	Till or bedrock, medium-gray, sandy clay. Few pebbles	37	167
Fort Union formation			
	Shale, light-gray, moderately sandy	5	172

156-92-24ddd
USGS test 570

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Clay, yellowish-gray, sandy	2	3
	Sand	3	6
	Till, yellowish-gray, sandy	22	28
	Till, gray	90	118
	Till, yellowish-gray	8	126
	Till, gray	28	154
Fort Union formation			
	Shale, yellowish-gray	6	160

156-92-26aca
USGS test 594

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Clay, yellowish-gray, lake deposits	12	12
	Till, yellowish-gray	3	15
	Sand	1	16
	Till, yellowish-gray	26	42
	Till, gray	11	53
	Gravel, fine	4	57
	Till, gray	13	70

156-92-26add
USGS test 593

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, dark-brown	1	1
	Clay, yellowish-gray, lake deposit	13	14
	Till, yellowish-gray, clayey	14	28
	Till, gray	48	76
	Till, yellowish-gray, bouldery	38	114
Fort Union formation			
	Clay, yellowish-gray, sandy	21	135

157-91-32aaa
USGS test 607

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift			
	Soil, black	2	2
	Clay, yellowish-gray	6	8
	Till, yellowish-gray	34	42
Fort Union formation			
	Shale	8	50

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