Ground Water Branch

GROUND WATER IN THE WYNDMERE AREA
RICHLAND COUNTY, NORTH DAKOTA

BY

P. E. DENNIS, P. D. AKIN, AND SUZANNE L. JONES

NORTH DAKOTA GROUND WATER STUDIES NO. 13

PREPARED IN COOPERATION BETWEEN THE GEOLOGICAL SURVEY
U. S. DEPARTMENT OF THE INTERIOR; THE NORTH DAKOTA STATE
WATER CONSERVATION COMMISSION; AND THE NORTH DAKOTA STATE
GEOLOGICAL SURVEY

DECEMBER 1949

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ABSTRACT

This is a progress report on the study of the geology and ground water resources of Richland County, North Dakota, being made by the U. S. Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the State Geological Survey. The area covered by this report includes chiefly the four townships nearest the village of Wyndmere.

Information regarding the geologic formations in the area was obtained from 37 test holes drilled by the U. S. Geological Survey during the course of the invevtigation and from logs of a few privately owned wells.

The geologic units found in the area are as follows: the surficial Lake Agassiz deposits of Pleistocene age which in this area consist of deltaic silt and fine sand; Pleistocene till and associated glacioaqueous deposits; Cretaceous shale and shaly sandstone; and pre-Cambrian crystalline igneous and metamorphic rocks which are locally termed "granite."

Sands of the Sheyenne delta of Lake Agassiz range up to 92 feet in thickness and are tapped by most of the farm wells in the area. Estimates of transmissibility of the sands made from laboratory permeability tests range from 1,040 to 9,600 gallons a day per foot, with an average of 2,700 gallons a day per foot. It is estimated that it should be possible to develop supplies on the order of 30,000 to 70,000 gallons a day from

adequately spaced individual wells penetrating these deposits at several locations in the Wyndmere area.

A part of the deltaic materials at most localities, and the entire thickness of the Lake Agassiz deposits in some localities, are too fine grained to serve as aquifers. The southern part of the village of Wyndmere lies within one of these areas in which satisfactory wells cannot be obtained in the Lake Agassiz deposits.

Till and associated glacioaqueous deposits underlie the Lake Agassiz deposits and averaged 177 feet in thickness in the three test holes which completely penetrated them. The till itself will not effectively transmit water, but glaciofluvial and glaciolaustrine sands and gravels found irregularly distributed within and associated with the till may be sufficiently permeable and interconnected so as to cause the unit as a whole to act as a weak aquifer. Many farm wells in the southeastern part of the area derive water from these glacioaqueous deposits. Several such deposits were encountered during the test drilling, the most promising of which, for the development of water supplies, was that found in USGS test 11 in Wyndmere.

Shales and siltstones were encountered in USGS test 3 at Wyndmere at depths between 240 and 500 feet below the land surface. Their stratigraphic position and lithologic character and the presence of fish scales suggest that the rocks represent a part of the Benton shale of Cretaceous age. Records of wells indicate that the formation is generally present in the Wyndmere area and westward. It becomes thinner eastward and is present at least as far as Barney where USGS test 13 penetrated it between the depths of 250 and 360 feet. It was apparently absent in USGS test 14 near Mooreton. The formation is generally not water bearing, although some of the weak flows of rather highly mineralized water, which came from wells reported to be 250 to 350 feet deep, may come from beds of silt and fine sand in this formation.

About 40 feet of shaly sandstone was encountered in USGS test 3 and 13 just below the Cretaceous shale, and about the same amount of sand in USGS test 14 between the drift and the granite. Flowing wells are obtained at this horizon, which is about 500 feet below the land surface, throughout most of the Wyndmere area. The quality of the water from all wells of this depth is rather uniform and is similar in both composition and concentration to waters from the Dakota sandstone (Cretaceous) in adjacent areas. For these reasons the aquifer is generally considered to be a facies of the Dakota sandstone. In the Wyndmere area the flows are very weak to moderate, and the water is so highly mineralized as to be generally unfit for drinking and culinary purposes.

The basement rock of the area consists of undifferentiated crystalline igneous and metamorphic rocks which locally are termed "granite." In the three USGS test holes which reached it, and in the Ruddy Bros. No. 1 oil test, decomposed "granite" was encountered at 550, 406, 410, and 275 feet below the land surface. No wells in the area derive their water from the "granite" and it is generally considered useless to drill deeper when it is reached.

Chemical analyses of waters from wells in the area show three distinct types of water. Water from the sands of the Sheyenne delta is the least highly mineralized, but is much harder than the other waters. The flowing well water from the deep aquifers at or near the base of the Cretaceous shale is highly mineralized, containing about 3,000 parts per million or more of dissolved solids. The principal mineral constituents are sodium salts, however, and the waters are comparatively soft. Waters from the aquifers at intermediate depth in the glacio-aqueous materials associated with the till are intermediate in quality, as regards both dissolved solids and hardness.

INTRODUCTION

Scope and purpose of the investigation

This is a progress report on the study of the geology and ground-water resources of Richland County, North Dakota, being made by the U. S. Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the State Geological Survey. The purpose of these general studies is 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, industrial, and others. At present, the most critical need is for adequate and perennial water supplies for many towns and small cities throughout the State wishing to construct municipal water-supply and sewage-disposal systems. For this reason, the county-wide studies are being started in the vicinity of those towns requesting the help of the State Water Conservation Commission and the State Geologist in locating suitable ground-water supplies. Progress reports, such as this one, are being released before the completion of the general studies so that the data may be available to the towns and to others as soon as possible for use in connection with immediate problems. The area described in this report comprises chiefly the four townships nearest the village of Wyndmere (Tps. 132 and 133 N., Rs. 51 and 52 W.), as that area is of the most immediate interest to the community in its search for an adequate water supply.

Acknowledgments

The investigation was made under the general supervision of A. N. Sayre, Geologist in Charge of the Ground Water Branch, Water Resources Division, United States Geological Survey. The field work and test drilling were done under the direct supervision of P. E. Dennis, District Geologist, during the fall of 1947 and summer of 1948. Most of the well-inventory work was done by Robert Aaker and Gordon Andreason. In addition, well records obtained in 1939 by the county assessors as part of a State-wide well inventory under the Works Projects Administration were available, and many of these records are included in this report. Thirty-seven test holes were drilled by Ray Danielson, George McMaster, Keith Hanson, and Gilbert Rupp. Work was facilitated by the excellent cooperation of all residents and particularly by the interest and assistance of Mayor Johnson of Wyndmere. The assistance of D. H. Pfeiffer in examining cuttings from three of the test holes is gratefully acknowledged.

Previous investigations

Previously no studies have been made specifically of the geology and ground-water resources of the Wyndmere area. Simpson[1/] discussed the ground-water resources of Richland County in general terms and listed typical wells in the area. Upham[2/] discussed the area in his treatment of the Sheyenne delta of glacial Lake Agassiz. Bulletins of the

1/ Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, pp. 208-214, 1929.
2/ Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, pp. 315-317, 1896.

North Dakota Geological Survey have been of great value as background material, especially Bulletin 11[3] which lists many data on the quality of ground-water supplies in North Dakota.

Location and general features of the area

The area covered by this report includes Tps. 132 and 133 N., Rs. 51 and 52 W. Some data from T. 132 N., R. 50 W., are also included, and the log of the Ruddy Bros. No. 1 oil test in T. 132 N., R. 48 W., was studied in preparing the report.

The principal town, near the center of the area, is Wyndmere. It is about 6 miles east of the Sargent County line and about 25 miles west of Wahpeton. It is served by the Fergus Falls branch of the Northern Pacific Railroad and the Minnesota Division of the Minneapolis, St. Paul, and Sault Ste. Marie Railroad, and is at the junction of State Highways 13 and 18. According to the U. S. Bureau of the Census, the population of Wyndmere was 499 in 1940. The elevation is about 1,060 feet above sea level.

Farming is the principal occupation in the area, corn and wheat being the major crops. Wyndmere serves as a shopping and trading center for the farm community.

The climate is characterized by cold winters and warm summers. Winter temperatures of 20° to 30° below zero are common, and summer temperatures reach 100° or higher. The mean annual temperature at Wahpeton is 42.4°. Eighty percent of the mean annual precipitation of 20.67 inches occurs from April through September (see fig. 7).

3/ Abbott, G. A., and Voedisch, F. W., The municipal ground-water supplies of North Dakota: North Dakota Geol. Survey Bull. 11, 1938.

Physiographic features

The area is part of the Western Young Drift section of the Central Lowland province[4/] and is in the Red River Valley area described by Simpson[5/] (see fig. 1). The Red River Valley is a broad, flat glacial lake plain, modified chiefly by low beach ridges and deltas. The Wyndmere area is in the south-central part of one of the larger deltas, known as the Sheyenne delta (see fig. 2).

The Sheyenne delta is one of the largest formed in the lake and covers an area of about 800 square miles. Its surface is an almost featureless plain sloping gently eastward. Its northern and eastern margins are marked by a steep slope or escarpment which rises as much as 75 feet above the lowest part of the Red River Valley plain. The escarpment decreases in height to the south and is almost indiscernible along the highway between Wyndmere and Wahpeton. It has been variously interpreted as an ice-contact face[6/] and a wave-cut slope.[7/]

A succession of beaches formed along the shores of Lake Agassiz at its various stages trend in a general north-south direction across the delta. However, the beaches are not as prominent across the delta as they are in some other regions, and Leverett does not show them on his map.[8/] The Herman beach in the Wyndmere area and the Tintah beach east of Barney (fig. 2) appear to be wave-cut rather than wave-built features, and the materials underlying them are identical with the delta materials elsewhere.

4/ Fenneman, N. M., Physiography of eastern United States, p. 559, McGraw-Hill Book Co. Inc., 1938.
5/ Op. cit., p. 4.
6/ Leverett, Frank, Quaternary geology of Minnesota and parts of adjacent States: U. S. Geol. Survey Prof. Paper 161, pp. 126-127, 1932.
7/ Upham, Warren, op. cit., p. 316.
8/ Op. cit., fig. 17., p. 124.

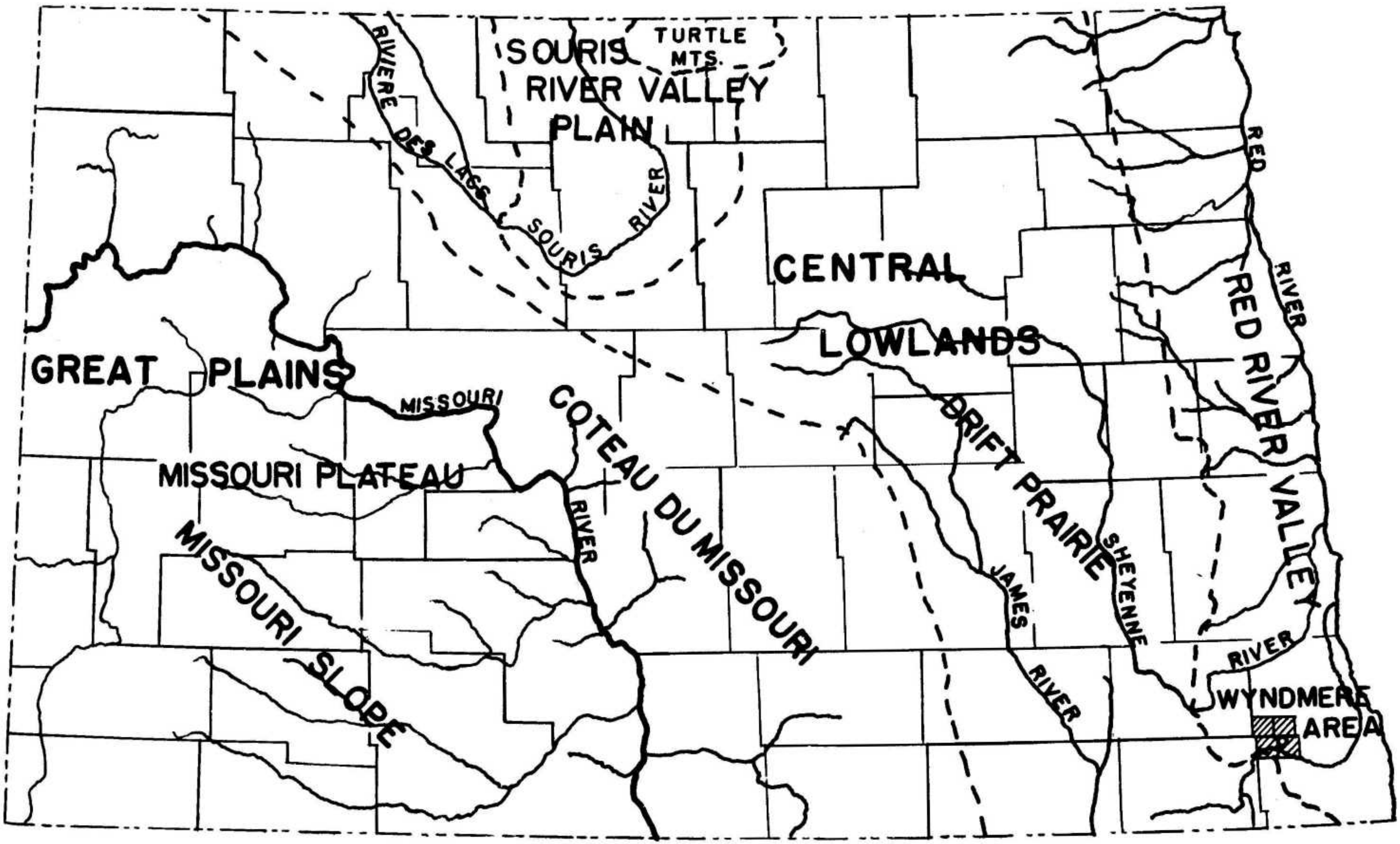

FIGURE I. MAP SHOWING LOCATION OF THE WYNDMERE AREA WITH RESPECT TO PHYSIOGRAPHIC FEATURES IN NORTH DAKOTA (AFTER SIMPSON)

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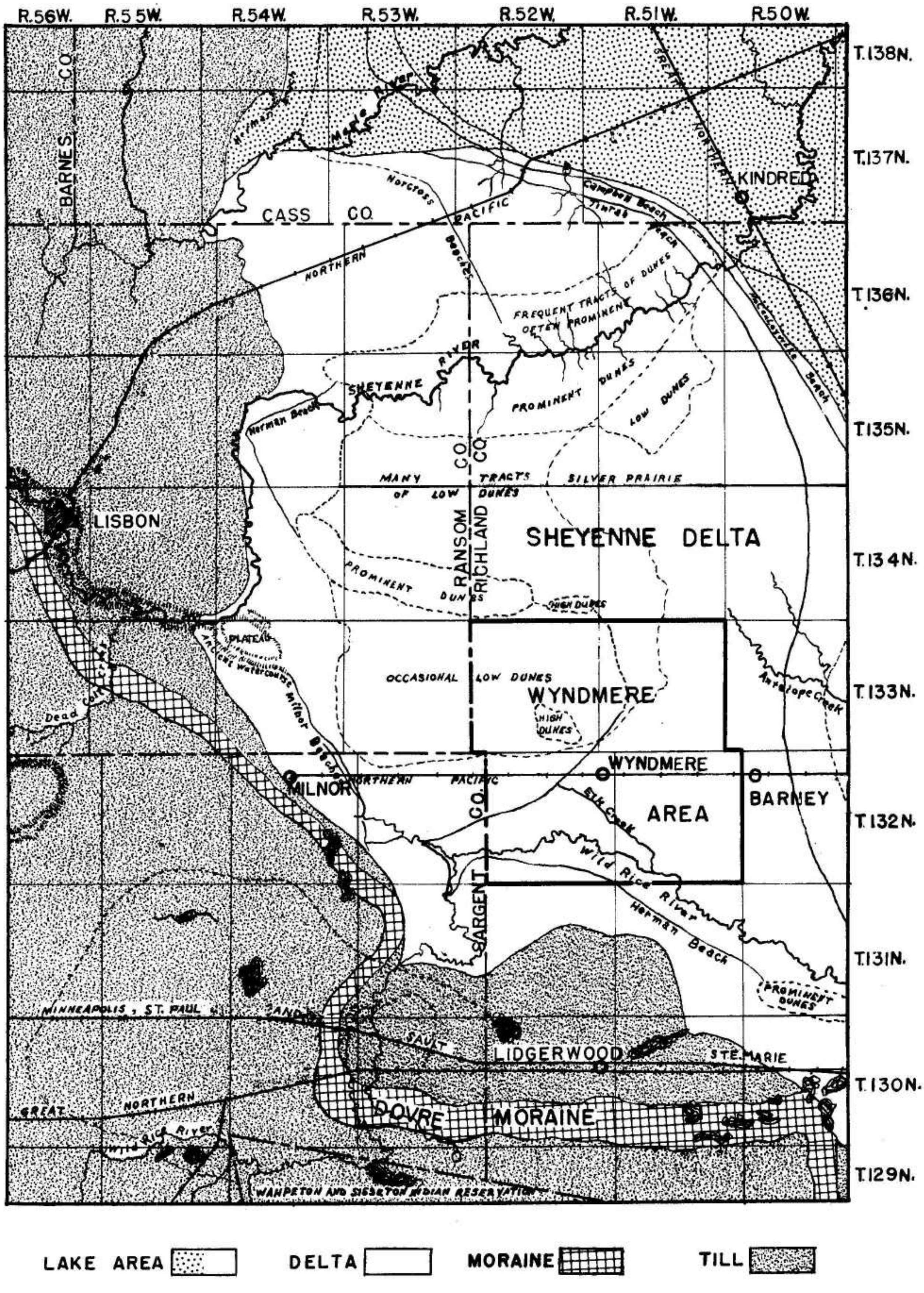

FIGURE 2. MAP SHOWING GENERAL GEOLOGY IN THE VICINITY OF THE WYNDMERE AREA (AFTER UPHAM).

The Sheyenne and Wild Rice Rivers are the main streams draining the delta. Tributaries are few and many of them are wholly or partly intermittent. The drainage, having been developed since the last glaciation, is youthful and is not yet well established on the postglacial surface.

In the Wyndmere area the principal stream is the Wild Rice River. Elk Creek and an unnamed intermittent stream are its main tributaries. The channel of the Wild Rice River ranges from 15 to 30 feet in width and its flood plain from a sixth to a third of a mile. The flood plain is about 10 feet above the water level in the river. Because the gradient is low, the river wanders across the valley floor in numerous meanders, and many meander scars and sloughs are present along its course. It is incised about 40 feet into the delta plain and the summit levels of its bluffs are accordant with the plain. The bluffs are gullied and the longer and deeper gullies are occupied by intermittent streams. Elk Creek and the unnamed intermittent tributary have carved valleys which are about two-thirds as wide as that of the Wild Rice River. Meander scars and sloughs along these tributaries are not as well developed as they are along the main stream.

Sand dunes are present in the northwestern part of the area, producing a somewhat hilly topography, although the maximum relief is less than 20 feet. Smaller dune areas are also present west and north of Wyndmere. The areas in which sand dunes are most prominently developed in the Wyndmere area are shown in figure 3. The chief sand-dune areas of the entire delta as mapped by Upham are shown in figure 2.

GEOLOGY AND OCCURRENCE OF GROUND WATER

General

Stratigraphic units

Information concerning the geologic formations in the area was obtained principally from 37 test holes drilled by the U. S. Geological Survey during the course of the investigation and from logs of a few privately owned wells. The test holes ranged from 27 to 570 feet in depth. Eighteen holes about 100 feet in depth were drilled to obtain information concerning the sands of the Sheyenne delta of Lake Agassiz. Three of the test holes were drilled into the "granite"; they were 410, 420, and 570 feet in depth, respectively. The other test holes averaged about 200 feet in depth and penetrated the till to varying depths. Locations of the test holes in the area are shown in figure 3, and logs are given on pages 42-59.

The stratigraphic nomenclature used in this report conforms generally to that established by Dennis, Akin, and Worts 9/ for Cass and Clay Counties, North Dakota and Minnesota. The following is the stratigraphic section for the Wyndmere area:

Cenozoic
- Quaternary system
  - Pleistocene series
    - Wisconsin stage
      - Lake Agassiz deposits
        - Silt and sand of the Sheyenne delta
      - Till and associated glacioaqueous deposits
    - Pre-Wisconsin (?) stage
      - Older lake clay and drift

Mesozoic
- Cretaceous system
  - Upper Cretaceous series
    - Benton (?) shale
    - Dakota (?) sandstone

Pre-Cambrian
- "Granite"

9/ Dennis, P. E., Akin, P. D., Worts, G. F., Jr., Geology and ground-water resources of parts of Cass and Clay Counties, N. Dak. and Minn., U. S. Geol. Survey mimeographed report, pp. 16-17, 1949.

The surficial sediments in the Wyndmere area consist of the silt and sand of the Sheyenne delta of Lake Agassiz. This unit is thought to be the time equivalent of the lower or clay unit[10] of the Lake Agassiz deposits and to grade into that unit east of the delta. The equivalent of the upper or silt unit of the Lake Agassiz deposits is not found in the Wyndmere area and presumably was not deposited there, because the entire area lies above the elevation of the Campbell shore line, which represents the maximum extent of the lake during the deposition of the silt unit. Near Wyndmere the delta materials consist largely of fine to very fine sand, silt, and clay. They average about 104 feet in thickness.

The Lake Agassiz deposits are underlain by till and associated glacioaqueous deposits. The till consists largely of clay and silt mixed with varying proportions of shale pebbles. Interbedded with the till are lenticular and usually small bodies of poorly to moderately well assorted glacioaqueous sand and gravel. Some parts of this unit, especially the lower part, consist of clay and silt with very few enclosed pebbles, and it is possible that older lake clay and interbedded drift may be included. The whole unit averages about 120 feet in thickness.

The till and associated glacioaqueous deposits are underlain by siltstone and shale containing fish scales which may represent the Benton shale of upper Cretaceous age. In the two holes which penetrated it, 110 and 260 feet, respectively, of this formation was encountered. About 40 feet of shaly sandstone and sandy shale underlie the Benton (?) formation, and it is thought that this may be the Dakota sandstone.

Underlying the Cretaceous rocks in the Wyndmere area is highly decomposed crystalline rock ("granite") of probable pre-Cambrian age.

10/ Dennis, P. E., Akin, P. D., and Worts, G. F., Jr., op. cit., pp. 16-17.

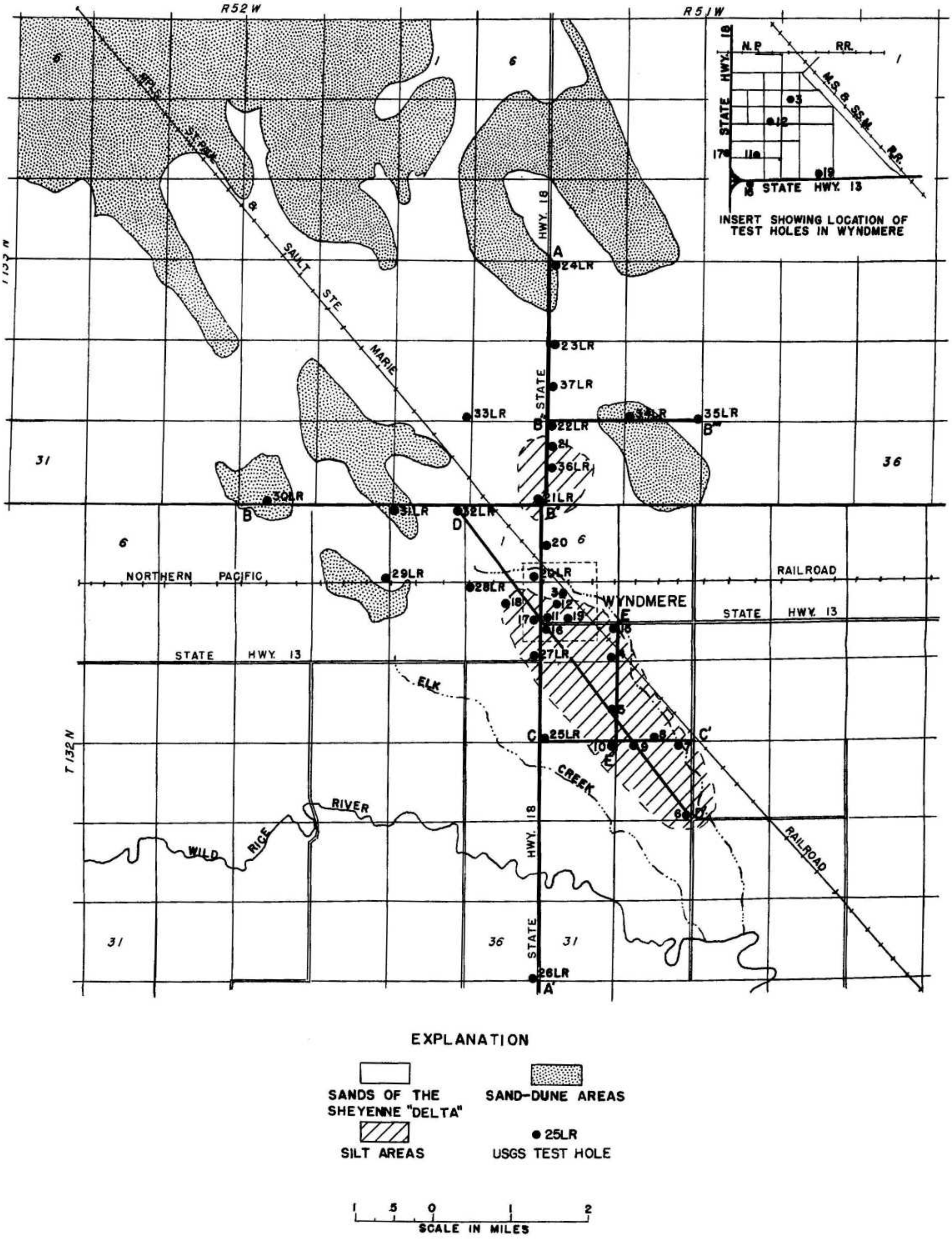
R52W
R51W
T132N
STATE HWY. 18
N.P.
RR.
M.S. & S.S.M.
R.R.
STATE HWY. 13
INSERT SHOWING LOCATION OF TEST HOLES IN WYNDMERE
MPLS. ST. PAUL & SAULT STE MARIE
HWY. 18
STATE
A
24LR
23LR
37LR
33LR
35LR
B
22LR
B'''
21
36LR
21LR
30LR
31LR
32LR
B'
D
20
29LR
NORTHERN PACIFIC
RAILROAD
20LR
28LR
WYNDMERE
STATE HWY. 13
E
27LR
ELK
CREEK
C
25LR
C'
E'
D'
RIVER
WILD RICE
RAILROAD
26LR
A'
EXPLANATION
SANDS OF THE SHEYENNE "DELTA"
SAND-DUNE AREAS
SILT AREAS
● 25LR
USGS TEST HOLE
SCALE IN MILES

Figure 4 is a geologic section along State Highway 13 east of Wyndmere, showing the stratigraphy as determined from the logs of three of the deeper Geological Survey test holes and the Ruddy Bros. No. 1 oil test.

Hydrologic concepts

An "aquifer" is any rock formation or stratum that will yield water in sufficient quantity to be of importance as a source of supply.[11]

The amount of water that can be stored in an aquifer is measured by the porosity of the rock material. The unconsolidated rocks such as clay, sand, and gravel are generally more porous than consolidated rocks such as sandstone and limestone, although in some areas the consolidated rocks are highly porous. The "specific yield" (effective porosity or water-yielding capacity) of a rock is generally somewhat less than its total porosity because some water is held in the pore spaces by molecular forces and cannot be removed by gravity drainage.

If the water in an aquifer is not confined by impervious strata above, the water is said to occur under water-table conditions. In this case water may be obtained from storage in the aquifer by lowering the water level, resulting in gravity drainage, and the specific yield is some large fraction of the porosity and in coarse-grained materials may approach very closely the total porosity. If the water is confined in the aquifer by an overlying impermeable stratum, however, so that the water rises above the top of the aquifer under hydrostatic pressure, the water is said to occur under artesian conditions. In this case the water will be yielded as the water

11/ Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, p. 52, 1923.

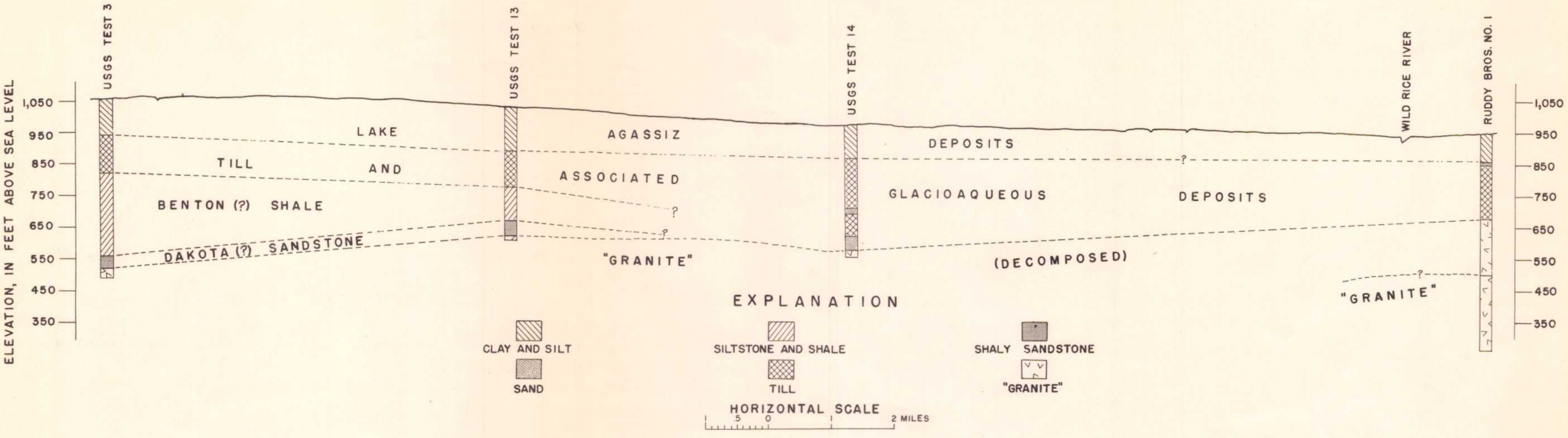

FIGURE 4. — GEOLOGIC SECTION ALONG STATE HIGHWAY 13 EAST OF WYNDMERE, SHOWING THE GENERAL STRATIGRAPHY OF THE AREA.

level in a well is lowered, but the aquifer remains saturated and the water is yielded because of its own expansion and because of the compression of the aquifer due to the lowered pressure, rather than by gravity drainage. The water-yielding capacity is called the "coefficient of storage" and is generally much smaller than the specific yield of the same material when drained by gravity.

If the pore spaces are large and interconnected, as they commonly are in sand and gravel, the water is transmitted more or less freely, and the rock is said to be permeable; but if the pore spaces are very small, as they are in clay, the water is transmitted very slowly or not at all, and the rock is said to be impermeable.

There are, then, two fundamental physical properties of an aquifer that largely control the movement of water through it, the specific yield or coefficient of storage and the permeability. The specific yield may be defined as the amount of water, expressed as a fraction of a cubic foot, that will drain by gravity from a cubic foot of saturated material. The coefficient of storage is 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 an artesian aquifer having a base 1 foot square, when the water level falls 1 foot.

The permeability of a rock is measured by the "coefficient of permeability" or by the "coefficient of transmissibility," the latter being the average permeability multiplied by the thickness of the aquifer. The coefficient of transmissibility is expressed in gallons per day per foot and 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 unit hydraulic gradient. Likewise, it may be defined as the number of gallons of water that will pass in 1 day through a vertical strip of the aquifer 1 mile wide under a hydraulic gradient of 1 foot per mile.

Essentially all ground water of economic importance is in process of movement through the ground from a place of intake or recharge to a place of disposal or discharge. Velocities of a few hundred feet a year probably are most common in aquifers under natural conditions, though the range is from nearly zero to many thousands of feet a year.

Ground-water discharge may occur by direct evaporation from the soil surface and by transpiration by plants in areas where the water table is very near the surface, or by seepage to streams or other surface-water bodies.

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 by the water is dependent upon the kind of soluble materials present in the aquifer and the length of time the water is in contact with them. Therefore, the waters that have been underground longest and have traveled the greatest distances are commonly more highly mineralized than those that are relatively near the recharge areas.

In the Wyndmere area, the sands of the Sheyenne delta, the glacio-aqueous deposits associated with the till, and the Dakota (?) sandstone are the only water-bearing units of importance. These units and the occurrence of ground water in them are discussed in the following sections.

Lake Agassiz deposits

During the waning stages of the Wisconsin glaciation, a marginal glacial lake known as Lake Agassiz was formed in the northward-sloping Red River Valley. Sediments derived mainly from glacial till were deposited in this lake directly from the melting ice front and by streams fed by glacial meltwater. The deposits laid down in the deeper water consist mainly of clay, and coarser material was concentrated along the shores to form the present beach ridges, bars, deltas, and other shore features. Irregularities of the former land surface were filled in and partially or completely obscured by this blanket of sediment. The Wyndmere area lies in the south-central part of one of the largest of the deltas formed in the lake, and the character and water-bearing properties of the deltaic materials can best be understood in the light of the lake history insofar as it has been worked out.

The history of Lake Agassiz has been studied and described by Upham,[12/] Tyrell,[13/] Johnston,[14/] Leverett,[15/] and Nikiforoff.[16/] These authors are not in complete agreement concerning the history of the lake, and much additional work will have to be done before the complete story is known. The following brief summary utilizes factual data and interpretations from all these authors, coordinated in the light of data obtained during the present study.

12/ Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1896.

13/ Tyrell, J. B., The genesis of Lake Agassiz: Jour. Geology, vol. 8, pp. 811-815, 1896.

14/ Johnston, W. A., The genesis of Lake Agassiz: A confirmation: Jour. Geology, vol. 24, pp. 625-658, 1916.

15/ Leverett, Frank, Quaternary geology of Minnesota and parts of adjacent States: U. S. Geol. Survey Prof. Paper 161, 1932.

16/ Nikiforoff, C. C., The life history of Lake Agassiz: Alternative Interpretation: Am. Jour. Sci., vol. 245, pp. 205-239, April 1947.

The ice appears to have melted back at an early date in the area southwest of Wyndmere, and the local Milnor beaches were formed at an elevation 20 to 25 feet above the highest beaches that extend entirely around the lake (Herman beaches). The northeastern shore of this small ancestor of Lake Agassiz probably was formed by the ice and its exact position is not known, although it probably was northeast of the Wyndmere area. According to Upham[17] the formation of the Sheyenne delta began at this stage. As the ice melted and the lake occupied a larger part of the valley, it stood at the height of the Herman beaches and formed an outlet to the Mississippi drainage. Cutting down of the outlet channel caused the lake waters to drop by successive stages to the level of the Campbell shore line. As the ice front retreated northward, the lake waters also receded northward until the lake was very nearly or completely drained. Subsequently, a readvance of the ice again blocked the northward-flowing drainage, and a final lake was formed in the Red River Valley. It rose only to the level of the outlet (Campbell beach) and then receded.

Below the Campbell shore line two distinct units have been identified as corresponding to the two stages of lake flooding.[18] The lower and thicker unit is thinly laminated blue-gray clay; the upper and thinner unit is a more coarsely laminated buff to yellow silt. The Campbell shore line cuts the eastern (lakeward) margin of the Sheyenne delta (see fig. 2), and the waters of the last lake flooding never covered the delta.

17/ Op. cit., p. 212.
18/ Dennis, P. E., Akin, P. D., and Worts, G. F. Jr., op. cit., p. 18.

Upham[19] described the formation of the Sheyenne delta as resulting largely from the sediment carried into the lake by the glacial Sheyenne River, although he recognized the possibility of large contributions of sediment directly from the melting ice front. Leverett[20] was concerned about the absence of similar deltas at the mouths of larger rivers such as the Red Lake River and believed that the greater part of the material was contributed directly by the melting ice. The fine-grained character and excellent assortment of the sediments, together with the almost total lake of pebbles, boulders, and unassorted blocks and balls of clayey material, which one would expect to find in ice-laid deposits, lead the authors to favor Upham's theory of a deltaic origin for the Sheyenne delta at least.

The character of the delta sediments in the Wyndmere area is known chiefly from 37 test holes drilled during the investigation. The sediments consist largely of silt and very fine sand. The sands near the surface are generally yellow in color and grade to a whitish-gray or gray with depth. The whitish-gray color is associated with the coarser, cleaner sands which have a higher percentage of quartz and contain flakes of shale and coal. The color changes to gray with increasing fineness and siltiness. Coal flakes are a prominent constituent of the sands from test holes 33 LR and 37 LR. Considerable clay is interbedded with the silt, and some medium sand occurs with the fine sand in some places. Practically no pebbles, boulders, gravel, or other coarse or unassorted materials were encountered in the test holes, and pebbles and boulders are extremely rare at the surface of the

19/ Op. cit., p. 316.
20/ Op. cit., pp. 126-127.

delta in this area. The sandy and clayey portions of the delta materials are rather irregularly distributed both horizontally and vertically, and the logs of the test holes and the map (fig. 3) show only the general character of the materials. Thus, sections consisting largely of fine sand usually contain thin beds of silt and clay not shown in the logs; and many areas shown on the map as dominantly silt include small subareas of sand, and many areas shown as dominantly sand contain subareas of silt.

Much of the surface material has been reworked by the wind, and sand dunes cover rather large tracts in the northwest part of the area. Three types of surficial material are shown in figure 3, based on the distribution of these various grain sizes. The boundaries of the areas are approximate and gradational.

Two areas are shown in which the surface material is composed of silt. In the northern area the silt overlies sand, but in the southern area it rests upon silt and clay which persist to the bottom of the Lake Agassiz deposits.

Six more or less definite sand-dune areas have been mapped. The sand in these areas is generally coarser than elsewhere. In most of the smaller areas and in a large part of the larger areas the dunes are, at present, more or less stabilized by grass and other vegetation. Most of the dunes are low, but some attain heights of 20 to 30 feet.

The delta deposits, as determined from the test holes drilled in the area, range from 70 to 136 feet in thickness and average about 104 feet. The contact between the Lake Agassiz deposits and the underlying till and associated glacioaqueous deposits was picked at the depth at

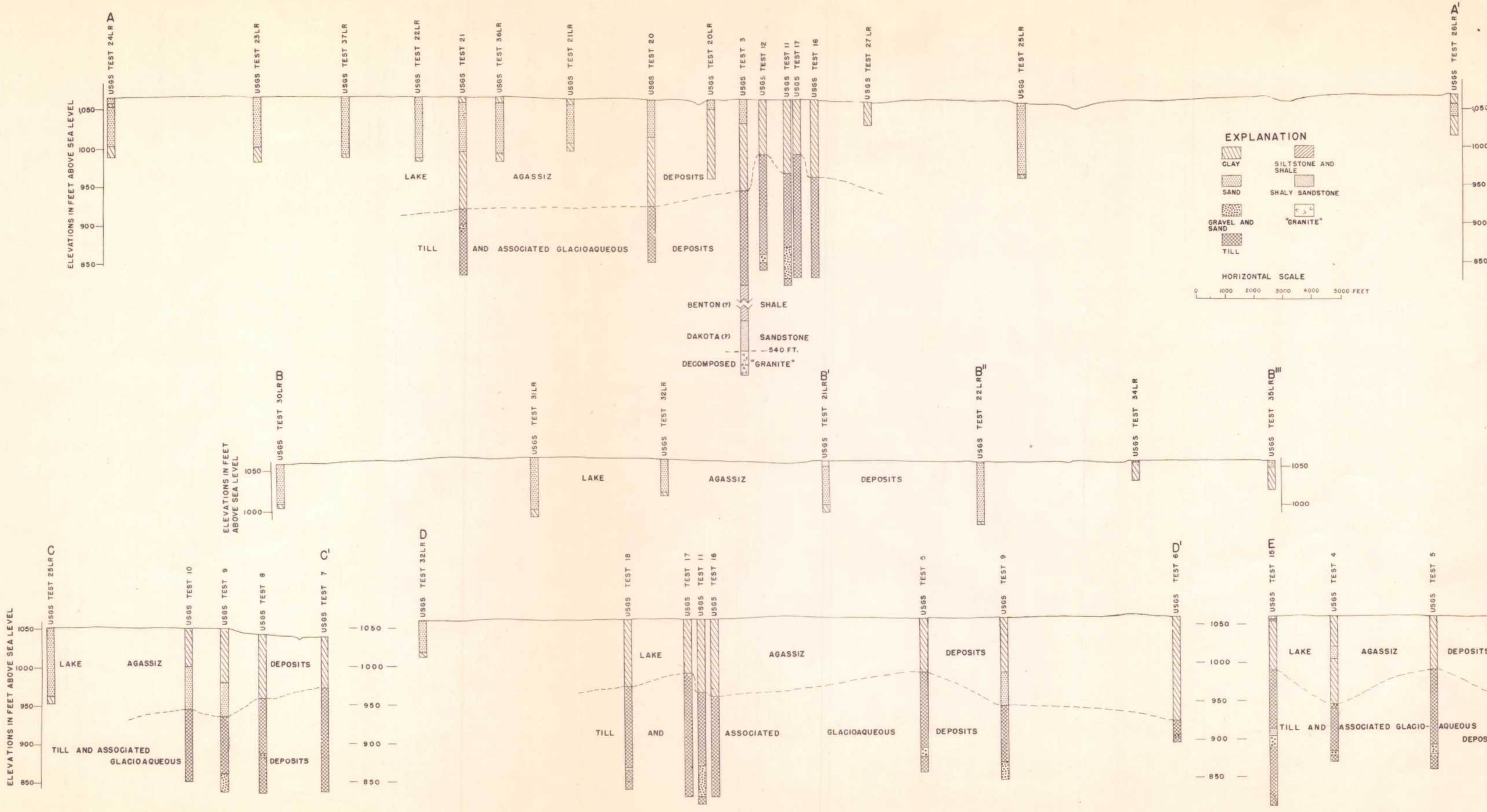

FIGURE 5. GEOLOGIC SECTIONS IN THE WYNDMERE AREA.
(LOCATIONS OF SECTIONS SHOWN ON FIGURE 3.)

which pebbles and gravel were found in the silt and clay. In some places the silt and clay with contained shale pebbles may be pebbly lake clay rather than till, and the boundary between the units (see fig. 5) is only approximate.

Oxidized zones of yellow-brown silt and clay are present at test holes 5, 12, and 15 at depths of 160 to 169 feet, 70 to 135 feet, and 70 to 95 feet, respectively. They may represent an old weathered surface, or they may be clays derived from till composed of weathered material.

A thick body of very fine silty sand overlies the till at test holes 9 and 10 at depths of 70 to 112 feet and 50 to 104 feet, respectively (see fig. 5). The sand is similar to the surface sands of the delta and not unlike that found in test hole 25 LR a mile west. It is possible that there is an interfingering of surface sand and this body of deeper sand.

Most of the farm wells in the area draw from the delta sands, the water being obtained for the most part from driven sand-point wells equipped with hand pumps. The sands constitute the most important aquifer in the area, for they are distributed over most of the area, generally contain potable water, are accessible to recharge from precipitation, and constitute a large reservoir of water in transient storage. Figure 6 shows the distribution of present wells in the area and their reported or measured depths.

In order to obtain some idea of the ability of the delta sands to transmit water, permeability tests were made on many of the samples taken from the test holes. Inasmuch as the samples were obtained by rotary drilling, much of the fine material in the sands may have been washed out, in which case the laboratory permeabilities probably are somewhat higher than would be obtained from tests on undisturbed materials in the formations. Transmissibilities (permeability times thickness) estimated from the laboratory tests on sands from 13 test holes ran from 1,037 to 9,610 gallons per day per foot with an average of 2,720 gallons per day per foot.[21/] Estimates from calculations based upon theoretically ideal hydraulic conditions and a saturated thickness of sand of 60 feet indicate that ground-water supplies on the order of 30,000 gallons a day could be developed where the transmissibility averages 1,000 gallons per day per foot over an area sufficiently large to permit the required recharge. Likewise, under the same conditions, sands having a transmissibility of 1,500 gallons per day per foot should yield supplies on the order of 40,000 gallons per day. Supplies on the order of 55,000 gallons per day should be obtained where the transmissibility is 2,000 gallons per day per foot, and about 70,000 gallons per day where the transmissibility is 2,500 gallons per day per foot.

The highest estimated transmissibilities were at test holes 20 and 21 LR north of town, 30 LR, 31 LR, 32 LR, and 33 LR west and north of town, and 25 LR south of town. Estimated transmissibilities at 30 LR and 25 LR are 9,610 and 5,841 gallons per day per foot, respectively. It should be possible to develop supplies of 30,000 to 70,000 gallons per day at any of the above locations, and it should be possible to obtain still larger supplies near 30 LR and 25 LR. Because of the uncertainty involved in the determination of the permeabilities in the laboratory, wells should be constructed and test-pumped to determine if

21/ Expressed as gallons a day through a vertical strip of the aquifer 1 foot wide under unit hydraulic gradient, or gallons a day through a section of the aquifer 1 mile wide under a hydraulic gradient of 1 foot per mile.

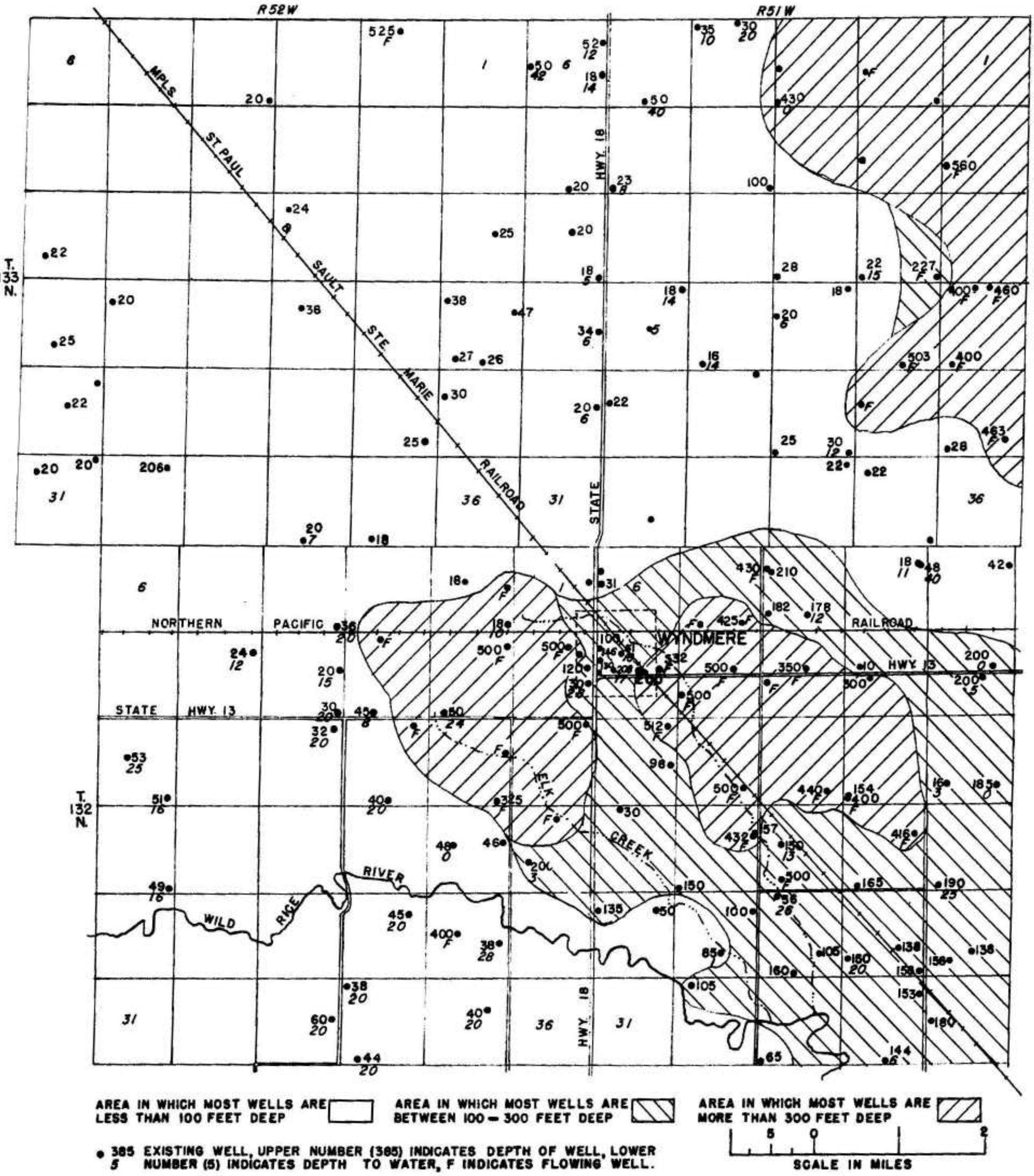

FIGURE 6. MAP SHOWING LOCATIONS, DEPTHS, AND DEPTHS TO WATER IN WELLS IN THE WYNDMERE AREA

yields sufficient for the contemplated use can be obtained at locations under consideration before any expensive developments are made, especially if the success of the development may depend upon the availability of a given volume of water.

Recharge to the delta sands is a complex function of precipitation, temperature, and other climatic factors. Figure 7 is a hydrograph of an observation well at the location of USGS test 30 LR, 1 mile north and 3½ miles west of Wyndmere, which shows the effects of natural recharge and discharge.

In general, the greatest amount of recharge occurs in the spring after the spring thaw. During this time, the water from the melting snow collects in undrained or poorly drained areas and gradually seeps into the sands as the frost leaves the ground. Also, evaporation from the soil and from open water surfaces at this time is low because of the low temperature. Rainfall during this season will augment the water available from the melting snow, and thus increase the amount of water available for recharge.

As a result of recharge during this period, water levels ordinarily attain their highest stages during the late spring or early summer, and may be very near the land surface over most of the area. With the advent of warmer, drier weather in the early summer, natural discharge of water from the sands is accelerated by increased evaporation from the soil and open water areas, as well as by underground drainage to the streams in the area.

Recharge occurs also as a result of rainfall during the summer and fall, but much of this precipitation evaporates from the soil surface and is transpired by the vegetation without reaching the water table. For this reason, only heavy or sustained precipitation during the summer and fall seasons effectively contributes to the ground-water reservoir.

Little or no recharge occurs during the winter season while the ground is frozen and little or no melting of snow occurs.

The amount of water in transient underground storage in the delta sands is very great. The average saturated thickness of sand in 34 of the USGS test holes is 33 feet. Assuming an average specific yield of 15 percent, this would indicate an average of more than 1 billion gallons of water in storage for each square mile of the area, though probably only a small part of this could be economically recovered through wells.

In the southern area of silt shown on figure 3, the delta materials are composed almost entirely of silt and clay. A few farm and domestic water supplies are obtained from them in this area, but the materials are so fine-grained that it would not be possible to develop wells suitable for industrial or municipal uses.

Till and associated glacioaqueous deposits

The average thickness of till and associated glacioaqueous deposits in the area is about 120 feet, as determined from test holes 3, 13, and 14 where the total thickness was penetrated. The bottom of the unit ranges from 240 to 397 feet below the surface in the three holes. This variation is probably the result of the irregular land surface upon which the till was deposited.

The till is generally a dark- to light-gray calcareous silty clay with varying amounts of unassorted sand and gravel. The gravel consists mainly of shale fragments with variable amounts of limestone or dolomite, and granitic and basic igneous rocks.

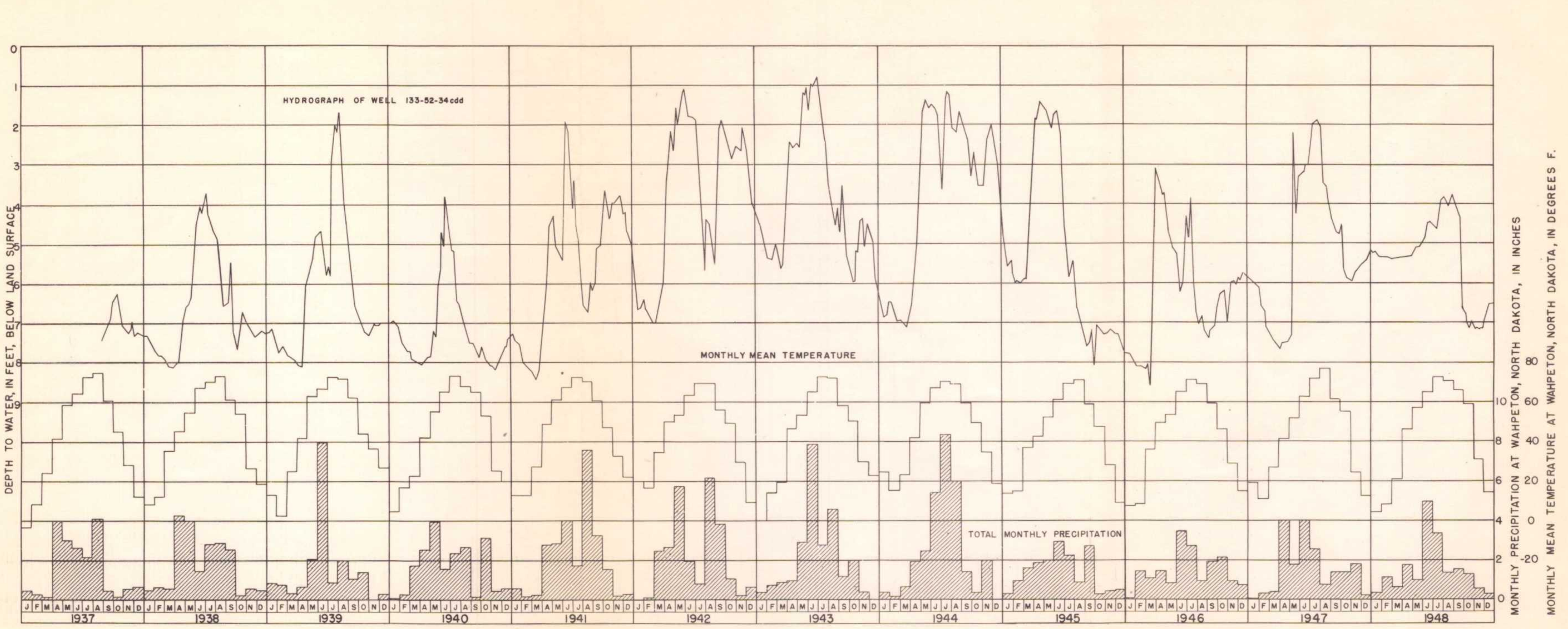

FIGURE 7.–HYDROGRAPH OF SHALLOW WELL WEST OF WYNDMERE AND GRAPH OF MONTHLY MEAN TEMPERATURE AND MONTHLY PRECIPITATION AT WAHPETON, NORTH DAKOTA.

In the southeastern part of the Wyndmere area, (where most of the wells are from 100 to 300 feet deep, as shown in fig. 6), most of the farm and domestic water supplies are obtained from sand and gravel within the till and deposited in glacial waters (glacioaqueous deposits). Probably most of the sand and gravel was deposited in glacial streams (glaciofluvial), but some perhaps was laid down in glacial ponds or lakes (glaciolacustrine). It is possible that farm and domestic supplies could be obtained from such aquifers elsewhere in the area, and that the concentration of wells tapping these aquifers in the southeastern part of the area is the result of the fact that adequate quantities of water are not there available from the shallow delta sands. As indicated in figure 3, this is the general area in which the Lake Agassiz deposits are composed largely of silt.

Figure 6 shows several areas in which most of the wells are deeper than 300 feet, the deepest reported being 560 feet. Most of the wells in this depth range flow, and it is probable that the reason for the concentration of these wells in certain areas is that flowing wells were desired, and any aquifers penetrated above the flows were disregarded. It seems likely that flows can be obtained almost everywhere in the area at depths of approximately 400 to 500 feet, but that flows can be obtained at shallower depths in only a few places. Two wells, 520 and 470 feet deep are reported to have been drilled in T. 132 N., R. 50 W., without encountering water. Only one well in the area less than 300 feet deep is reported to flow (well 132-51-12cad, 203 feet deep).

Simpson[22] believed that the flowing wells of depths greater than 300 feet derive their water from the Dakota (?) sandstone. However, it seems probable that the flowing wells between 300 and 450 feet deep derive their water from glacioaqueous materials in the till or from sandy zones in the Benton (?) shale. It seems likely that the pressure necessary to produce some of the flowing wells in the Wyndmere area may be transmitted from the Dakota (?) sandstone through the till by way of the interconnecting glacioaqueous materials. The presence of flowing wells in the area does not of itself indicate the presence or absence of the Dakota (?) sandstone.

The glacioaqueous aquifers may be quite permeable, especially where composed essentially of coarse sand and gravel, and wells tapping these aquifers may have large yields. However, the materials composing the aquifers in places may be entirely encased in impermeable materials so that essentially no recharge can reach them, or at best can enter very slowly. As a consequence, if the areal extent of such an aquifer is small and the pumping rate high, water levels will fall rapidly and the well may fail within a short time. The larger the aquifer, of course, the longer it will take to unwater it at a given pumping rate.

It has been demonstrated through water-level records that the aquifers associated with the till in the Fargo area[23] are interconnected with each other so that the till and associated glacioaqueous materials as a unit have a transmissibility of about 1,000 gallons per day per foot. If the glacioaqueous materials in the Wyndmere area are

22/ Simpson, H. E., op. cit., fig. 1.
23/ Dennis, P. E., Akin, P. D., and Worts, G. F., Jr., Geology and ground-water resources of parts of Cass and Clay Counties, N. Dak. and Minn.: U. S. Geol. Survey mimeographed report, pp. 70-84, 1949.

interconnected as they apparently are in the Fargo area, it would be expected that supplies from individual wells up to 70,000 gallons a day could be pumped for many years, provided that the wells were spaced sufficiently far apart to avoid local overdevelopment. On the other hand, the available evidence from the test holes and from wells in the area suggests that interconnection of the glacioaqueous materials may not be as well developed in this area as in the Fargo area, and that the aquifers are much smaller. For these reasons the aquifers might be unwatered quite rapidly, and wells producing heavily from them might fail within a comparatively short time.

It seems unlikely that wells of capacities of several hundred gallons a minute could be obtained in any of the glacioaqueous aquifers encountered during the test drilling.

The glacioaqueous gravel is similar in composition to the gravel mixed with the till (see p. 21). In test holes 4, 5, 9, and 10 sand and gravel occur at the top of the till, underlying the Lake Agassiz deposits. In test hole 15 sand and gravel underlie the top 5 feet of till. In seven of the test holes, 4, 9, 11, 12, 14, 18, and 21, glacioaqueous material is interbedded with the till. In test hole 14, the 42 feet of sand which occurs at the base of the till may be related in some way to the Dakota (?) sandstone (see fig. 4), although it may be a glacioaqueous deposit.

Glacioaqueous gravel and sand was found at about the same depths in test holes 6, 8, 9, 5, 4, and 15, and the deposits may be interconnected. Their total thickness ranges from 3 to 25 feet, the greatest thickness being in test holes 9 and 15. The gravel and sand consist mainly of shale with fragments of limestone, dolomite, quartz, feldspar, and granite. The material is relatively free of silt and clay.

Similar glacioaqueous material is found at a slightly greater depth in test holes 11 and 12. Forty feet of sand and gravel occurs in test hole 11, whereas only 10 feet occurs in test hole 12. The best gravels are the top 20 feet of gravel in test hole 11 and the top 5 feet of gravel in test hole 12. No sand or gravel was found in nearby test holes 17, 16, or 19. It is assumed that this aquifer is separate from the gravel aquifer mentioned in the preceeding paragraph, although it is possible that they are interconnected.

Older lake clay and drift

A unit of older lake clay and drift was identified in the Fargo area,[24] and it is not unlikely that some parts of the deposits classified as till and associated glacioaqueous deposits in the Wyndmere area may be of glaciolacustrine origin. However, it is difficult to make the distinction between clay till containing small amounts of shale gravel and pebbly lake clay, and insufficient test holes were drilled to the bedrock in the Wyndmere area to permit the positive determination of the presence or absence of such a unit. It would not be water bearing.

Cretaceous (Benton?) shale

The glacial drift in a part of the Wyndmere area is underlain by siltstone and shale believed to be of Cretaceous age and possibly belonging to the Benton shale. Only two of the test holes penetrated these rocks, but in each hole cores of a few feet of the formation were obtained. In USGS test 3 at Wyndmere there was 260 feet of these beds, at Barney in USGS test 13 there was 110 feet, and at Mooreton in USGS test 14 the beds were apparently absent (see fig. 4). The cores consist

24/ Dennis, P. E., Akin, P. D., and Worts, F. G., Jr., op. cit., p. 26.

of silty shale and siltstone rather uniformly light gray in color. The rock is generally noncalcareous, but thin beds of calcareous shale and shaly limestone occur in it. The silt and fine sand washed from the cores was found to consist almost exclusively of angular quartz grains. Fossils consist of fish scales, one fish tooth, fragments of plant stems and leaves, and what D. H. Pfeiffer has identified as Inoceramus prisms.[25] At its base the formation becomes variable in color (see log of test hole 3, p. 44).

The Cretaceous shale is not known definitely to be water bearing in the Wyndmere area, but weak flows of saline water from some wells reported to be between 250 and 450 feet in depth may come from fine sandy and silty beds in this formation.

Dakota (?) sandstone

The Dakota sandstone, of Cretaceous age, is one of the most widespread aquifers known in the world. It is present in parts of nearly a dozen States. It is believed to underlie the entire State of North Dakota except in the Red River Valley area, where it has been at least partially removed by erosion or modified by glacial activity. It is a fine-grained grayish-white to buff sandstone which may be interstratified with clay or shale. It is famous for the high pressures under which the water occurred in it in the early years of its development and for the relatively large flows obtained. It is not, however, a highly permeable formation, and only small flows are obtained where the artesian pressure is low.

25/ Personal communication

The Dakota (?) sandstone is of most importance as an aquifer in North Dakota in the south-central part of the State. Where it occurs elsewhere in the State it is so deeply buried that it is generally impractical to drill to it and the water is highly mineralized.

The presence and extent of the Dakota (?) sandstone in the Wyndmere area have not been established definitely. Two wells, 520 and 470 feet deep, are reported to have been drilled in T. 132 N., R. 50 W., without obtaining water, and it is reported that the "granite" was reached in the latter well. This would seem to indicate that the Dakota (?) sandstone is not present everywhere in the area. Nevertheless, flowing wells are generally obtained at a horizon that appears to be near the contact between the Cretaceous rocks and the "granite." Furthermore, the water from these wells is rather uniform in character and concentration and similar to waters that are known to come from the Dakota (?) sandstone in areas west and south of Wyndmere.

About 40 feet of sand overlying the "granite" was encountered in USGS test 14 near Mooreton. The Cretaceous shale was apparently absent in this hole, and till probably overlies the sand. The sand contains some grains and pebbles of shale and crystalline rocks. For these reasons it is believed that the sand is a glacioaqueous deposit, although it might be reworked Dakota (?) sandstone and might have a hydrologic connection with that aquifer.

About 40 feet of sandy shale was encountered in USGS tests 3 and 13 at the base of the Cretaceous shale, and this may be a local facies of the Dakota (?) sandstone. At any rate, this seems to be the horizon from which most of the flowing wells obtain their water, and in view of the fact that the water is similar in quality to that of water from the Dakota (?) sandstone in adjacent areas, the beds are provisionally assigned to that formation.

The water from the Dakota (?) sandstone is generally more highly mineralized than is desirable for public or domestic use.

"Granite"

The basement rock of the area consists of undifferentiated crystalline igneous and metamorphic rocks that locally are termed "granite." Little is known of their composition except what can be learned through the examination of well cuttings, for the rocks do not crop out in or near the area.

A zone of decomposition exists at the surface of the "granite," and drilling in test holes was stopped while in this zone and before the fresh rock was reached. Generally not more than 20 feet of the zone was penetrated. The decomposed material derived from the "granite" is reddish-brown, greenish-gray, or white in color. It consists of a greasy-feeling clay, and fine to coarse angular quartz crystals. The presence of fragments of shale, granite, and basic igneous rocks in some of the well cuttings from the "granite" contact suggests that the upper part of this zone was reworked by the glacier and some glacial material was incorporated within the decomposed zone.

Only three of the test holes, nos. 3, 13, and 14, entered the "granite." In addition, an oil test, Ruddy Bros. No. 1, was drilled into the "granite." The elevation of the irregular surface of the "granite" in these four holes was approximately 510, 624, 578, and 675 feet above sea level, respectively - a rise of 165 feet in about

22 miles from test hole 3 in the west to the Ruddy Bros. No. 1 oil test in the east (see fig. 4). At the latter well, 125 feet of decomposed "granite" was penetrated, and drilling was continued 245 feet into the underlying hard gneissic and schistose crystalline basement rock.

Zones of fracture within or at the surface of the "granite have been known to yield small supplies of water. However, no wells derive their water from the "granite" in this area, and it is generally considered useless to drill deeper when the zone of decomposed "granite" is reached.

QUALITY OF GROUND WATERS IN THE WYNDMERE AREA

Eleven chemical analyses of well waters from the Wyndmere area are given in the following table. Four of these analyses represent waters from shallow wells tapping the Lake Agassiz deposits, three show the character of the water from wells in the glacioaqueous aquifers at intermediate depth in the till, and four are of water from wells in the deepest aquifer of the area, the Dakota (?) sandstone.

The shallow waters in the Lake Agassiz deposits generally contain the least amount of dissolved solids. However, these waters contain moderate amounts of mineral matter and are generally very hard. The dissolved solids are composed largely of calcium and magnesium salts in the form of sulfate and bicarbonate.

Waters from the aquifers at intermediate depth generally contain more dissolved solids than waters from the shallow aquifers, but they are less highly mineralized than the waters from the deepest aquifer. The intermediate-depth aquifers yield waters that are softer than the shallow waters and contain smaller amounts of calcium and magnesium salts and greater amounts of sodium salts. The chloride concentration is much higher than that in the shallow waters.

The waters in the deepest aquifers are the most highly mineralized, most being unsatisfactory for many uses. However, these waters are the softest found in the area. The calcium and magnesium content is much lower than in the upper waters, and the sodium concentration is much higher. The quantities of sulfate and chloride are also much higher.

CHEMICAL ANALYSES OF GROUND WATERS
(PARTS PER

Location number	Owner	Date of analysis	Source of analysis	Depth of well (feet)	Dissolved solids	Iron (Fe)
132-51-6	City of Wyndmere	1938	a/	545	2,650	.1
132-51-6	A. Lein	1938	a/	49	463	.5
132-51-6bcc	William Snyder	3-29-49	b/	31	1,970	.1
132-51-7accl	City of Wyndmere	4-6-49	b/	500	2,860	.9
132-51-7acc2	Conrad Vantassel	4-6-49	b/	200	1,510	.2
132-51-7bccl	Johnson	2-26-49	b/	208	1,090	.4
132-51-8acd	Joseph Kuchera	2-31-49	b/	500	3,110	4.4
132-51-20ada2	George Vosberg	3-25-49	b/	157	915	.5
132-52-12abd	Louis Cagley	2-24-49	b/	500	3,000	.2
133-51-30add	Raymond Kelly	3-30-49	b/	20	918	1.5
133-52-34cdd	USGS test 30 LR	1-8-49	b/	20	664	2.8

a/ Abbott, G. A., Voedisch, F. W., The municipal ground-water supplies
b/ North Dakota State Department of Health, Bismarck, N. Dak., 1949.

IN THE WYNDMERE AREA
MILLION)

Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$
16	8.3	915	-	1,300	1,180	412	2.2	78
102	28	5.0	-	345	75	8.0	.4	450
200	85	240	0	639	770	35	4.3	850
10	1.7	862	18	302	1,240	418	4.3	31
24	13	287	55	398	152	116	.1	112
19	8.8	285	40	393	154	160	.1	84
14	5.9	1,040	31	364	1,240	495	4.3	59
10	36	201	0	458	164	42	4.4	172
14	3.9	890	43	308	1,210	496	0	62
6.0	91	128	29	308	356	1.0	0	390
100	48	59	0	538	116	12	0	445

of North Dakota; North Dakota Geol. Survey Bull. 11, p. 75, 1938.

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 running along the Kansas-Nebraska State line. The second number is that of the range west of the sixth principal meridian. The third number is that of the section within the designated township. 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. If more than one well occurs within a 10-acre tract (quarter-quarter-quarter section), consecutive numbers are given to them as they are scheduled. This number follows the letters. Thus, well 132-51-20ada2 is in Township 132 North, Range 51 West, section 20. It is in the northeast quarter of the southeast quarter of the northeast quarter of that section and was the second well scheduled in that 10-acre tract. Similarly well 132-51-17cdd (see USGS test 8, fig. 3) is in the southeast quarter of the southeast quarter of the southwest quarter of sec. 17, T. 132 N., R. 51 W. Numbers for wells not accurately located within the section in the field may contain only one or two letters after the section number, indicating that the locations of such wells are accurate only to the quarter section or the quarter-quarter section, respectively.

The following diagram, showing the method of numbering the tracts within the section, may be helpful to the reader in determining locations of the wells shown in the illustrations.

bbb	bba	bab	baa	abb	aba	aab	aaa
(b)		(a)		(b)		(a)	
bbc	bbd	bac	bad	abc	abd	aac	aad
	b				a		
bcb	bca	bdb	bda	acb	aca	adb	ada
(c)		(d)		(c)		(d)	
bcc	bcd	bdc	bdd	acc	acd	adc	add
cbb	cba	cab	caa	dbb	dba	dab	daa
(b)		(a)		(b)		(a)	
cbc	cbd	cac	cad	dbc	dbd	dac	dad
	c				d		
ccb	cca	cdb	cda	dcb	dca	ddb	dda
(c)		(d)		(c)		(d)	
ccc	ccd	cdc	cdd	dcc	dcd	ddc	ddd

Depth to water: Measurements given to hundreths or tenths are measured water levels. Those given in units only are reported.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
132-50-7caa	USGS test 13	420	5	Drilled	1948
132-50-8a 1/	C. H. Kehrberg	470	......	....	....
132-50-9b 1/	Elizabeth Heilkamp	520	......	....	....
132-50-11b 1/	A. Schwam	170	3	....	....
132-50-12dab	USGS test 14	410	5	Drilled	1948
132-50-22b 1/	Adam Stan	280	......	....	....
132-50-22 E½	Gust Lelland	280	......	....	....
132-50-31 N	H. M. Bailey	470	2	....	....
132-51-2ada	J. H. Busching	42	2	Drilled	....
132-51-3aac1	......do......	17.8	1½	Dug	....
132-51-3aac2	......do......	48	2	....	....
132-51-4bcb1	Delbert Jones	430	2	Drilled	....
132-51-4bcb2	......do......	210	2	....	....
132-51-4ccb	Vincent Jones	182	......	...do...	1935
132-51-4dcb	George H. Pelvit	178	2	...do...	....
132-51-5ccd	J. Mead	....	......	...do...	1917
132-51-5dcd	Jacob Lillestol	425	......	...do...	1920
132-51-6 2/	Town of Wyndmere	545	2	...do...	....
132-51-6 2/	A. Lein	49	2	...do...	....
132-51-6bcb	....	....	......	...do...	....
132-51-6bcc	William Snyder	31	1¼	Driven	1933
132-51-6cbb	USGS test 20	210	5	Drilled	1948
132-51-7acc1	Town of Wyndmere at stock pens	500+	......	...do...	....
132-51-7acc2	Conrad Vantassel	200+	......	...do...	....
132-51-7adc	George Kuchera	532	......	...do...	....
132-51-7bbc	Howard Jones	100	......	Bored	1945
132-51-7bbd	USGS test 3	570	5	Drilled	1948

Use of water: D, domestic; M, municipal;
O, observation; S, stock; U, unused

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
......	....	U	Hole refilled. See log
Flow	....	...	Into blue shale; said to overlie granite. Little water.
......	....	...	No water.
6	....	...	Aquifer, sand.
......	....	U	Hole refilled. See log.
......	....	...	
......	....	...	
......	....	...	470 feet to granite. No water.
......	....	S	Water reported hard; well pumps dry easily; aquifer in sand from 42 to 43 feet. Test well sunk nearby ground; only few inches of sand in 200 feet.
10.89	10-18-47	DS	Water reported hard. Yellow clay to 18 feet. Aquifer, black sand.
40	10-18-47	D	Chief aquifer, sand at 48 feet. Water reported very hard.
Flow	10-18-47	S	Excellent flow; has salty taste.
......	....	D	Water reported soft.
......	....	DS	Water reported soft and good.
12	1941	DS	Water reported soft, some alkali. Aquifer, sand from 166 to 178 ft.
Flow	....	DS	
..do..	....	DS	Water salty. Slow flow in house, 10 feet above ground.
6	....	D	Aquifer, Dakota (?) sandstone. See chemical analysis.
28	....	D	Aquifer, fine sand, lacustrine. See chemical analysis.
......	....	DS	
......	....	D	Aquifer, sand. See chemical analysis.
......	....	U	Hole refilled. See log.
Flow	....	S	See chemical analysis.
......	....	D	Do.
Flow	10-11-47	DS	Water reported salty, soft.
......	....	D	Water reported hard, good.
......	....	U	Hole refilled. See log.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
132-51-7bca	USGS test 12	220	5	Drilled	1948
132-51-7bcb	V. J. Swanson	146	......	....	....
132-51-7bcc1	Johnson	208	......	...do...	....
132-51-7bcc2	Dinger	130	2	Jetted	1941
132-51-7bcc3	USGS test 11	240	5	Drilled	1948
132-51-7bdb	Mrs. Tingum	51	2	Jetted	1947
132-51-7bdc	USGS test 19	250	5	Drilled	1948
132-51-7cbb	USGS test 16	230	5	...do...	1948
132-51-7daa	USGS test 15	246	5	...do...	1948
132-51-7ddd	USGS test 4	189	5	...do...	1948
132-51-8a 1/	J. H. Spohn	464	2	....	....
132-51-8acd	Joseph Kuchera	500+	......	...do...	....
132-51-8cbc	Eugene Klosterman	500	......	...do...	1918
132-51-9acc	F. Rodenbaugh	350+	......	...do...	....
132-51-9cbb	John Pokarny	....	......	...do...	....
132-51-10bcd	George Jorgenson	9.6	......	Dug	....
132-51-10cab	Robert Nagle	300	......	Drilled	....
132-51-11adc	W. M. Gabriel	200+	3	...do...	....
132-51-11dba	Adolf Haberman	200	......	...do...	....
132-51-12ada	Bernard Hager	465	5	...do...	1932
132-51-12cad	Ernest Beigert	203	2	...do...	....
132-51-12dab	J. W. Johnson	385	3	...do...	1938
132-51-14c 3/	J. Haberman	16	48	Dug	1912
132-51-14d 3/	Ed. Goerger	185	2	Drilled	1932
132-51-15cc1	T. S. Paulson	154	34	Bored	....
132-51-15ccc2	.....do.....	400	......	Drilled	....
132-51-16d 3/	F. Rogers	440	2	...do...	1924
132-51-17cdd	USGS test 8	200	5	...do...	1948
132-51-17d 3/	Hannah Baumbeck	500	2½	...do...	1914

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
......	....	U	Hole refilled. See log.
......	....	...	
17	8-28-48	D	Water reported good, soft. See chemical analysis.
......	....	D	Water reported hard, has metallic taste.
......	....	U	Hole refilled. See log.
184	11-1-47	...	Water reported hard, good.
......	....	U	Hole refilled. See log.
......	....	U	Do.
......	....	U	Do.
......	....	U	Do.
Flow	....	...	
..do..	10-11-47	DS	Water reported soft, salty. See chemical analysis.
..do..	10-18-47	DS	Weak flow.
..do..	10-11-47	DS	
..do..	10-18-47	DS	Very weak flow, salty.
......	....	S	Water reported poor, red and hard. Aquifer, fine sand.
..do..	10-11-47	DS	Good pressure.
Surface	....	DS	
5	10-18-47	DS	
10	10-18-47	DS	Water reported highly mineralized.
Flow	10-18-47	DS	Flow enough to water stock.
5	10-18-47	DS	Water reported salty.
3	1939	DS	Aquifer, sand. Water reported adequate for 8 head stock.
0	1939	DS	Aquifer, sand. Water reported adequate for 100 head stock.
......	....	DS	Good during drought years. Aquifer, sand.
Flow	10-11-47	...	
..do..	1939	DS	Aquifer reported as sandstone.
......	....	U	Hole refilled. See log.
..do..	1939	DS	Aquifer reported as sandstone.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Daimeter (inches)	Type	Date completed
132-51-18a 3/	Florence Bagg	512	2	Drilled	1905
132-51-18ccc	USGS test 25 LR	97	4	...do...	1948
132-51-18daa1	Frank Dahl	96		Bored	1937
132-51-18daa2	USGS test 5	200	5	Drilled	1948
132-51-19aaa	USGS test 10	200	5	...do...	1948
132-51-19bab	Alvin Manstrom	30	......	Dug	....
132-51-20aab	USGS test 7	200	5	Drilled	1948
132-51-20ada1	George Vosberg	432	......	...do...	1907
132-51-20ada2	......do......	157	......	...do...	1946
132-51-20bba	USGS test 9	210	5	...do...	1948
132-51-20ccc	Clair Jones	150	2	...do...	1933
132-51-20ddd	USGS test 6	164	5	...do...	1948
132-51-21b 3/	Chris Hansen	150	2	...do...	1932
132-51-21c 3/	Ernest Klawitter	500	2	...do...	1924
132-51-22a 3/	Nat. Life Ins. Co.	416	2	...do...	1936
132-51-22ccd	Alfred Springer	165	......	...do...	1907
132-51-23c 3/	Villand Mort. Co.	190	2	...do...	1929
132-51-26cdb	Becker Bros.	148	......	...do...	1935
132-51-26dbc	......do......	138	......	...do...	....
132-51-27ccb	H. V. Springer	150	......	...do...	1917
132-51-27ddd	R. L. Wodarz	158	2	...do...	....
132-51-28bba	George Brosowoske	36.3	20	Dug	....
132-51-28cdd	Jerry Little	160+	......	Drilled	....
132-51-28dbd	Ernest Trimmer	105	......	...do...	....

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
Flow	1939	DS	Aquifer reported as sandstone.
......	....	U	Hole refilled. See log.
......	....	DS	Aquifer, gravel from 86 to 95 feet. Water reported good, hard.
......	....	U	Hole refilled. See log.
......	....	U	Do.
......	....	DS	Aquifer, fine sand from 20 to 30 feet.
......	....	U	Hole refilled. See log.
Flow	10-11-47	S	
......	....	DS	Aquifer, fine sand. Water reported very hard. See chemical analysis.
......	....	U	Hole refilled. See log.
......	....	DS	Sand point in gray coarse gravel.
......	....	U	Hole refilled. See log.
13	1939	S	Aquifer, sand. Reported adequate to water 40 head stock.
Flow	1939	DS	Aquifer, sandstone.
..do..	1939	DS	Do.
......	....	DS	Adequate during drought time. Water reported soft and good.
25	1939	DS	Aquifer, sand. Reported adequate to water 40 head stock.
......	....	DS	Aquifer, medium sand from 152 to 158 feet. Produced 7 g.p.m. when new. Water reported hard.
......	....	S	Aquifer, medium sand at 138 feet. Water reported soft.
20	11-18-47	DS	Aquifer, coarse gravel from 140 to 150 feet. Reported adequate during drought years.
......	....	DS	Aquifer, coarse sand from 154 to 158 feet.
26.12	10-11-47	D	
......	....	DS	Aquifer, gravel. Water reported soft, good.
......	....	...	Water reported soft, good.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
132-51-29aad	Earl Vosberg	100+	......	....	....
132-51-29dbc	Wm. Wasvick	85+	......	Drilled	....
132-51-30aac	Joe Kuzel	50	......	...do...	....
132-51-30bbc	Frank J. Wacha	135	......	Driven	1932
132-51-32bba	Ruben Holza	105	3	Drilled	....
132-51-33ccc	Leo Neidviecky	65	......	...do...	1939
132-51-34aad	Marvin Heartling	153	2	...do...	....
132-51-34dcc	L. T. Anderson	144	......	...do...	1922
132-51-35bcc	Rupert Goerger	180	......	...do...	1900
132-51-36ddd	R. H. Bellin	180	......	...do...	1917
132-52-1add	....	....	2	....	....
132-52-1ddd	USGS test 20 LR	102	4	...do...	1948
132-52-2aaa	USGS test 32 LR	47	4	...do...	1948
132-52-2add	Harley Springer	....	......	...do...	Old
132-52-2bbb	USGS test 31 LR	77	4	...do...	1948
132-52-2bdd	Nulph Bros.	18	1¼	Driven	....
132-52-2ddd	Erwin Kressin	18	1¼	...do...	Old
132-52-3ddd	USGS test 29 LR	97	4	Drilled	1948
132-52-4d 3/	Walter Dinger	36	1¼	Driven	1923
132-52-8a 3/	Walter Williamson	24	3½	Dug	1936
132-52-9a 3/	Wm. Williamson	20	3	Dug	1926
132-52-9d 3/	Marie Solberg	30	2	....	1936
132-52-10baa	Jess Dinger	....	2	Drilled	Old
132-52-10cdc	G. G. Poppen, Jr.	45	2	Jetted	1947
132-52-11aad	Forest Selzli	500	2	Drilled	Old
132-52-11ccd	G. G. Poppen, Sr.	50	......	Driven	Old
132-52-12abc	USGS test 18	220	5	Drilled	1948
132-52-12abd	Louis Cagley	500+	......	...do...	Old

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
......	....	DS	Water reported hard; turns yellow upon standing. Aquifer, fine sand.
1	10-11-47	DS	Inadequate.
......	....	DS	Water reported hard and rusty.
......	....	DS	Adequate during drought years.
......	....	DS	Aquifer, black sand from 100 to 105 feet; yellow clay to 100 feet.
......	....	DS	Water reported hard.
......	....	DS	Adequate during drought years. Water reported hard.
6	10-18-47	DS	Aquifer, blue sand.
......	....	DS	Adequate during drought years. Water reported good.
20	....	DS	Has pumped 1,000 gallons a day occasionally.
......	....	....	
......	....	U	Hole refilled. See log.
......	....	U	Do.
Flow	....	DS	Water reported soft, slightly salty.
......	....	U	Hole refilled. See log.
......	....	DS	Aquifer, sand from 3 to 18 feet. Water reported soft, good.
104	10-11-48	DS	Do.
......	....	U	Hole refilled. See log.
20	....	S	
12	....	S	
15	....	S	
20	....	S	
Flow	10-11-47	DS	
18	10-11-47	DS	Aquifer, sand from 18 to 45 feet. Water reported hard, bad.
Flow	10-11-47	DS	Water salty.
24	10-11-47	DS	Water reported hard, good.
......	....	U	Hole refilled. See log.
Flow	10-11-47	D	See chemical analysis.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
132-52-12ada	Mrs. B. Ehlers	....	......	Jetted	....
132-52-12add	John Shorma	120	2	...do...	1939
132-52-12bbb	USGS test 28 LR	27	4	Drilled	1948
132-52-12ccc	USGS test 27 LR	27	4	...do...	1948
132-52-12daa	USGS test 17	230	5	...do...	1948
132-52-12daa	Roy Springer	30	24	Bored	....
132-52-13aaa	J. B. Stuckey	500	2	Drilled	1908
132-52-14ada	Elsie Klamen	....	2	...do...	Old
132-52-14ddc	Emil Luebke	325	2	...do...	Old
132-52-15aab	Carl Solberg	....	2	...do...	1914
132-52-15d 3/	Leo A. Pelvit	40	2	...do...	1930
132-52-16a 3/	Joseph Cink	32	1¼	Driven(?)	1920
132-52-18a 3/	Christine Butland	53	48	Dug	1900
132-52-18d 3/	E. B. Lunde	51	2	Drilled	1936
132-52-19d 3/	Peter J. Kjos	49	2	...do...	1936
132-52-23add	John Fourtache	46	2	...do...	....
132-52-23bdc	Ed Foyt	48	3	Driven	....
132-52-24abc	Erling Johnson	....	2	Drilled	1917
132-52-24cbd	Wm. Wittkopp	200	2	...do...	....
132-52-26bdc	Louis Blazek	400+	2	...do...	1937
132-52-26daa	Will Wacha	38	10	Bored	Old
132-52-27a 3/	Ethel Liljemarck	45	2	Drilled	1939
132-52-33d 3/	......do......	60	3	...do...	1925
132-52-34b 3/	I. H. Blazek	38	2	...do...	1938
132-52-34c 3/	C. W. Carey	44	3	...do...	1900
132-52-35a 3/	Joe Mauch	40	1¼	...do...	1900
132-52-36ddd	USGS test 26 LR	52	4	...do...	1948
133-51-2cbb	....	....	2	...do...	....
133-51-2ddd	F. K. Arrvis	....	2	...do...	Old

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
......	....	D	Water reported hard, good.
......	....	DS	Water reported hard.
......	....	U	Hole refilled. See log.
......	....	U	Do.
......	....	U	Do.
28	10-11-47	S	Reported unfit for human consumption. Dries up in summer. Water level 7 feet below land surface in the spring.
Flow	10-11-47	DS	Water reported soft, slightly salty.
..do..	10-11-47	DS	Water reported hard, slightly salty.
..do..	10-11-47	DS	Water reported soft, slightly salty.
..do..	10-11-47	DS	Do.
20	....	S	
20	....	S	
25	....	S	
16	....	S	
16	....	S	
......	....	DS	
Surface	10-11-47	DS	Water reported hard, good.
Flow	10-11-47	DS	Water reported salty but palatable.
3.1	10-11-47	DS	Water level taken in pit which is 5.84 feet deep and represents shallow water level.
Flow	10-11-47	...	Water reported soft, slightly salty.
28	10-11-47	DS	Water reported hard, good.
20	....	S	
20	....	S	
20	....	S	
20	....	S	
20	....	...	
......	....	U	Hole refilled. See log.
Flow	10-18-47	U	
......	....	DS	Water reported soft, slightly salty.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
133-51-3cbb	Richard Nittkup	....	1¼	Driven	....
133-51-3ccc	Paul Drager	430	2	Drilled	1935
133-51-4abb	Christ Peterson	30	1¼	Driven	Old
133-51-5cdd	Julius Versdahl	50	1¼	...do...	Old
133-51-6ada	Ray Pinkham	52	1¼	...do...	Old
133-51-6cbb	Oscar Olson	50	1¼	...do...	....
133-51-6dad	Lloyd Snyder	18	1¼	...do...	Old
133-51-7dcc	Mrs. Vern Mathiesen	20	1¼	...do...	....
133-51-8ccc	Theo. Shorma	23	1¼	...do...	....
133-51-9ddd	G. O. Sanden	100	4	Drilled	Old
133-51-11cbc	Ed. Buckholz	....	2	Driven	Old
133-51-12cbc	Jacob Hoffert	560	2	Drilled	1939
133-51-14ccc	Herman Buckholtz	21½	48	Dug	Old
133-51-14ddd	Gordon Anderson	226½	2	Drilled	1917
133-51-15ccc	LaVerne Olson	28	2	Driven	1920
133-51-18acc	Eli Erickson	20	1¼	...do...	....
133-51-18ddd	Alfred Meyers	18	1¼	...do...	1942
133-51-19dad	Peter Haugen	34	1¼	...do...	1917
133-51-20aaa	John Hovak	18	1¼	...do...	1946
133-51-20bbb	USGS test 24 LR	77	4	Drilled	1948
133-51-20dbb	Ben Swenele	....	2	Driven	Old
133-51-21ccd	Joe Hovack	16	24	Dug	Old
133-51-22aaa	Thurston Gilje	18	2	Driven	....
133-51-22bcc	Albert Thompson	20	....	...do...	Old.
133-51-23dcc	Norman Krogness	503	2	Drilled	1933
133-51-24abb	John Score	460	2	...do...	1939
133-51-24baa	Andrew Braaton	400	2	...do...	Old
133-51-24ccd	Carl Huset	400(?)	2	...do...	Old
133-51-25ccc	Elmer Lischefski	28	2	Driven	Old

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
......	....	DS	Water reported hard, good.
Surface	10-18-47	DS	
20	10-47	DS	Never pumped dry.
40	10-47	...	Water reported hard, good.
12	10-47	DS	Aquifer, delta sand. Crust forms on sand point, which is changed every 3 to 4 years.
47	....	DS	Aquifer, delta sand. Water rusts pail.
14	10-47	DS	
......	....	DS	Water reported good, hard.
8	10-47	DS	
......	....	DS	
......	....	DS	
Flow	....	DS	Water reported soft, slightly salty.
14.95	10-18-47	S	Water reported unfit for human consumption.
Flow	....	DS	
......	....	DS	Aquifer, delta sand. Water level fluctuates.
......	....	DS	Water reported good, hard.
5	1947	DS	Do.
6	1944	DS	Do.
14	1946	DS	Do.
......	....	U	Hole refilled. See log.
4.56	10-18-47	DS	Water reported hard, good.
14	10-11-47	DS	Inadequate. Hauls water for stock. Unable to get sand point well.
......	....	DS	
6	5-47	DS	
Flow	10-11-47	DS	Water reported soft, slightly salty.
..do..	10-11-47	DS	Artesian pressure used for plumbing purposes.
..do..	10-11-47	DS	Do.
..do..	10-11-47	DS	Water reported soft, slightly salty.
......	....	DS	Water reported unfit for drinking, very hard.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
133-51-25ddb	H. G. Anderson	463	$2\frac{1}{2}$	Drilled	1933
133-51-26bcc	Victor Hlavnicka	....	2	...do...	Very old
133-51-27ccc	F. J. Blazek	25	$1\frac{1}{4}$	Driven	Old
133-51-27ddd	Matt Dahl	30	....	...do...	....
133-51-28aab	Frank Rhadenbaugh	....	2	...do...	....
133-51-28ccc	USGS test 34 LR	27	4	Drilled	1948
133-51-28ddd	USGS test 35 LR	37	4	...do...	1948
133-51-29bbb	USGS test 23 LR	82	4	...do...	1948
133-51-29bcc	Carl Freybert	22	2	Driven	Old
133-51-29cbb	USGS test 37 LR	77	4	Drilled	1948
133-51-30add	Raymond Kelly	20	2	Driven	Old
133-51-31ddd	USGS test 21 LR	67	4	Drilled	1948
133-51-32	J. B. Kelly	....	....	....	....
133-51-32bbb	USGS test 22 LR	82	4	...do...	1948
133-51-32bcb	USGS test 21	230	5	...do...	1948
133-51-32cbb	USGS test 36 LR	82	4	...do...	1948
133-51-34aaa	Jim Sherma	22	$1\frac{1}{4}$	Driven	Old
133-51-35bbd	Lou Nagel	22	$1\frac{1}{4}$	...do...	....
133-51-35ddd	Norman Berg	....	2	Drilled	Old
133-52-2 3/	Geo. and M. Grain	525	....	...do...	1937
133-52-4d 3/	J. Waldron	20	....	Driven	....
133-52-13a 3/	L. W. Mashek	25	....	...do...	....
133-52-15b 3/	Luth. Brotherhood	24	....	...do...	1934
133-52-18c 3/	Fed. Land Bank	22	....	...do...	....
133-52-19c 3/	Geo. Dahl	25	....	...do...	....
133-52-20b 3/	Ed Bleyhl	20	Sandpoint	...do...	1918
133-52-22b 3/	Luth. Brotherhood	38	....	...do...	1931
133-52-24a 3/	Farm Mech. Sav..Bank	47	..do....	...do...	1939
133-52-24b1 3/	H. Nelson	....	..do....	...do...	1939
133-52-24b2 3/	Henry Nelson	38	....	...do...	....
133-52-24c 3/	Dell Lyman	27	..do....	...do...	1939
133-52-24d 3/	F. Staples	26	..do....	...do...	1939
133-52-25b 3/	Evelyn Gillham	30	..do....	...do...	1939
133-52-25ddd	USGS test 33 LR	62	4	Drilled	1948

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
Flow	10-11-47	DS	Flowed 45 feet above surface when casing was installed in 1933.
..do..	10-11-47	DS	Water reported soft, slightly salty.
......	....	DS	Water reported hard, good.
12	10-11-47	DS	
......	....	U	
......	....	U	Hole refilled. See log.
......	....	U	Do.
......	....	U	Do.
......	....	DS	Water reported hard, good.
......	....	U	Hole refilled. See log.
5.6	10-18-47	DS	Water reported hard, good. See chemical analysis.
......	....	U	Hole refilled. See log.
......	....	U	
......	....	U	Do.
......	....	U	Do.
......	....	U	Do.
......	....	DS	Water reported hard, good.
......	....	DS	Do.
......	....	DS	
Flow	....	DS	
......	....	...	
......	....	...	
......	....	D	
......	....	...	
......	....	...	
......	....	D	
......	....	D	
......	....	D	
......	....	D	
......	....	...	
......	....	D	
......	....	D	
......	....	D	
......	....	U	Hole refilled. See log.

(See footnotes at end of table)

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date completed
133-52-26d 3/	Nick Smitt	25	Sandpoint	Driven	....
133-52-30aad	....	....	....	....	....
133-52-30a 3/	A. Anderson	22	...do...	...do...	....
133-52-31a 3/	John Ellend	20	...do...	...do...	....
133-52-31b 3/	John Hintz	20	...do...	...do...	....
133-52-32a 3/	L. Staber	206	....	Drilled	1931
133-52-34cdd	USGS test 30 LR	57	4	...do...	1948
133-52-35c 3/	Roy Dinger	18	....	Driven	....

Depth to water (feet below land surface)	Date of measurement	Use of water	Remarks
......	....	...	
......	....	DS	
......	....	D	
......	....	D	
......	....	D	
......	....	DS	
......	....	O	Cased to 20 feet and preserved for observation well. See log and chemical analysis.
......	....	...	

1/ Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 211, 1929.
2/ Abbott, G. A., and Voedisch, F. W., The municipal ground-water supplies of North Dakota: North Dakota Geol. Survey Bull. 11, p. 74, 1938.
3/ From well inventory made by county assessors in 1939 as part of State-wide well inventory under Works Projects Administration.

132-51-11cbb
Ruddy Bros. No. 1

Formation	Material	Thickness	Depth
	No samples	95	95
Till and associated glacioaqueous deposits:			
Glacioaqueous deposits:			
	Sand, fine to medium, angular grains, silty..........................	10	105
Till:			
	Clay, dark-gray, sandy, gravelly....	170	275
"Granite":			
	"Granite," gray to light greenish-gray, decomposed, micaceous	175	450
	Gneissic granite, schist chips	245	695

132-50-7caa
USGS test 13

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Clay, yellow, sandy, silty	7	8
	Clay, light-gray	126	134
Till and associated glacioaqueous deposits:			
Till (?):			
	Silt and clay, medium-gray, gravelly, some fine sand with medium sand from 235 to 250 feet. Soft red stone at 168 feet (red sandstone boulder?)	116	250
Benton (?) shale (Cretaceous):			
	Core of shaley siltstone, thinly laminated and fissile. Coarser fragments consist largely of angular quartz. Secondary pyrite and fish scales present	10	260
	Clay, medium-gray, silty, shell fragments from 320 to 330 feet ...	90	350
	Core of clayey siltstone. Coarser fragments mostly angular quartz. Black carbonaceous plant fragments, secondary pyrite and secondary aragonite present	10	360
Dakota (?) sandstone (Cretaceous):			
	Clay, dark-gray, silty, gravelly; thin sand beds	46	406
"Granite":			
	"Granite," light grayish-white, decomposed	14	420

132-50-12dab
USGS test 14

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Silt, yellow-brown	10	10
	Silt, light-gray	96	106
Till and associated glacioaqueous deposits:			
Till (?):			
	Silt, gray, sandy, gravelly	41	147
Glacioaqueous deposits:			
	Sand, gray, coarse with fine gravel, silty	2	149
Till:			
	Silt and clay, gray, sandy, gravelly	115	264
Glacioaqueous deposits:			
	Sand, gray, gravelly, clayey	16	280
Till:			
	Clay and silt, blue-gray, very gravelly	20	300
	Core of till. Limestone and granite pebbles in clay matrix. Much wood, not carbonized	10	310
	Silt and clay, gray, sandy, gravelly	45	355
Glacioaqueous deposits:			
	Sand, gray, very fine to coarse, gravelly, silty	42	397
"Granite":			
	"Granite," whitish-gray, decomposed.	13	410

132-51-6cbb
USGS test 20

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black, silty	1	1
	Sand, light-brown, very fine to fine.	47	48
	Clay, light-brown, silt, shale and coal chips	88	136
Till and associated glacioaqueous deposits:			
Till:			
	Clay, medium-brown, sandy, gravelly, unassorted	74	210

132-51-7bbd
USGS test 3

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	2	2
	Sand, brown, fine	12	14
	Sand, buff to light-gray, silt, very fine	16	30
	Clay and silt, blue-gray, sandy	87	117
Till and associated glacioaqueous deposits:			
	Clay, very light-gray, silty, gravelly	18	135
	Clay, light-gray, sandy	65	200
	Silt and clay, light gray-brown, clayey, sandy, gravelly	40	240
Benton (?) shale (Cretaceous):			
	Clay, black, soft, gravelly. Cemented bed or boulder at 294 feet	70	310
	Core of gray silty shale. Silt is mostly very angular quartz grains with some euhedral quartz crystals. A little lignite. Fish scales and plant fragments present	10	320
	Clay, gray, compact; little or no gravel	60	380
	Clay, black, with thin sand beds; no gravel. Cemented bed or boulder at 422-436 feet	65	445
	Clay, alternating beds of black, dark-brown and gray	55	500
Dakota (?) sandstone (Cretaceous):			
	Clay, dark-brown with a few thin sand beds	30	530
	Clay, pink and white, sandy	7	537
	Clay, alternating beds of dark-brown, black and red	3	540
"Granite":			
	Clay, reddish, with quartz crystals.	10	550
	Clay, light greenish-gray and white, with quartz crystals	20	570

132-51-7bca
USGS test 12

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Silt, yellow-brown, sandy	9	10
	Silt, yellow-brown, gravelly	10	20
	Silt, light olive-gray, with fine gravel	25	45
	Silt, gray, sandy, gravelly	25	70
Till and associated glacioaqueous deposits:			
	Silt, yellow-brown, with a little gravel, last 5 feet sandy	65	135
	Silt, light olive-gray, sandy, with a little gravel	40	175
Till:			
	Clay and silt, gray, sandy, gravelly	25	200
Glacioaqueous deposits:			
	Gravel, gray, fine to medium, sandy, silty	5	205
	Gravel, gray, very silty, sandy	5	210
Till:			
	Clay and silt, gray, sandy, gravelly	10	220

132-51-7bcc
USGS test 11

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Silt, yellow, sandy	9	10
	Silt, light olive-gray	85	95
Till and associated glacioaqueous deposits:			
Till:			
	Silt, light olive-gray, sandy, gravelly	95	190
Glacioaqueous deposits:			
	Gravel, gray, fine to medium, sandy	20	210
	Gravel, gray, fine-medium, sandy, very silty	20	230
Till:			
	Silt, dark-gray, sandy, gravelly ...	10	240

132-51-7bdc
USGS test 19

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Silt and clay, yellow, sandy, fine, some shale gravel	6	7
	Clay, light olive-gray, silty	8	15
	Clay, light olive-gray, silty, sandy	25	40
	Clay, light olive-gray	5	45
	Clay, light olive-gray, silty	57	102
Till and associated glacioaqueous deposits:			
	Clay, light olive-gray, silty, sandy, gravelly	68	170
Till:			
	Clay, light olive-gray, silty, sandy, gravelly	80	250

132-51-7cbb
USGS test 16

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Silt, yellow-brown, clayey, limonitic	7	8
	Silt and clay, light olive-gray, small amount very fine sand	47	55
	Clay, light olive-gray	15	70
	Clay, light olive-gray, silty	21	91
	Clay and silt, light-gray, sandy	9	100
Till and associated glacioaqueous deposits:			
	Clay and silt, light-gray, sandy, some fine gravel	55	155
	Clay and silt	15	170
	Clay and silt, light-gray, coarse sand, gravelly except from 195 to 205 feet	40	210
	Clay and silt, gray-brown, sandy	5	215
	Clay and silt, dark-gray, sandy	5	220
	Clay and silt	5	225
	Clay and silt, dark-gray, little gravel	5	230

132-51-7daa
USGS test 15

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Silt, yellow-brown, sandy, with fine gravel	3	4
	Sand, yellow-brown, with fine gravel	2	6
	Silt, yellow-brown, with fine gravel	6	12
	Silt, light olive-gray, clayey	58	70
Till and associated glacioaqueous deposits:			
	Silt, yellow-brown, with clay and shale pebbles, slightly sandy at 85 feet and becoming more grayish.	25	95
	Silt and clay, light olive-gray, sandy, few small shale pebbles less than ¼ inch in diameter	45	140
	Silt, light-gray, sandy with fine gravel	5	145
	Sand, light-gray, medium coarse, with fine gravel, silty	10	155
	Gravel, gray, medium coarse, sandy, silty	15	170
	Clay, gray, silty, sandy with fine gravel	15	185
	Silt and clay, gray, sandy, gravelly	50	235
	Clay, dark-gray, silty, sandy	5	240
	Clay, dark-gray, gravelly, sandy ...	6	246

132-51-7ddd
USGS test 4

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Silt, yellow-buff	8	8
	Silt, light-gray	32	40
	Sand, blue, fine	15	55
	Silt, light-gray	59	114
Till and associated glacioaqueous deposits:			
	Gravel, fine, silty	4	118
	Silt, light-gray, some fine to medium gravel, clayey	53	171
	Gravel, fine	3	174
	Silt, light-gray, gravelly, clayey	15	189

132-51-17cdd
USGS test 8

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Clay, yellow-buff, silty	16	17
	Silt, light-gray	65	82
Till and associated glacioaqueous deposits:			
	Silt, light-gray, gravelly	69	151
Glacioaqueous deposits:			
	Gravel, light-gray, fine, silty, sandy	3	154
Till:			
	Clay, light-gray, gravelly	41	195
	Clay, dark-gray, gravelly	5	200

132-51-18ccc
USGS test 25 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand, dark-brown, fine, silty	2	2
	Sand, yellow-brown, very fine to fine, silty	5	7
	Sand, yellow, very fine to coarse, silty	15	22
	Sand, light-gray, very fine to fine, silty	70	92
	Silt, light-gray, sandy	5	97
	Silt and clay (bit sample)		97

132-51-18daa2
USGS test 5

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Silt, yellow-buff	13	14
	Silt, light-gray	56	70
Till and associated glacioaqueous deposits:			
	Silt, medium-gray, some fine gravel.	90	160
	Clay, buff, silty	8	168
Glacioaqueous deposits:			
	Gravel, gray to buff, fine to medium, clayey	11	179
Till:			
	Clay, gray, gravelly	21	200

132-51-19aaa
USGS test 10

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	2	2
	Silt, yellowish-buff, sandy, clayey	7	9
	Silt, light-gray, sandy, clayey	11	20
	Silt, light-gray, clayey	10	30
	Silt, light-gray, sandy, gravelly ..	20	50
	Sand, light-gray, very fine, silty, gravelly	25	75
	Sand, light-gray, very fine	29	104
Till and associated glacioaqueous deposits:			
Till (?):			
	Silt and clay, gray, sandy, gravelly	96	200

132-51-20aab
USGS test 7

Formation	Material	Thickness	Depth
Lake Agassiz deposits;			
	Topsoil, black, sandy, silty	3	3
	Silt, buff	27	30
	Silt, light-gray	35	65
Till and associated glacioaqueous deposits:			
	Silt and clay, light-gray, some fine gravel	70	135
Till:			
	Silt and clay, light-gray, with fine gravel	40	175
	Silt and clay, dark-gray, gravelly .	25	200

132-51-20bba
USGS test 9

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Clay, yellowish-buff	10	10
	Silt, light-gray	38	48
	Silt, light-gray, some fine gravel	22	70
	Sand, light-gray, very fine, silty, some fine gravel	42	112
Till and associated glacioaqueous deposits:			
Till (?):			
	Silt, light-gray, sandy, some fine gravel	75	187
Glacioaqueous deposits:			
	Gravel, gray, fine to medium, sandy	8	195
	Gravel, gray, fine, sandy, very silty	15	210

132-51-20ddd
USGS test 6

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Clay, grayish-buff, sandy, gravelly	4	5
	Clay, yellow-buff	13	18
	Silt, gray	55	73
	Silt, gray, sandy	62	135
Till and associated glacioaqueous deposits:			
Till:			
	Silt and clay, gray, slightly gravelly	18	153
Glacioaqueous deposits:			
	Gravel, gray, silty, sandy	3	156
Till:			
	Silt and clay, gray, slightly gravelly	8	164

132-52-1ddd
USGS test 29 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, sand, brown, clayey	2	2
	Sand, yellow, fine, silty	10	12
	Silt, grayish-buff to gray, sandy ..	90	102

132-52-2aaa
USGS test 32 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, silt and clay, brown-black, with fine sand	2	2
	Sand, buff, very fine, silty	5	7
	Sand, whitish-gray, very fine to medium, clean; becomes finer with depth	30	37
	Sand, light-gray, very fine, silty .	5	42
	Clay, light olive-gray, silty	5	47

132-52-2bbb
USGS test 31 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, dark-brown, with very fine sand and silt	2	2
	Sand, buff-brown, fine silty	15	17
	Sand, light-gray, very fine to coarse	40	57
	Sand, gray, very fine to fine, silty	10	67
	Clay, gray, silty	10	77

132-52-3ddd
USGS test 29 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand, dark-brown, very fine, silty ..	7	7
	Sand, light-brown, very fine to fine, silty	5	12
	Silt and clay, buff-gray, sandy	15	27
	Sand, light-gray, very fine to coarse, silty	5	32
	Sand, light-gray, very fine to coarse, silty, with fine to medium gravel .	5	37
	Sand, light-gray, very fine to coarse, silty	5	42
	Sand, light-gray, very fine to coarse	35	77
	Silt, light-gray, clayey, sandy	15	92
	Silt, light-gray, clayey	5	97

132-52-12abc
USGS test 18

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	2	2
	Silt, yellow	5	7
	Clay, gray-brown, silty	79	86
Till and associated glacioaqueous deposits:			
Till:			
	Silt, gray-brown, clayey, sandy, gravelly	19	105
	Silt, gray-brown, clayey, with fine sand	89	194
Glacioaqueous deposits:			
	Sand, dark-gray, medium to coarse, with fine gravel	1	195
Till:			
	Silt and clay, gray, sandy, gravelly.	13	208
Glacioaqueous deposits:			
	Sand, coarse, with fine gravel, clayey	2	210
Till:			
	No sample taken. Driller's log records clay, dark-brown, small amount fine gravel	10	220

132-52-12bbb
USGS test 28 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, fine sand, brown-black, clayey	2	2
	Sand, yellow-brown, clayey	10	12
	Silt, light-gray, sandy, clayey	15	27
	Silt, light olive-gray (bit sample).		27

132-52-12ccc
USGS test 27 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, silt and clay, brownish-black, sandy	2	2
	Silt and clay, yellowish-buff to yellowish-gray, sandy	20	22
	Silt, light olive-gray, clayey	5	27

132-52-12daa
USGS test 17

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Silt and clay, yellow-brown, sandy .	8	9
	Silt, light olive-gray, clayey, clay pebbles, some very fine sand from 40 to 60 feet	61	70
Till and associated glacioaqueous deposits:			
	Silt, light olive-gray, clayey, with fine to coarse sand and shale and dolomite gravel	35	105
	Silt and clay, light-gray, with small amount very fine sand	65	170
	Silt and clay, light-gray, sandy, gravelly	25	195
	Silt and clay, dark-gray, sandy, with some medium gravel at 215 to 220 feet	35	230

132-52-36ddd
USGS test 26 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, clay, black to brown, sandy, silty	2	2
	Clay, buff, sandy, silty	10	12
	Sand, buff, very fine, clayey	15	27
	Silt, buff to gray, sandy with fine gravel	20	47
	Clay, light-gray, silty, with some large gravel	5	52

133-51-20bbb
USGS test 24 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand, brown, very fine, silty	7	7
	Silt, light creamy-brown, sandy	5	12
	Sand, grayish-buff, very fine, silty	5	17
	Sand, light-gray, very fine to fine, silty	50	67
	Clay, light-gray, silty, sandy	5	72
	Clay, light olive-gray, silty	5	77

132-51-28ccc
USGS test 34 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, sand, brown-black, very fine	2	2
	Silt, yellowish-brown, sandy	5	7
	Silt, grayish-brown	20	27

133-51-28ddd
USGS test 35 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, brownish-black, sandy	2	2
	Sand, yellowish-brown, very fine, very silty	5	7
	Silt, light olive-gray, clayey, sandy	30	37

133-51-29bbb
USGS test 23 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Sand, light gray to buff, very fine, silty	7	7
	Sand, gray, silty	60	67
	Silt and clay, light-gray, sandy ...	10	77
	Clay and silt, gray	5	82

133-51-29cbb
USGS test 37 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, brown-black, very fine, sandy	2	2
	Sand, yellow-brown to buff, very fine, clayey	15	17
	Sand, gray, fine to medium, with coarser coal flakes	55	72
	Clay, gray	5	77

133-51-31ddd
USGS test 21 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black, sandy	2	2
	Silt, buff, sandy	5	7
	Sand, buff, very fine	40	47
	Sand, buff, silty	10	57
	Silt, buff, slightly sandy	5	62
	Silt, grayish-buff	5	67

133-51-32bbb
USGS test 22 LR

Lake Agassiz deposits:			
	Sand, brown, fine, silty	12	12
	Sand, gray, fine, silty	60	72
	Sand, buff, very fine, silty	5	77
	Silt, buff, sandy	5	82

133-51-32bcb
USGS test 21

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, black	1	1
	Clay, yellow, sandy, silty	6	7
	Sand, light-gray, fine, silty	63	70
	Clay and silt, light-gray, sandy ...	75	145
Till and associated glacioaqueous deposits:			
Till:			
	Clay, light-gray, sandy, gravelly ..	19	164
Glacioaqueous deposits:			
	Gravel, light-gray, fine, sandy, silty	5	169
Till:			
	Clay, light-gray, sandy, gravelly ..	61	230

133-51-32cbb
USGS test 36 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, silt and very fine sand, yellowish-brown	7	7
	Sand, light-buff, very fine, 67 to 72 feet, silty	65	72
	Silt, light-buff, sandy	5	77
	Silt, light-gray, clayey	5	82

133-52-25ddd
USGS test 33 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, brownish-black, sandy	2	2
	Sand, yellowish-brown, very fine to fine, silty, coarser from 17 to 22 feet	20	22
	Sand, light-gray, very fine to medium, silty, many coal flakes from 37 to 42 feet, finer and siltier below 42 feet	30	52
	Silt and clay, light-gray, with very fine sand	5	57
	Silt, light olive-gray, clayey	5	62

133-52-34cdd
USGS test 30 LR

Formation	Material	Thickness	Depth
Lake Agassiz deposits:			
	Topsoil, brown, with very fine sand and silt	2	2
	Sand, orange-brown, very fine, silty	5	7
	Sand, whitish-gray, very fine, silty (some medium to coarse sand below 22 feet)	45	52
	Clay and silt, sandy, with fine to medium gravel	5	57

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