GEOLOGY AND GROUND-WATER RESOURCES OF THE HANKINSON AREA RICHLAND COUNTY, NORTH DAKOTA

BY

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NORTH DAKOTA GROUND-WATER STUDIES NO. 25

PREPARED COOPERATIVELY BY THE UNITED STATES GEOLOGICAL SURVEY,
THE NORTH DAKOTA STATE WATER CONSERVATION COMMISSION, AND THE
NORTH DAKOTA GEOLOGICAL SURVEY

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ABSTRACT

The area described in this report is in Richland County in southeastern North Dakota and consists of 84 square miles in the vicinity of the city of Hankinson.

The geologic units in the area are as folows, from the land surface down: Surface deposits of Pleistocene age consisting of Lake Agassiz deposits and deposits of end moraine; till and associated melt-water deposits of sand and gravel of Pleistocene age; shale of Cretaceous age; and Precambrian rocks.

The deposits of glacial Lake Agassiz date from the Mankato substage of the Wisconsin stage of the Pleistocene epoch. They cover all the area except a small part of the southwest corner, which is occupied by end moraine. These glacial-lake deposits include clay and silt in the eastern part of the area and sand of the Sheyenne River delta in the central and northwestern parts.

The sand deposits of the Sheyenne River delta constitute the most important aquifer in the area. An aquifer test was made at the well of the Minneapolis, St. Paul, and Sault Ste. Maire Railroad, which is near the site of test hole 803; the average coefficient of transmissibility of the delta sands was calculated to be 18,000 gallons per day per foot and

the coefficient of storage to be 0.17. Properly spaced wells probably could produce 200,000 gallons of water per day each without seriously lowering the water levels. The sand deposits, which contain small amounts of silt, extend from the land surface to a maximum determined depth of 166 feet and average 89 feet in thickness. Water obtained from these deposits is generally potable and of good quality; it is suitable for irrigation as well as for general domestic use.

Clay and silt deposited in glacial Lake Agassiz constitute the surface deposits of the eastern part of the area covered by this report. They generally are thin and compact and are not regarded as a source of ground water in the Hankinson area.

Glacial till and associated sand and gravel deposits underlie the Lake Agassiz deposits throughout the report area. The average thickness of the till, as determined at five test holes that penetrated it entirely, is 180 feet. Most farm wells outside the delta area obtain their water from sand and gravel deposits within the till. These wells generally produce small amounts of water, which is more highly mineralized than water from the delta deposits. However, the water usually is adequate for farm and domestic use except during periods of prolonged drought.

Samples from test holes penetrating the galcial till did not reveal an oxidized zone that would indicate the presence of an older drift. However, a considerable amount of additional test drilling would be necessary to determine whether or not a pre-Mankato substage or pre-Wisconsin stage of glaciation is represented in the area.

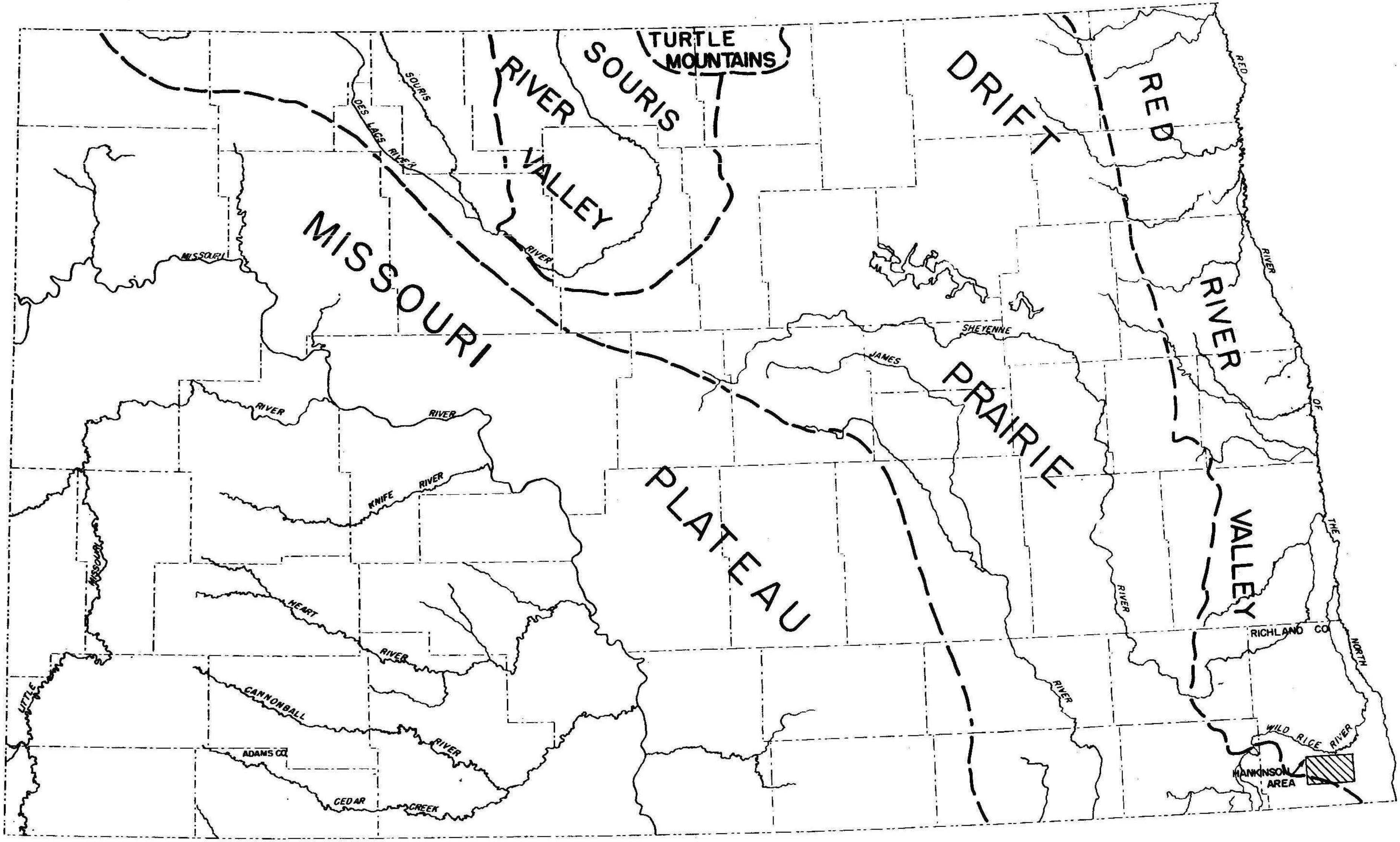

FIGURE 1

MAP SHOWING PHYSIOGRAPHIC PROVINCES IN NORTH DAKOTA (MODIFIED AFTER SIMPSON) AND LOCATION OF THE HANKINSON AREA.

A shale, believed to be the Benton shale of Cretaceous age, underlies the glacial drift at the sites of all test holes that completely penetrated the drift deposits. As no fossils were recovered from the shale, it could not be positively identified. The Benton (?) shale underlies the glacial drift in the Fairmount area 9½ miles east of the Hankinson area.

The Dakota sandstone is not known to underlie the Hankinson area. Cuttings from the only test hole drilled to a sufficient depth to reach the Dakota produced no evidence of the presence of that formation. However, it is present 12 miles to the west at a depth of 960 feet, and 10 miles to the east at a depth of 230 feet. Although the presence of the Dakota sandstone in the report area has not been proved, it is believed to be present as isolated remanents or narrow extensions. At some places in the area it may be represented by a sandy facies at the base of the shale.

The shale of Cretaceous age is underlain by light-gray to green clay deposits that are believed to represent a decomposed Precambrian granite. Decomposed granite was reached at a depth of 383 feet in test hole 813. Drilling was continued 17 additional feet without reaching the unaltered granite.

INTRODUCTION

Location and General Features of the Area

Hankinson, population 1,350 (1950 census), is in the south-central part of Richland County. The area covered by this report is approximately 84 square miles and is in the following townships: All of T. 130 N., Rs. 49 and 50 W., and the southern tier of sections of T. 131 N., Rs. 49 and 50 W. Hankinson, the only city in the area, is served from the east and the west by State Highway 11 and by branches of the Soo Line and Great Northern Railroads. A United States Weather Bureau station is located at the railroad station in Hankinson, where the average annual precipitation recorded from 1891 to 1954 was 20.54 inches. Most of the precipitation falls during the growing season. The mean annual temperature during the same period was 42.9 degrees. The principal occupation in the area is farming; the main crops are oats, corn, barley, flax, and soybeans. Cattle and sheep grazing are practical in the southwest (end moraine) part of the area and in the northwest (dune) part of the area. (See pl. 1.)

Purpose and Scope of the Investigation

This report is a progress report on a study of the geology and ground-water resources of Richland County, N. Dak., which is being made by the United States Geological Survey in cooperation with the North Dakota Water Conservation Commission and the North Dakota Geological Survey. This investigation is one of a series being made to study the surface and subsurface geology and to determine the occurrence, movement, dishcarge, and recharge of the ground water, as well as the quantity and quality of ground water available for municipal, domestic, industrial, and irrigation purposes. At present (1954) the most cirtical need in the State is for an adequate and perennial water supply for the many small towns and cities that are attempting to install water-supply systems or are expanding present facilities. Because of this need, the countywide studies are begun in the vicinities of those towns which have requested aid from the State Water Conservation Commission and the State Geologist.

Progress reports are released as soon as possible so that the data may be available to aid in the solution of the water-supply problems of the towns and for general reference material. This investigation was made in 1953 and 1954 under the direct supervision first of P. D. Akin, district engineer, and then of Joseph W. Brookhart, district geologist, Grand Forks, N. Dak. The field work and test drilling were done by or under the direct superivision of the author, using a rig owned by the North Dakota State Water Conservation Commission. Chemical analyses included in the report were made by the North Dakota State Laboratories Department.

Previous Investigations and Acknowledgments

A general study of the geology and ground-water resources of Richland County was made by Simpson (1929, p. 208-214, 296),[1] and he includes in his report the records and chemical analyses of several wells in the Hankinson area. Abbott and Voedisch (1938, p. 74) made an investigation of the municipal water supplies of North Dakota and their report included a well description and chemical analysis of the water from a Hankinson city well.

The first investigation of the geology of the area was made by Upham (1895) who made a study of the surface features in the vicinity of Hankinson in connection with his report on glacial Lake Agassiz. A similar investigation was made later by Leverett (1932).

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[1] See Selected Bibliography for references given

The cooperation of the residents of the Hankinson area was of great help in the present investigation. Valuable assistance was given by members of the city council, one of whom, Mr. Peter Wollack, helped with the well inventory and the collection of water samples and supplied other useful information.

Physiographic Features

The area is a part of the Western Young Drift section of the Central Lowland province (Fenneman, 1938, p. 599) and, except for a small portion in the southwest corner, is in the Red River Valley area as designated by Simpson (1929, p. 4). The Red River Valley is a broad, flat glacial-lake plain modified by low beach ridges and deltas. In the Hankinson area the valley floor is slightly irregular and reflects the modified morainal surface of the underlying till, which, because of the thinness of the lake deposits, alters the surface topography.

The Sheyenne River delta is the largest known to have been deposited in glacial Lake Agassiz. It covers an area of approximately 800 square miles to an average depth of 40 feet (Upham, 1896, p. 315). The material in the delta consists principally of sand and varying amounts of clay and silt. The sand of the Sheyenne delta composes the surficial materials over approximately half the area, and in places wind action has formed rugged dunes 25 to 100 feet high. One dune-sand area extends into and occupies approximately 4 square miles in the northwestern part of the report area. The dune sand is fairly stable and is covered with prairie grasses and brush, which provide forage for cattle and sheep. Other isolated dunes are scattered throughout the area, the most prominent

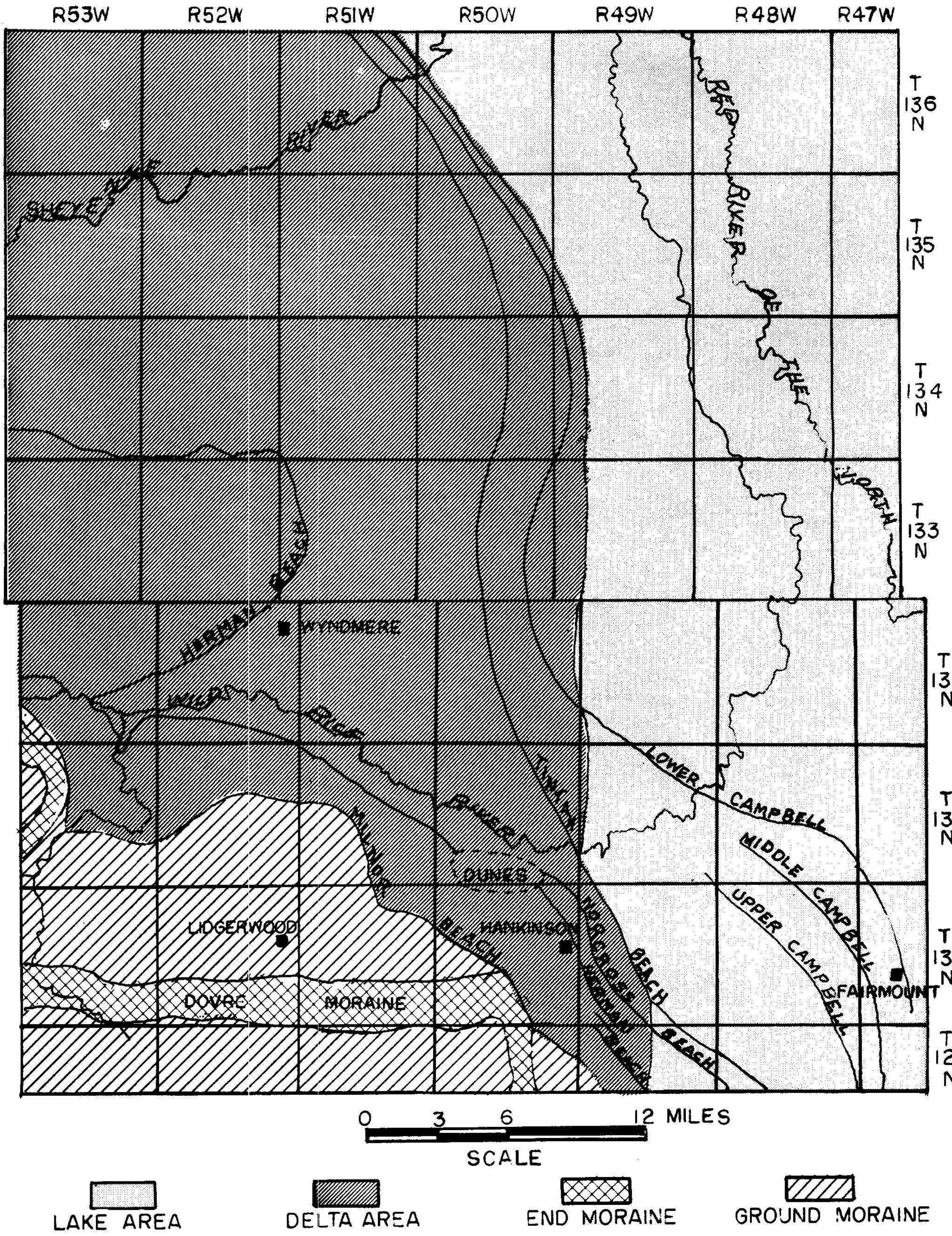

FIGURE 2

MAP SHOWING PART OF THE SHEYENNE DELTA AND OTHER TOPOGRAPHIC FEATURES ASSOCIATED WITH GLACIAL LAKE AGASSIZ (AFTER UPHAM)

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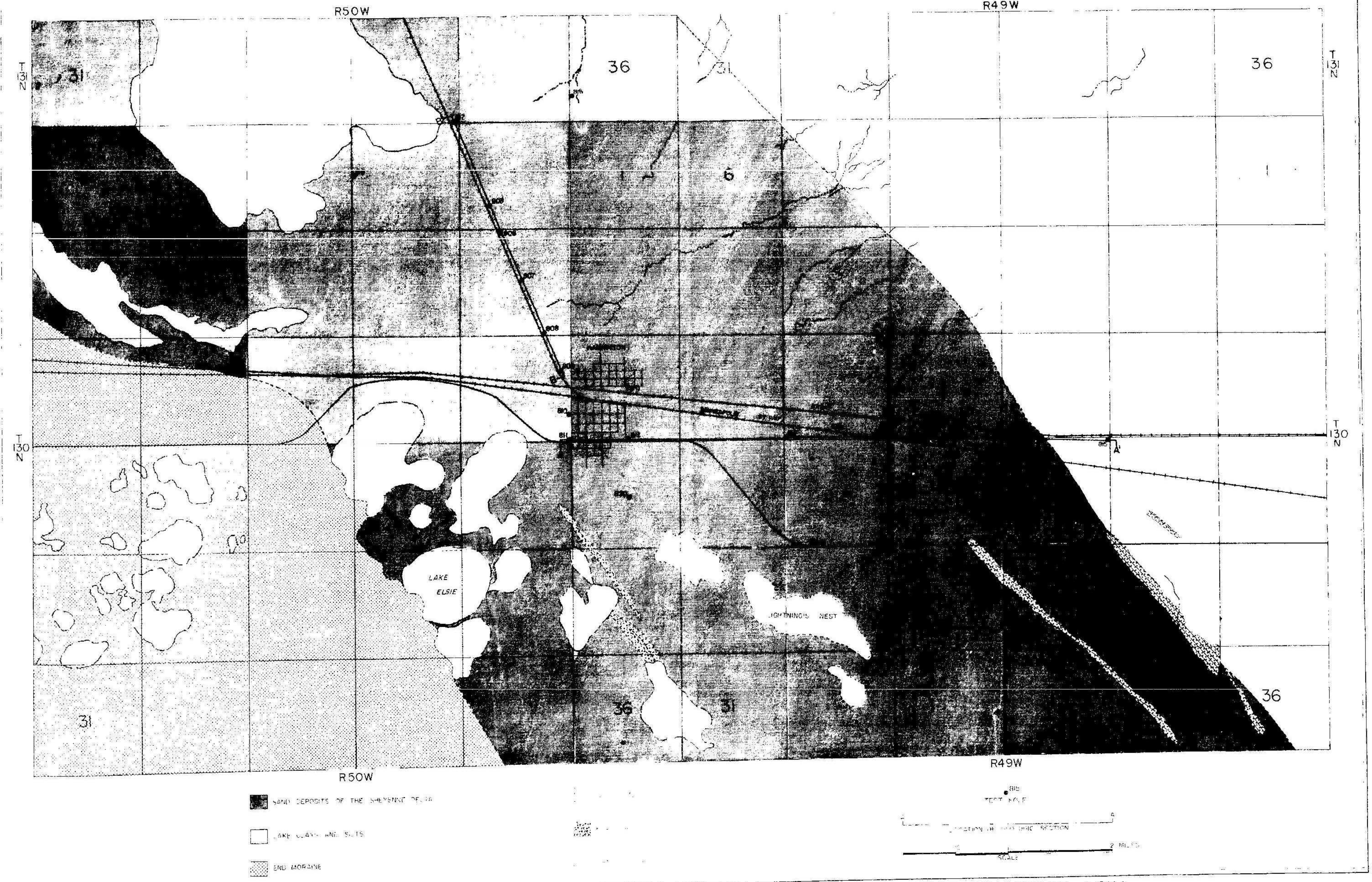
NORTH DAKOTA GROUND-WATER
STUDIES NO. 25 PLATE 1



MAP SHOWING SURFACE GEOLOGY AND LOCATIONS OF TEST HOLES IN THE HANKINSON AREA being "Lightning's Nest," a name translated from the original Sioux Indian tongue. This dune is approximately 1¼ miles long and a quarter of a mile wide and ranges in height from 10 to 60 feet. The prominent dunes follow approximately the trend of the Herman beach (Upham, 1896, p. 309), which in the Hankinson area is northwestward. (See fig. 2)

In its southwestern corner the area is predominantly hilly and has a rough morainic surface, which is strewn with numerous boulders and contains many potholes and small lakes. This moraine, designated the Seventh or Dovre by Upham (1896, p. 147), varies in width from half a mile to 2 miles (see fig. 2). It trends generally northwestward and is traceable to the galcial Lake Souris area in the northwestern part of the State (Upham, 1896, p. 157).

An approximate line of transition between the delta deposits to the west and the lake clays and silts to the east can be drawn from about the SE¼ sec. 36, T. 130 N., R. 49 W., and proceeds thence in a northwesterly direction across the area to the southwest corner of sec. 31, T. 131 N., R. 49 W. (see pl. 1). This line follows the course of a group of indistinct and discontinuous beach ridges, the Tintah Beaches (Upham 1896, p. 402), which extend along the eastern margin of the Sheyenne delta.

Most of the area is imperfectly drained by the Wild Rice River, which follows a course roughly parallel to the northern border of the area and then turns northeastward to its confluence with the Red River of the North. The Red River of the North flows northward and is a part of the Hudson Bay drainage system. Numerous small, shallow coulees drain northward to the Wild Rice River, but they flow only intermittently in the spring, when the ground surface is frozen. The sandy soil of the delta area is so permeable that little additional runoff occurs except when the rainfall is exceptionally heavy. Drainage is very poorly developed in the lake-silt parts of the area and excess moisture remains ponded before slowly draining off, evaporating, or percolating into the soil.

A small southwestern part of the report area drains southward. This part is adjacent to the end moraine and is partly occupied by a chain of lakes and potholes, the most prominent of which is Lake Elsie. Leverett (1932, p. 122-123) states that this area was occupied by Lake Milnor, a preliminary stage of Lake Agassiz, which was a long, narrow glacial lake along the ice margin and which had an outlet about 4 miles south from Hankinson.

Beach ridges in the report area were formed by wave and ice action during the several stages of Lake Agassiz; however, they are not conspicuous topographic features, as they are very broad in comparison with their height and generally are discontinuous.

Water Supply

Residents of the Hankinson area depend almost exclusively upon wells for water for domestic, farm, and industrial purposes. Cisterns are used to augment well supplies in some parts of the area, especially in the eastern part. Ground water in that part of the area is usually insufficient in quantity or objectionable because of its poor chemical quality.

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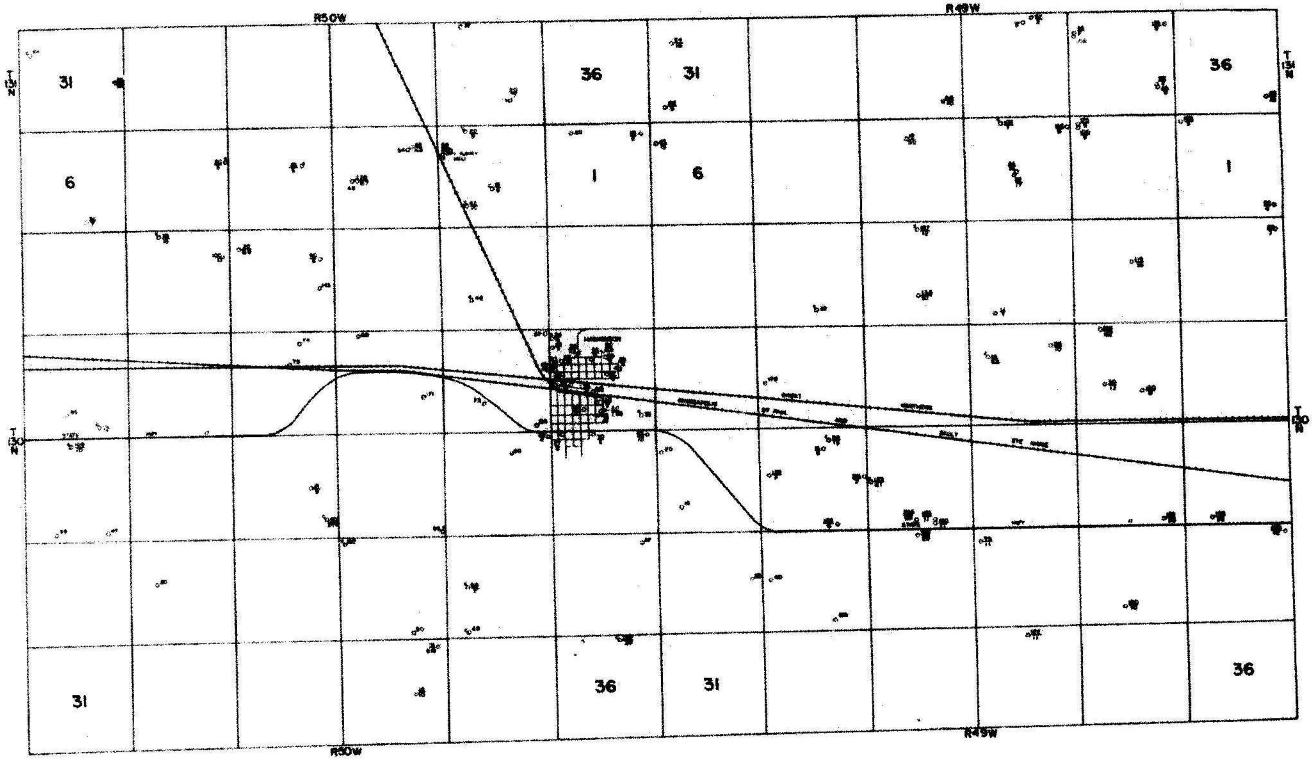
NORTH DAKOTA GROUND-WATER
STUDIES NO. 25 PLATE 2



EXPLANATION

120
4.1

EXISTING WELL. UPPER NUMBER (120) INDICATES DEPTH OF WELL. LOWER NUMBER (4.1) INDICATES DEPTH TO WATER BELOW LAND SURFACE. LETTER "F" INDICATES FLOWING WELL. LETTER "C" INDICATES WELL FROM WHICH WATER SAMPLE WAS OBTAINED FOR CHEMICAL ANALYSIS. SINGLE NUMBER INDICATES DEPTH OF WELL.

0 1 2 MILES
SCALE

MAP SHOWING LOCATIONS OF WELLS, DEPTHS OF WELLS, AND DEPTHS TO WATER IN WELLS IN THE HANKINSON AREA.

Prior to the installation of the municipal water-supply system, residents of the city of Hankinson obtained water from numerous shallow wells in the city. These supplies were supplemented by water hauled from a spring at the base of the moraine on the west side of Lake Elsie. Two wells (City wells 1 and 2) were drilled to depths of 156 and 158 feet, respectively, and a municipal distribution system was installed in 1920. The wells penetrated a sand-and-gravel aquifer in the glacial drift. The water produced by the wells, however, was highly corrosive and caused considerable expense in well repair. Additional expense was caused by the deposition of black scale in the water mains, as discussed in the quality-of-water section of this report. Another well (City well 3) was drilled in 1948, but by 1951 the well casing and pump bowls were corroded so much that they had to be repaired at a cost of $5,000. From 1951 to 1954 only one city well produced a satisfactory amount of water. Problems arising from corrosion and hardness continued until 1954 when, on the basis of information gathered in this investigation, a new well (City well 4) was drilled 2 miles northwest from the city. The new well, 60 feet deep, produces water of much better quality than that produced by the earlier municipal wells.

When the investigation began, about 50,000 gallons of water per day was used by the city of Hankinson, but now that water of better quality is available it is estimated that the demand will increase twofold.

Well-Numbering System

The well-numbering system used in this report is illustrated in figure 3 and is based upon the location of the well within the U. S. Bureau of Land Management's survey of the area. The first numeral denotes the township north of the base line; the second numeral denotes the range west of the fifth principal meridian, and the third numeral denotes the section in which the well is located. The letters a, b, c, and d, designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections (10-acre tracts). Consecutive terminal numerals are added when more than one well is located within a given 10-acre tract. Thus, well 130-50-2bbc is in the southwest quarter of the northwest quarter of the northwest quarter of section 2, T. 130 N., R. 50 W. Similarly, well 130-50-2cca2 is the second well located in the northeast quarter of the southwest quarter of the southwest quarter of section 2, T. 130 N., R. 50 W.

GEOLOGY AND OCCURRENCE OF GROUND WATER

Principles of Occurrence of Ground Water

Essentially all ground water is derived from precipitation. Rain or melting snow enters the ground by direct penetration or by percolation from streams and lakes that lie above the general water table. Ground water generally moves laterally from areas of recharge to areas of natural discharge.

Ground water is discharged by evaporation from lakes and ponds, by transpiration by plants and evaporation from the land surface in areas

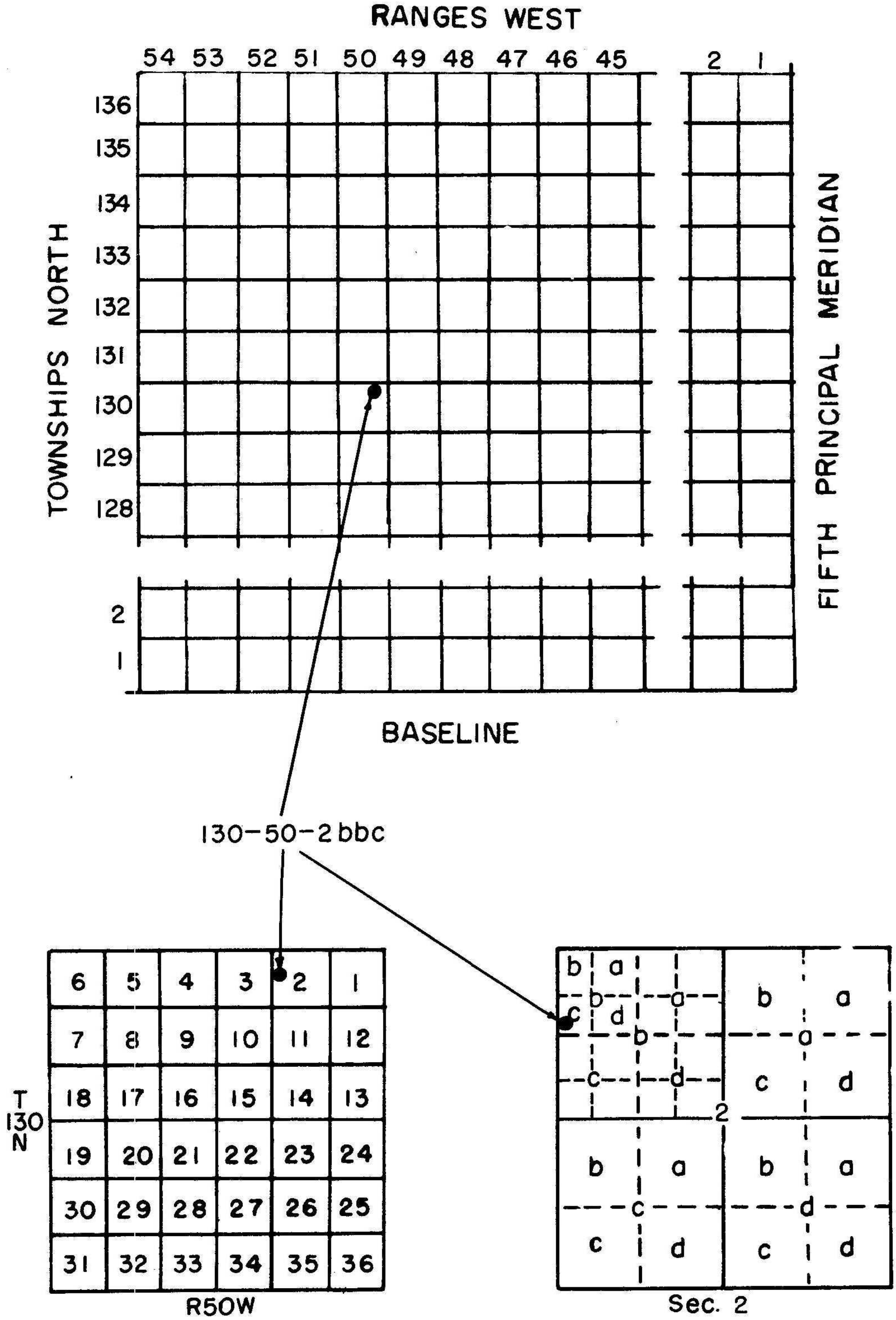


Figure 3 -- Sketch illustrating well-numbering system.

where the ground-water level is near the land surface, by seepage to streams, and by pumping from wells.

Any rock formation or stratum that will yield water in sufficient quantity to be important as a source of supply is called an "aquifer" (Meinzer, 1923, p. 52). Water moving in an aquifer from recharge to discharge areas may be considered to be in "transient storage."

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

The capacity of an aquifer to yield water by gravity drainage may be much less than indicated by its porosity because part of the water is held in the pore spaces by molecular attraction between the water and the rock particles; the smaller the pore, the greater the proportion of water that will be held. The amount of water, expressed as a fraction of a cubic foot, that will drain by gravity from 1 cubic foot of an aquifer is called the "specific yield" of the aquifer.

If the water in an aquifer is not confined by overlying, impervious strata the water is under water-table conditions. Under these conditions, water can be obtained from storage in the aquifer by gravity drainage-that is, by lowering the water level as in the vicinity of a pumped well.

Water is under artesian conditions if it is confined in the aquifer by an overlying, impermeable stratum. Under these conditions, hydrostatic pressure will raise the water in a well, or other conduit penetrating the aquifer, above the top of the aquifer and water is yielded as the water level in the well is lowered. However, the aquifer remains saturated and water is yielded because the water expands and because the aquifer is compressed as the pressure is decreased. Gravity drainage does not occur under normal artesian conditions. The water-yielding capacity of an artesian aquifer is called the "coefficient of storage" and generally is very much smaller than the specific yield of the same material under water-table conditions. The coefficient of storage of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

To aid in visualizing this concept, it is helpful to imagine an artesian aquifer which is elastic and uniform in thickness and which for convenience is assumed to be horizontal. If the head of water in this aquifer is reduced, there will be released from storage a certain volume of water. The amount of water thus released will be proportional to the decrease in head. Imagine further a representative prism extending vertically from the top to the bottom of this aquifer, and extending laterally so that its cross-sectional area is coextensive with the area of the aquifer over which the head change occurs. The volume of water released from storage in that prism, divided by the product of the prism's cross-sectional area and the change in head, results in a demensionless number which is the coefficient of storage.

In the case of a water-table aquifer, regardless of its position in relation to a horizontal plane, the water released from or taken into storage in response to a change in head is attributed partly to gravity drainage or refilling of the zone through which the water table moves and partly to compressibility of the water and of the material in the saturated zone. The volume of water thus released or stored, divided by the product of the area of aquifer surface over which the head change occurs and the component of head change normal to that surface, correctly determines the storage coefficient of the aquifer.

Generally, under water-table conditions, the volume of water attributable to compressibility is a negligible part of the total volume of water released from or taken into storage and can be disregarded. Thus, for a water-table aquifer, the coefficient of storage is essentially equal to the specific yield.

The resistance to the movement of water through pore spaces that are relatively large, as in coarse gravel, is not great and the material is said to be permeable. However, the resistance to the movement of water through small pore spaces, as in clay or shale, may be very great and the material then is said to be impermeable or to have low permeability. Permeability is expressed quantitatively, for field use, as the number of gallons of water per day that will pass through a cross-sectional area of 1 square foot under unit, or 100 percent, hydraulic gradient at the local temperature of the ground water.

The "coefficient of transmissibility" is convenient to use in ground-water studies because it indicates a characteristic of the aquifer as a whole rather than that of a small section. It is the average field permeability of the aquifer multiplied by the thickness, in feet, of the saturated part of the aquifer.

The suitability of an aquifer as the source of water supply is governed by the permeability and transmissibility of the aquifer, by its volume, and by its capacity to store and release water. Recharge to the aquifer also must be adequate if the water-supply development is to last indefinitely, because even a small rate of withdrawal will deplete the water in storage ultimately unless there is equal or greater recharge. Aquifers high in permeability, but small in areal extent and completely enclosed in relatively impermeable material, have been pumped nearly dry in a comparatively short time, to the detriment and disappointment of those concerned. The rather high initial yield of a well may give an erroneous impression that a great volume of water would be available from the aquifer indefinitely. Thus, before any substantial ground-water development is made, sufficient test drilling, aquifer tests, and related studies should be made to determine the capabilities of the aquifer being considered as well as its recharge.

General Stratigraphic Relationships

Information regarding the stratigraphy was obtained in part from a study of samples from 18 test holes drilled in the Hankinson area, and in part from published information. Locations of the test holes drilled in the area are shown on plate 1. The test holes were drilled with a hydraulic-rotary drilling machine owned by the North Dakota State Water Conservation Commission. The depth of the test holes ranged from 60 to 400 feet and samples were taken of each 5-foot interval. The stratigraphic nomenclature used in this report conforms generally to that used by Paulson (1953, p. 13) for the Fairmount area, the western boundary of which is 4 miles east of the area covered in this report. A close correlation between the stratigraphy of the two areas was indicated by an examination of samples from test hole 813 (130-49-17ccc) which was drilled to granite.

A stratigraphic section of the Hankinson area follows:

- Cenozoic
  - Quaternary system
    - Pleistocene series
      - Wisconsin stage
        - Deposits of glacial Lake Agassiz
          - Deposits of the Sheyenne delta
          - Lake clay and silt
        - Till and associated glacioaqueous deposits
      - Pre-Wisconsin(?) stage
- Mesozoic
  - Cretaceous system
    - Upper Cretaceous series
      - Benton(?) shale
      - Dakota(?) sandstone
- Precambrian
  - Granite

Deposits of the Wisconsin Stage of the Pleistocene Epoch

The surface deposits in the Hankinson area consist entirely of drift deposited during the Mankato substage of the Wisconsin stage. Considering the nature of these drift deposits, the area may be divided into three units (see pl. 1). The topography of each unit is controlled by the type of drift deposits represented. In the southwestern corner of the area the drift deposits are in the form of an end moraine, and have comparatively high relief and typical knob-and-kettle topography. In the adjoining area to the east, the surface deposits consist of deltaic sand and silt, which in places are modified by wind action into dunes. Except for low beach ridges the eastern part of the area is a flat and featureless plain, the surface of which is lake clay and silt.

Five test holes penetrated the entire thickness of the drift, which averaged 180 feet and ranged from 108 feet in test hole 812 (130-50-13dcc) to 257 feet in test hole 806 (130-50-11bab). An examination of drilling samples from the five test holes did not reveal an oxidized zone that would be indicative of an older drift. However, the number of test holes drilled through the drift was not sufficient to establish definitely whether more than one sequence of glacial deposition was involved. It is not known, therefore, whether a pre-Mankato substage or a pre-Wisconsin stage of glaciation is represented in the report area.

Deposits of glacial Lake Agassiz

During the last substages of Wisconsin glaciation, Lake Agassiz was formed in the northward-sloping Red River Valley. Sediments were deposited in the lake directly by water from the melting ice front and also by streams of glacial melt water from outside the lake. Most of these sediments were derived from rock materials incorporated in the body of the ice. The finer materials, such as clay and silt, were deposited in quiet, comparatively deep water, while the coarser materials were concentrated along the shores by wave action to form the beaches. Wave action and thrusting action by lake ice forced these materials into beach ridges, which mark the shorelines of the glacial lake at different stages of elevation.

The earliest stage of Lake Agassiz is represented by the Milnor beaches, which were formed at an elevation 20 to 25 feet higher than that of the highest beaches which extend entirely around the lake (Herman beaches). This early stage was little more than a broad expansion of the glacial Sheyenne River. It was approximately 30 miles long and ranged in width from 1 to 3 miles (Upham, 1896, p. 211). The Milnor beaches are lower and cover considerably less area than the later beaches, indicating that the Milnor stage was of comparatively short duration.

Lake Milnor was formed when the ice melted back far enough to give passage to water from the Sheyenne River, which flowed southeastward to the Milnor outlet southwest of Hankinson. This outlet, extending along the eastern edge of the moraine in the southwestern part of the report area, is now occupied by a chain of lakes and sloughs (see pl. 1).

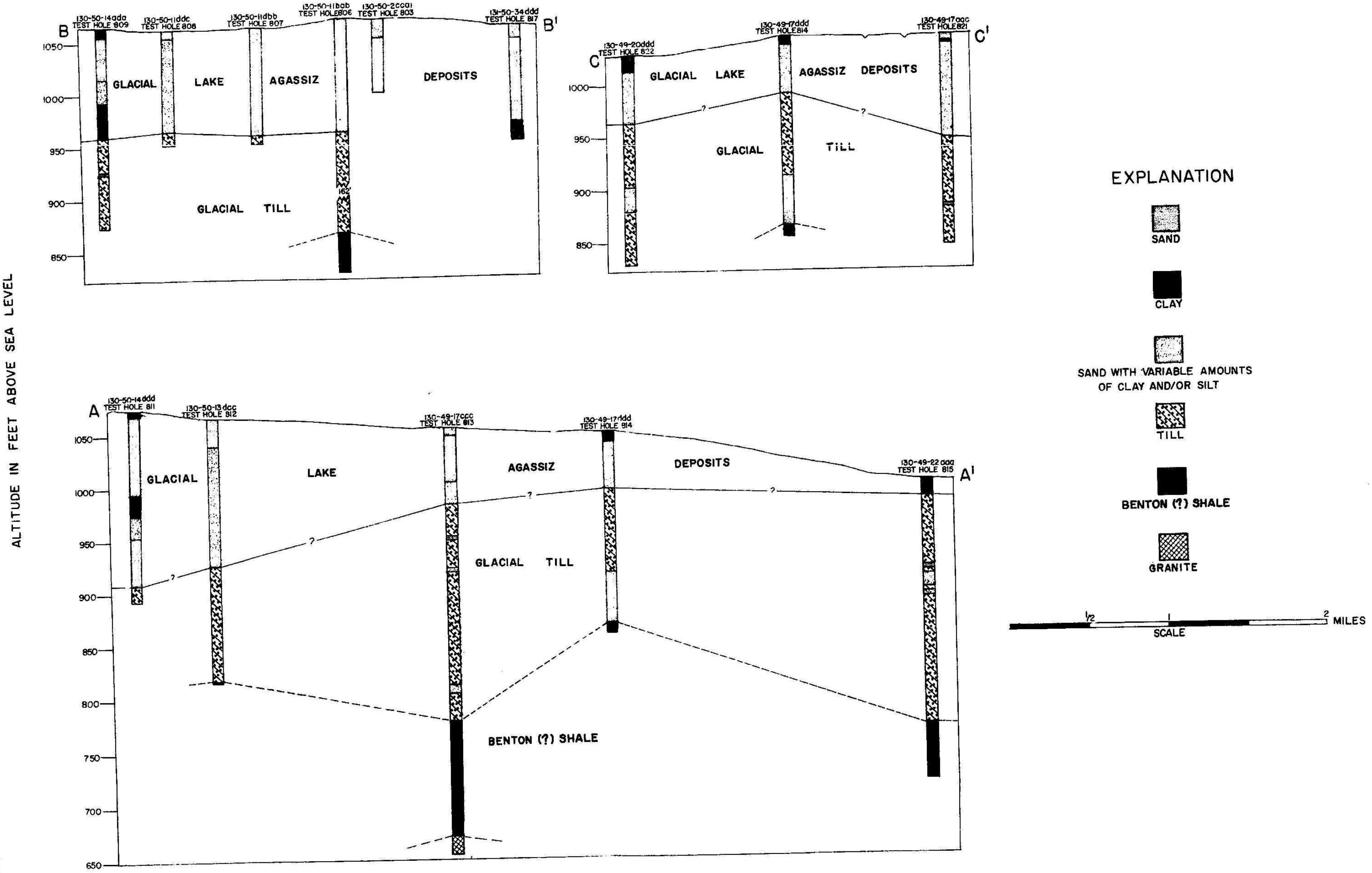
Lake Agassiz reached its maximum extent at the stage marked by the Herman beaches. During this stage the major outlet channel was developed at the southern end of Lake Agassiz. From this outlet channel, located approximately 30 miles southeast from Hankinson, water entered the Mississippi drainage system via the Minnesota River. The level of Lake Agassiz dropped by stages as the outlet channel was deepened until it stood at the level of the Campbell beach, which is about 11 miles east of Hankinson. The southern margin of the lake moved north as the ice retreated northward, until the lake was almost completely drained. A subsequent advance of the ice blocked the northward drainage and the lake again rose to the level of the southern outlet and then slowly receded.

The Lake Agassiz deposits in the Hankinson area are of two types--delta deposits and lake deposits. The delta sand and silt were deposited by the Sheyenne River as it entered Lake Agassiz and the lake deposits of clay and silt were dropped farther out, where the water was relatively quiet.

Delta deposits.--The Sheyenne delta is one of the prominent features of the Lake Agassiz basin. It is the largest delta deposited in Lake Agassiz, having a length of 50 miles, a maximum width of 30 miles, and an average thickness of 40 feet (Upham, 1896, p. 315). The surface geology of the delta area was described by both Upham and Leverett. They disagreed, however, as to the method of deposition of the delta sands. Upham (1896, p. 316) believed that the delta materials were derived from sand carried by the Sheyenne River during the upper Herman stage of Lake Agassiz, whereas Leverett (1932, pp. 126-127) believed that the materials were deposited as outwash from the melting ice front. The uniformity of size of the sand and silt grains composing the delta and the absence of gravel, boulders, and clay lend considerable support to [illegible] view.

The character of the delta materials was determined by examining samples of materials from 17 test holes. The materials consist mainly of fine sand and silt in varying proportions; however, sand is predominant in the materials overlying the glacial till in that part of the area classed as delta.

Alternating layers of sand and silt were penetrated in some test holes, such as 811 and 812, but continuous layers of sand were penetrated in others, such as test holes 803, 806, and 817 (see pl. 3). In general, the proportion of silt in the zones of sand and the number of clay and silt zones increase toward the south and east. These facts indicate that the Sheyenne River entered Lake Agassiz from the northwest and that offshore currents prevailed for a considerable distance to the southwest of the mouth of the river. It is probable also that the delta sands


B
B'
130-50-14ada TEST HOLE 809
130-50-11ddc TEST HOLE 808
130-50-11dbb TEST HOLE 807
130-50-11bab TEST HOLE 806
130-50-2ccal TEST HOLE 803
131-50-34ddd TEST HOLE 817
1050
1000
950
900
850
GLACIAL LAKE AGASSIZ DEPOSITS
GLACIAL TILL
162'
C
C'
130-49-20ddd TEST HOLE 822
130-49-17ddd TEST HOLE 814
130-49-17aac TEST HOLE 821
1000
950
900
850
GLACIAL LAKE AGASSIZ DEPOSITS
GLACIAL TILL
?
ALTITUDE IN FEET ABOVE SEA LEVEL
A
A'
130-50-14ddd TEST HOLE 811
130-50-13dcc TEST HOLE 812
130-49-17ccc TEST HOLE 813
130-49-17ddd TEST HOLE 814
130-49-22daa TEST HOLE 815
1050
1000
950
900
850
800
750
700
650
GLACIAL LAKE AGASSIZ DEPOSITS
GLACIAL TILL
BENTON (?) SHALE
?
EXPLANATION
SAND
CLAY
SAND WITH VARIABLE AMOUNTS OF CLAY AND/OR SILT
TILL
BENTON (?) SHALE
GRANITE
1/2
1
2
MILES
SCALE

were reworked many times as the mouth of the river migrated along the face of its delta, silt being deposited when the current velocities were small and sand when the velocities were greater. The foregoing is a possible explanation for the interfingering of sand and silt zones. The average thickness of the delta materials as determined by test drilling was 89 feet, and the thickness of delta materials at the several sites ranged from 42 to 166 feet (see pl. 3). In the Wyndmere area 17 miles to the northwest (see fig. 2) deposits of the Sheyenne delta ranged from 70 to 136 feet in thickness and averaged about 104 feet (Dennis, Akin, and Jones, 1949, p. 17). The greater average thickness of the delta deposits in the Wyndmere area is additional evidence of a gradual thinning of the deposits to the south and east.

The sand deposits of the Sheyenne delta constitute the most important aquifer in the Hankinson area. The deposits cover a large part of the delta region but vary considerably in thickness. The thickest sand deposits found were at the site of test hole 806 (130-50-11bab), where 108 feet of fine sand was penetrated. Here the sand extended from the land surface to the glacial till. Sand beds were penetrated by all the test holes in the delta area. Interbedded sand and silt were penetrated in some of the test holes.

Most wells that penetrate the delta materials are of small diameter and are equipped with sand points. Wells used for stock watering usually are powered by windmills; domestic wells usually are equipped with pressure systems or hand pumps. Ground water is adequate in the delta area and the water generally is potable, of good quality, and suitable for both irrigation and domestic purposes.

The most favorable well sites in the Hankinson area are in the vicinity of test-hole section B-B' (see pl. 3). The geologic cross sections are based upon logs of test holes and are generalized because of scale limitations. Therefore, zones shown to be sand may contain some clay and silt and those designated clay and silt may contain some sand and gravel.

An aquifer test was made at the well of the Minneapolis, St. Paul, and Sault Ste. Marie Railroad (130-50-2cca2) which is near the location of test hole 803 (130-50-2cca1). The railroad well was pumped at a rate of 69 gpm for 52.5 hours. At the end of this period the water level in the pumped well was drawn down a total of 4.36 feet. Water levels in 3 observation wells, located at distances from the pumped well of 38.6, 60.9, and 121.3 feet were drawn down 1.68, 1.30, and 0.68 feet, respectively. Computations based on drawdown and recovery values, in which the Theis (1935) formula was employed, showed the average coefficient of transmissibility to be 18,000 gallons per day per foot and the average coefficient of storage, 0.17. Figure 4 is based upon these and other calculations and shows theoretical drawdowns caused by pumping water from a well finished in an unconfined aquifer having the average characteritics computed from the test on the railroad well. Two scales were used to show drawdowns caused by pumping rates of 100 and 200 gpm.

On the basis of the information obtained in this investigation the city of Hankinson contracted for the construction of a new well (130-50-2bbc). The well was completed early in October 1954, approximately 1,200 feet south of test hole 817 (131-50-34ddd). The well was test pumped for 24 hours at rates that fluctuated between 100 and 257 gpm. Because of irregular variations in the pumping rate, the coefficients of transmissibility

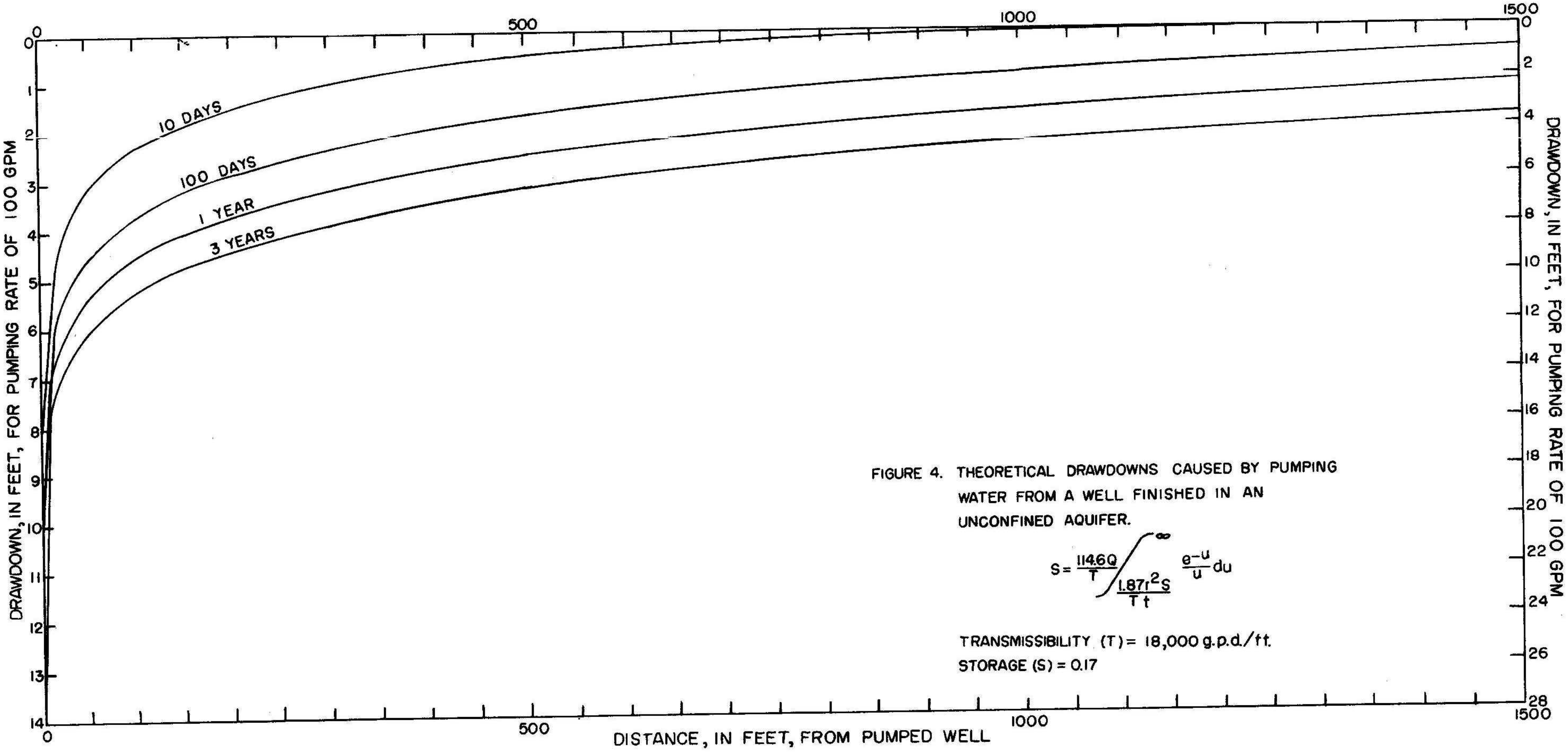


FIGURE 4. THEORETICAL DRAWDOWNS CAUSED BY PUMPING WATER FROM A WELL FINISHED IN AN UNCONFINED AQUIFER.

$$S = \frac{114.6Q}{T}\int_{\frac{1.87r^2S}{Tt}}^{\infty}\frac{e^{-u}}{u}du$$

TRANSMISSIBILITY (T) = 18,000 g.p.d./ft.

STORAGE (S) = 0.17

and storage could not be computed. The water level in the well was 36.50 feet lower when pumping stopped than when pumping began; it was 3.70 feet lower 7 hours after pumping stopped than when pumping began.

The new city well is approximately 3,100 feet northwest along the railroad tracks from the railroad well. Both wells are on section B-B' and between test holes 803 and 817 (see pl. 1). As the materials penetrated in test holes 803 and 817 are similar and the sandy sufical deposits are continuous between the two test holes, the city well and the railroad well are believed to be hydraulically connected. Thus, the coefficients of transmissibility and storage determined at the site of the railroad well should be approximately the same as those of the aquifer at the new city well.

Lake clay and silt deposits.--The line of demarcation between the delta deposits and the lake deposits follows approximately the course of the Tintah beaches (Upham, 1896, p. 316). The Tintah beach line is low and discontinuous in the Hankinson area. It crosses the eastern part of the area diagonally from the northwest to the southeast but is a visible topographic feature only in the southeastern part. The surface deposits to the east of this line are lake clay and silt (see pl. 1). Only one test hole, no. 815 (130-49-22aaa), was drilled in the area where lake sediments form the surface deposits, and here 16 feet of silty clay was penetrated before reaching glacial till (see pl. 3). In the Fairmount area, which begins 4 miles east from the Hankinson area, logs of 16 test holes indicate that the thickness of the lake depoists ranges from 3 to 18 feet (Paulson, 1953, p. 14). The lake clay and silt is not an important aquifer as it is relatively impermeable and yields little or no water to wells. Sandy zones in the deposit might yield small amounts of water, but no wells in the area are known to obtain water from such zones.

Till and associated sand and gravel deposits

Glacial till is present throughout the area. It underlies the deposits associated with Lake Agassiz and was penetrated by all but two test holes (see pl. 3). The till is composed of heterogeneous materials ranging from clay to large boulders. It was deposited directly from melting ice and was subjected to little or no subsequent sorting by wind or water. Because the till materials are unsorted and because the spaces between the larger particles are usually filled with fine materials, the till does not ordinarily yield water readily to wells.

The till in the Hankinson area is a dark- to light-gray clacareous silty clay that contains varying amounts of sand and gravel. The gravel is composed principally of shale fragments and irregular amounts of limestone, dolomite, and igneous-rock fragments.

Small bodies of sand and gravel are present within the till at many places. These deposits vary greatly in thickness and in area. They were deposited by running water, either water from precipitation or glacial melt water, and were subsequently covered by till. Their occurrence is erratic and generally impossible to predict from surface evidence.

Wells of rather high initial yield might be developed in the glacial sand and gravel deposits. However, the yield of wells penetrating aquifers that are completely surrounded by dense till would decrease rapidly as the aquifers became unwatered. Recharge through the glacial till to these aquifers is slow, and pumping rates must be correspondingly low if continuous production is to be maintained. Farm and domestic water is obtained from the till in the eastern and southwestern parts of the Hankinson area, some of it probably from sand and gravel deposits of the type described.

The three Hankinson city wells drilled prior to this investigation probably were completed in a sand and gravel lens in the till. All the wells are within a radius of 40 feet and are approximately 160 feet deep. The first city well was completed in this aquifer in 1920 and the water level was reported to be 3 feet above the land surface (Simpson, 1929, p. 296). As test drilling gave no evidence of an extensive aquifer at this depth, the cause of the high water level is not apparent. The water level in the single well in use at the time of this investigation could not be determined. However, the water level was reported to have been below the land surface for many years.

The depth of wells penetrating glacial till in the eastern part of the report area ranges from 55 to 220 feet and averages about 120 feet. Wells are much shallower in the southwestern part of the area, where deposits of glacial drift in the form of end moraine cover the surface, and well depths range from 18 to 160 feet and average about 60 feet. These wells are generally of low yield but are adequate for farm use.

Benton(?) Shale

A shale, possibly the Benton shale of Early and Late Cretaceous age, underlies the glacial drift in a part of the Hankinson area. Five test holes, 806, 812, 813, 814, and 815 (see pl. 3) were drilled to varying depths into the shale. In test hole 813 (130-49-17ccc) the entire thickness of the shale, which totaled 109 feet, was penetrated. During the drilling of those test holes bit samples composed of dark-gray to black silty shale were obtained. Fossils were not recovered from the shale, and its positive identification as the Benton was not possible.

The Benton shale is believed to underlie the glacial drift in the Fairmount area 4 miles to the east (Paulson, 1953, p. 28-29), and in the Wyndmere area 17 miles to the northwest (Dennis, Akin, and Jones, 1949, p. 25).

Test drilling indicates that the surface of the shale bedrock is irregular. Elevations of the bedrock surface range from 706 feet above sea level at the site of test hole 806 (130-50-11bab) to 867 feet above sea level at the site of test hole 814 (130-49-17ddd). The surface of the shale probably was eroded considerably either prior to or contemporaneous with the first glaciation of the area. No wells in the Hankinson area are known to obtain water from the shale, and it is not an important aquifer.

Dakota(?) Sandstone

The presence of the Dakota sandstone has not been definitely established. One test hole, 813 (130-49-17ccc), was drilled completely through the Benton(?) shale. The Dakota sandstone, if present at the site, was indistinguishable in the drill cuttings. However, the loss of 500 gallons of drilling fluid between 350 and 370 feet below the land surface, near the base of the shale, idnicates the presence of permeable material which might be sand. The sand could easily be unrecognizable in the drill cuttings of a hydraulic rotary rig such as was used for drilling the test holes. The permeable zone might represent a gradational contact or facies change involving the Benton(?) shale and the Dakota(?) sandstone.

Chemical analyses (see table 1) of water from two wells, (130-48-3bca and 131-48-34daa), which are a short distance east of the report area, are very similar to analyses of water from wells known to produce from the Dakota sandstone in the Fairmount area (Paulson, 1953, pp. 41a-41b). The depths of these wells are 243 feet and 250 feet, respectively, and both wells are reported to produce from sand. Water from both wells has high dissolved solids, sulfate, and chloride contents, which are typical of water from the Dakota sandstone. A well 12 miles west from Hankinson at the city of Lidgerwood produces water from the Dakota sandstone from a depth of 960 feet. Simpson (1929, p. 210) believed that the Dakota sandstone underlies the western half of Richland County and that buried outliers underlie the eastern half of the county and extend into western Minnesota.

Precambrian Granite

During this investigation only one test hole, 813 (130-49-17ccc), was drilled deep enough to reach granite. Decomposed granite was present in that test hole at the depth of 383 feet below the land surface. Drilling was continued 17 feet into the decomposed zone without reaching unaltered granite. The decomposed granite consists of clay which is white at the top of the zone and grades downward into light green. At the site of the Heitkamp-Downing test hole (132-49-7ccc), 12 miles due north from Hankinson, weathered granite (gray, grading into green kaolinitic clay) was reached at a depth of 400 feet below the land surface, and unaltered granite was reached at a depth of 420 feet below the land surface (personal communication, North Dakota Geological Survey, February 1956).

No wells penetrate the granite in the Hankinson area, and satisfactory ground-water supplies probably could not be obtained from it.

QUALITY OF THE GROUND WATER

Water dissolves a part of the soluble mineral constituents in an aquifer as it moves through the aquifer. The amount of mineral matter the water will dissolve from the rock material depends upon the length of time the water is in contact with these materials, and upon other factors including temperature and pressure. Therefore, water that has been underground the longest time or that has traveled the greatest distance through an aquifer usually is more highly mineralized than water that is recovered relatively near the recharge area, provided the aquifer is composed of rocks of homogeneous mineral composition.

Significance of the Chemical and Physical Characteristics of Water

The following is a partial list of maximum concentrations of chemical constituents specified by the U. S. Public Health Service (1946) for drinking water used on interstate carriers. These standards have been adopted by the American Water Works Association and many of the States for all public water supplies.

Chemical constituent	Maximum concentration (ppm)
Iron (Fe and Magnaese (Mn)	0.3
Magnesium (Mg)	125
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	1.5
Dissolved solids	500 [1]

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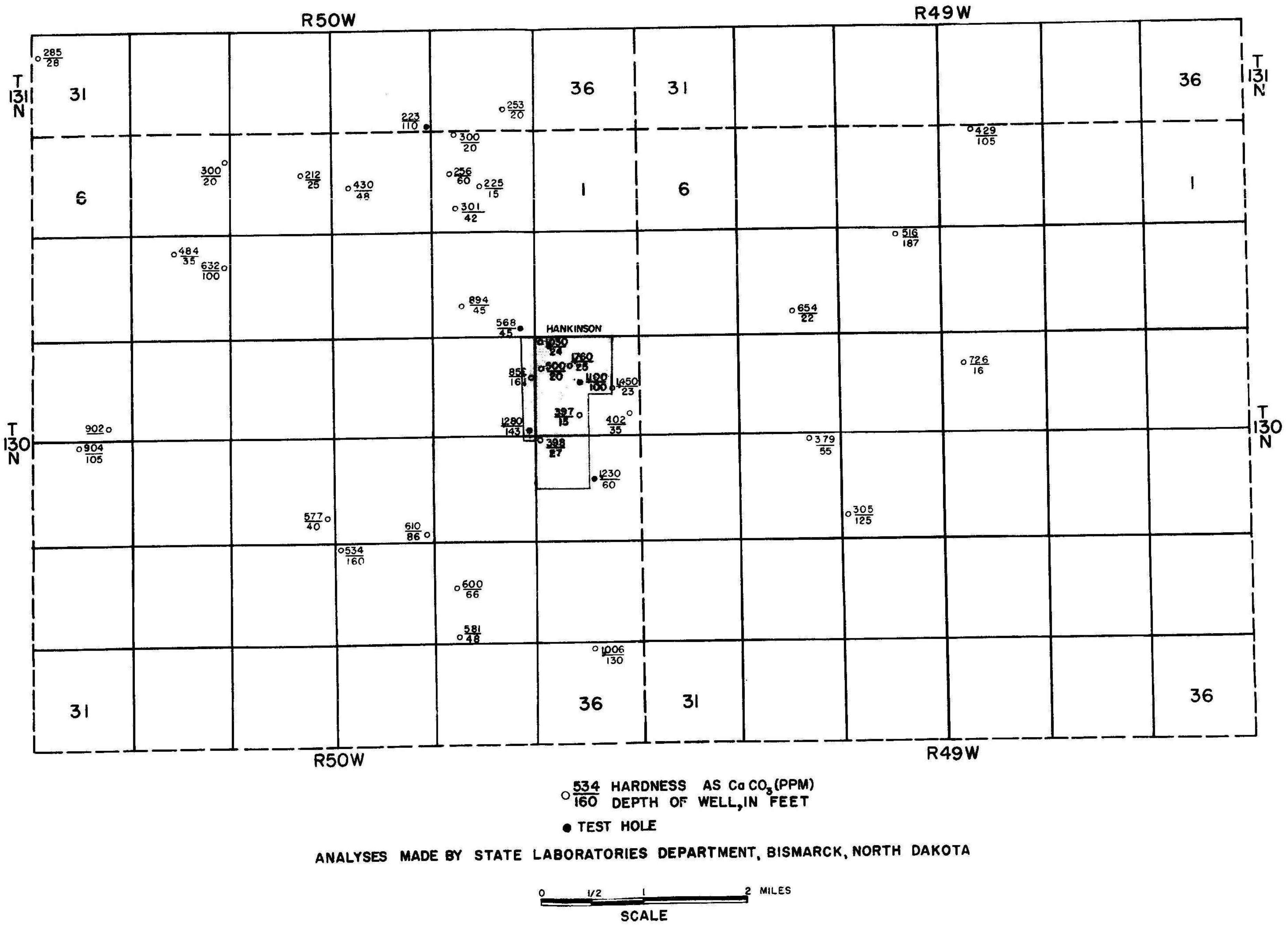
[1] 1,000 ppm permissible if water of better quality is not available.

UNITED STATES
GEOLOGICAL SURVEY

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
NORTH DAKOTA STATE GEOLOGICAL SURVEY

NORTH DAKOTA GROUND-WATER
STUDIES NO. 25 PLATE 4



ANALYSES MADE BY STATE LABORATORIES DEPARTMENT, BISMARCK, NORTH DAKOTA

High concentration of nitrate in ground water may be indicative of the presence of decaying organic matter in the well, in the aquifer, or on the ground surface in the vicinity of the well. Water containing more than about 44 parts per million of nitrate may cause cyanosis when fed to infants (Comly, 1945; Silverman, 1949).

Fluoride in concentrations of 0.8 to 1.5 ppm in water drunk by children is generally believed to be beneficial in the reduction of tooth decay. Higher concentrations may cause mottling of the enamel of the teeth (California State Water Pollution Control Board, 1952, p. 257).

Essentially all ground water contains at least a small amount of hardness-forming constituents. The hardness of water is caused principally by calcium and magnesium and, to a lesser extent, by iron, aluminum, strontium, barium, zinc, or free acid, by reason of the lower concentrations of these constituents in natural water. Hardness in water is especially undesirable when the water is used in laundering because it increases soap consumption and causes soap scum. Water having a hardness of about 100 ppm as $CaCO_3$ is considered to be fairly hard; water having a hardness of up to 200 ppm usually can be softened economically.

The percentage of sodium, expressed as "percent sodium," is the ratio of sodium to the sum of the principal cations (calcium, magnesium, sodium, and potassium), all expressed in chemical equivalents, multiplied by 100. Water containing large proportions of sodium is undesirable for irrigation, as it tends to cause the soil to become impermeable. Consequently, plant roots do not received the benefit of surface moisture resulting from precipitation or irrigation.

Quality of Ground Water in the Hankinson Area

The problems of locating satisfactory ground-water supplies in the Hankinson area involved the quality as well as the quantity of water. Therefore, a large number of water samples were collected from wells in the report area and were analyzed by the State Laboratories Department in Bismarck. Fifty-two determinations of hardness by the soap method also were made in the field. The soap method of determining hardness of water gives only approximate results which aid in establishing general trends.

The hardest ground water occurs within a circle of 1.2-mile radius, centered approximately at the center of the city of Hankinson. The hardness of the ground water in this area ranged from 397 to 1,760 ppm and averaged 870 ppm. All the wells produce water from aquifers in the glacial drift and the depth of most wells ranges from 15 feet to 35 feet. Only two wells exceed 100 feet in depth (see pl. 2).

The softest water was obtained from wells in the northwestern corner of the report area. This area of relatively low hardness includes secs. 1-11, T. 130 N., R. 50 W., and secs. 31-35, T. 131 N., R. 50 W. The hardness ranged from 212 to 632 ppm and averaged 335 ppm. All wells sampled produced water from sand deposits of the Sheyenne delta. The depth of the wells ranges from 15 feet to 100 feet and averages 37 feet.

The hardness of the Hankinson water supply at the time of this investigation was 852 ppm. Water considerably lower in hardness can be obtained in the above-mentioned area, where the thickest deposits of sand occur. On the basis of information resulting from this study a new city well (130-50-2bbc) was constructed in October 1954. The hardness of the water from that well was 256 ppm, less than one-third of that of water from the former supply.

High concentrations of sulfate and iron in the former city water supply caused many difficulties, including the deposition of black scale in pipes, which should be alleviated by the water from the new source. The deposition of black scale probably was cuased by the action of iron- and sulfate-reducing bacteria. As water from the new well contains only a trace of sulfate, the condition should gradually improve.

Problems caused by excess iron, however, will probably continue, but to a lesser degree. Water from the new source contains much less iron than that from the old, but the concentration, 0.8 ppm, still is high enough that it may cause staining of laundry and plumbing fixtures. The continued presence of iron-reducing bacteria in the water mains also may aggravate the effect of iron in the water.

The water that has the lowest dissolved-solids content also was obtained from wells in the area cited as having the softest water (secs. 1-11, T. 130 N., R. 50 W., and secs. 31-35, T. 131 N., R. 50 W.). The aquifer penetrated by these wells is composed of delta sand and silt and is the only aquifer in the Hankinson area capable of yielding water in sufficient quantity and of satisfactory quality to be used for irrigation. The dissolved-solids content of water from wells in this area ranged from 235 to 1,320 ppm and averaged 505 ppm. The percent sodium ranged from 2 to 27 and averaged 9. A total of 13 samples were taken from wells in the previously mentioned sections. According to analyses of these samples, and using the method of Wilcox (1948, p. 26) as a basis for classification, water from 7 of the wells rated excellent to good and water from 6 of the wells rated good to permissible for use in irrigation.

TABLE 1.--CHEMICAL

Analyses by State Laboratories, Bismarck
Results in parts per million except as indicated

Location number	Owner or name	Date of collection	Depth of well (feet)	Aquifer	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
130-48								
3baa	M. J. Meyer	10-18-53	243	Sand	...	26	27	1,040
130-49								
3bab	Mary Boelke	9-17-53	105	Sand	.9	108	39	195
8dcb	Henry Thomas	10-18-53	22	Sand	1.5	187	46	50
9abb	Ed Wieser	9-17-53	187	Sand	4.0	97	67	192
15bca	Rudy Gustman	9-17-53	16	Sand	...	170	73	75
20aba	G. Medenwaldt	9-24-53	55	Sand	1.0	91	37	155
21ccb	Fred Emde	9-24-53	125	Gravel	1.0	69	32	205
130-50								
2bab	John Pankow	9-25-53	20	Sand	.2	77	26	42
2bbc	City of Hankinson	10-13-54	60	Sand	.8	77	15	6.5
2caa	August Pankow	9-24-53	15	Sand	...	58	20	6.0
2cca2 1/	Soo Line Railroad	9-24-53	42	Sand	.4	74	28	19
2cca2 2/	Do	9-25-53	42	Sand	...	80	26	35
3cba2	T. Prochnow	9-24-53	48	Sand	1.6	99	44	9.0
4acd	Sheyenne Valley Land Grazing Association	9-25-53	25	....	...	51	20	2.5
5ada	Do	12-14-53	20	....	...	87	20	4.0
8ada	Edwin Staak	11-23-53	100	....	...	160	59	9.5
8bab	Mrs.L.Vedder	10- 6-53	35	Sand	11	99	57	88
11cac	Kenneth Jones	10- 6-53	45	Sand	1.2	210	90	23
11ddc	Test hole 808	10-25-53	45	Sand	...	126	62	40
11ddc	Do	10-26-53	84	Sand	.2	142	47	42
13acd	William Gollnick	11-19-53	23	Sand	.7	280	182	120
13bbb	Martin Wolfe	11-19-53	24	....	1.2	174	145	120
13bcb1	Robert Dumpke	11-18-53	20	Sand	.2	46	91	70
13bdb	Gilbert Miller	11-18-53	25	Sand	...	366	206	144

1/Sampled after 24 hours of pumping
2/Sampled after 50 hours of pumping

ANALYSIS OF GROUND WATER

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation)	Hardness as $CaCO_3$	Percent sodium
14	518	..	1,240	895	.2	7.3	3,630	177	92
8.5	348	..	645	8.0	.2	4.4	1,180	429	49
27	508	..	113	50	.2	119	844	654	13
11	567	27	616	55	.1	4.2	1,350	516	43
3.2	380	..	405	28	.5	108	1,050	726	18
9.2	555	..	454	68	.3	3.4	1,090	379	46
9.0	607	..	417	96	.3	2.5	1,130	305	58
11	328	..	258	11	...	18	604	300	22
...	322	..	....	4.0	.3	....	263	256	5
1.0	254	..	41	.....	.3	9.0	260	225	5
6.0	280	16	100	.....	.2	11	393	301	12
6.8	246	32	987	11	...	19	1,320	308	19
4.0	451	..	30	40	.2	2.0	451	430	4
1.0	228	26	21	.....	.1	1.2	235	212	3
1.0	247	..	37	35	.2	15	321	300	3
4.0	753	5	282	42	...	4.0	1,020	632	3
4.0	434	37	225	.....	...	1.9	736	484	27
7.0	422	..	480	59	.2	2.5	1,080	894	5
9.8	498	..	248	.....	.1	11	742	568	13
11	468	..	258	11	...	18	759	546	14
24	623	..	1,073	96	.2	3.5	2,090	1,450	15
20	624	..	794	25	.2	1.7	1,590	1,030	20
22	376	48	337	11	.2	1.3	812	500	23
90	496	..	1,040	28	.2	4.4	2,490	1,760	14

Location number	Owner or name	Date of collection	Depth of well (feet)	Aquifer	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
130-50-[illegible]ued								
13bdd	Test hole 819	11-24-53	100	Sand	....	154	174	120
13cda2	Mrs. Tom Bisek	11-19-54	15	Sand	....	77	50	50
13dda	Frank Boomersbach	11-19-53	35	Sand	[illegible]5	116	27	240
14add	City of Hankinson	6-22-55	161	Gravel	10	140	122	78
14ddd	Test hole 811	11- 3-53	43	Sand	.3	105	140	85
14ddd	Do	11- 4-53	143	Sand	4.4	131	230	100
18ddc	Oscar Prachnow	10 -53	...	....	1.2	202	96	60
19baa	Gustave Muchler	10- 7-53	105	Gravel	3.0	188	106	105
21dda	F. E. Coopin	9-18-53	40	Gravel	....	165	40	14
22ddd	H.O. Medenwaldt	9-17-53	86	....	.2	151	57	42
24acc	Test hole 820	11-26-53	60	Sand	....	147	210	120
24bbb	John R.Scheller	9-18-53	27	....	1.5	87	44	16
26bcd	R. C. Bladow	9-23-53	66	Gravel	1.0	151	54	23
26ccd	Hillview Farm Inc.	9-23-53	48	....	....	155	47	24
27bbb	Do	9-23-53	160	....	.2	127	52	16
36abb	Fred Buckhause	9-23-53	130	....	50	200	123	70
131-48								
34daa	Carrie Daman	10- 8-53	250	Sand	.6	38	33	1,350
131-50								
31bbc	A. Witt	9-25-53	28	....	....	62	32	3.2
34ddd	Test hole 817	11-19-53	110	Sand	....	51	23	8
35dca	August Pankow	9-25-53	20	....	.3	61	24	6

ANALYSIS OF GROUND WATER -- Continued

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation)	Hardness as $CaCO_3$	Percent sodium
25	663	38	819	16	...	3.4	1,680	1,100	19
11	400	22	664	110	.2	8.8	1,190	397	61
3.5	429	26	87	11	.2	1.3	723	402	56
14	561	..	499	.....	...	.3	1,140	852	17
5.8	541	..	556	11	.2	19	1,190	836	18
35	728	..	871	14	...	37	1,780	1,280	14
14	985	..	534	25	...	2.4	1,440	902	9
15	974	..	751	21	...	1.7	1,670	904	20
4	647	40	183	11	...	1.9	777	577	5
7.2	901	..	286	8	...	1.7	996	610	13
13	465	20	1,090	11	...	2.4	1,840	1,230	17
3.8	821	..	131	.....	.2	.8	688	398	8
6.5	932	..	293	11	...	2.0	1,000	600	8
7.2	918	..	279	11	...	1.9	977	581	8
5.2	675	53	251	.....	...	.9	837	534	6
14	1,110	..	707	11	...	2.8	1,720	1,010	12
13	344	28	1,280	1,500	2.4	7.7	4,420	230	92
2.5	266	8	49	11	.2	52	351	285	2
4.2	280	16	21	.....	.2	1.1	262	223	7
2	336	..	10	.....	.3	.9	270	253	5

TABLE 2.--RECORDS OF WELLS

Depth to water: Depths given to hundredths or tenths of feet are measured: those given in feet only are reported.

Type of well: Dr. drilled; Du, dug; Dv, driven

Remarks: All hardness values were determined by the soap method and are only approximate.

Location no.	Owner or name	Depth of well(feet)	Diameter (inches)	Type of well	Date ~~or year~~ completed	Depth to water(feet below land surface)
129-49						
1b1	Louis Herding	148	2	Dr	....	10
1b2	John Vellenga	84	2	Dr	1935	9
130-48						
3baa	M. J. Meyer	243	2	Dr	1952	12
4ddc	Arley Boll	75	5	Dr	....	...
130-49						
1bbb	Alvina Kinn	126	2 by 3	Dr	1946	3
1ddd	R. E. Brackin	90	2	Dr	1947	4
2bbb1	Mrs. Otto Stein	125	2	Dr	1935	8
2bbb2	do	100	3	Dr	....	8
3aaa	Arnold Burnard	125	2	Dr	1936	8
3bab	Mary Boelke	105	3	Dr	....	7
3caa1	Louis Wirtz	84	3	Dr	1922	18
3caa2	R. Hartleben	82	3	Dr	1923	17
4bad	C. Ziegleman	19	3	Dv	....	5.0
6bbc	John Scheller	45	$1\frac{1}{4}$	Dv	....	15
8dcb	Henry Thomas	22	...	Du,Dv	....	...
9abb	Ed Wieser	187	2	Dr	1951	12
9dbc	Mary Gustman	13.5	36 by 36	Du	....	5.1
10ccd	Ernest Hubrig	11	42	Du	1952	7
11acc	W. R. Miller	114	$2\frac{1}{2}$	Dv	....	10
12aa	Floyd Eickhorn	60	2	Dr	1943	3
14bba	Harry Gustman	156	2	Dr	1936	152
14cab	Ernest Tischer	20	36	Du	1923	12
14dbc	Robert Stein	120	$2\frac{1}{2}$	Dr	1927	8
15aac	Ernest Hubrig	20	48	Du	1940	10
15bca	Rudy Gustman	16	36 by 36	Du	1938	6.8

Date of measurement: Date given is date measured for measured depths to water; it is the date of report for reported depths to water.

Use of water: D, domestic; Ind, industrial; PS, public supply; RR, railroad; S, stock.

Date of measurement	Use of water	Aquifer	Chemical analysis	Elevation of land surface	Remarks
12- 3-53	D,S	Sand	...	.....	Hard; adequate supply.
12- 3-53	D,S	Sand	...	.....	Hard; colored water; adequate supply.
10- 8-53	D,S	....	x	.....	Soft, salty.
....	D,S	....	...	.....	Hardness 427 ppm.
12- 2-53	D,S	Gravel	...	.....	Hard; adequate supply.
12- 2-53	D,S	Gravel	...	.....	Medium soft; adequate supply.
12- 1-53	D,S	Sand	...	.....	Hard; adequate supply.
12- 1-53	D,S	Sand	...	.....	Hard.
12- 1-53	D,S	Sand	...	.....	Hard; adequate supply.
9-17-53	S	Sand	x	.....	Precipitate plugs screen.
12- 1-53	D,S	Sand	...	.....	Hard; adequate supply.
12- 1-53	...	Sand	...	.....	Hard; inadequate supply.
9-17-53	S	Sand	...	.....	Hard.
10- 6-53	D,S	Sand	...	.....	Hardness 230 ppm.
....	D,S	Sand	x	.....	
9-17-53	D,S	Sand	x	.....	
9-17-53	S	Sand	...	.....	
12- 1-53	D,S	Sand,clay	...	.....	Soft.
12- 2-53	D,S	Sand	...	.....	[illegible].
12- 2-53	D,S	Gravel	...	.....	Medium soft.
12- 1-53	D,S	Sand	...	.....	Soft; inadequate supply.
12- 1-53	D,S	Sand,clay	...	.....	Medium soft; adequate supply.
12- 2-53	D,S	Sand	...	.....	Medium soft; adequate supply.
12- 1-53	D,S	Sand,clay	...	.....	Hard.
9-17-53	D,S	Sand	x	.....	

TABLE 2.--RECORDS OF WELLS

Location no.	Owner or name	Depth of well(feet)	Diameter (inches)	Type of well	Date or year completed	Depth to water(feet below land surface)
130-49 -- Continued						
17aaa	Test hole 821	200	5	Dr	11-27-53	...
17cbb	Bill McGray	178	2	Dr	....	...
17ccc	Test hole 813	400	5	Dr	11- 6-53	...
17ddd	Test hole 814	190	5	Dr	11-11-53	...
19bbc	Frank Pietz	20	...	Dv	....	...
19cca	Carl Milbrandt	15	...	Dv	....	...
20aba	G. Medenwaldt	55	3	Dr	1951	15
20abc	do	16	36	Du	....	8
20add	do	125	2	Dr	1947	2
20bcc	F. O. Healy	135	...	Dr	....	Flow
20dcd	Nick Meyer	125	2	Dr	....	6
20ddd	Test hole 822	200	5	Dr	11-30-53	...
21ccb	Fred Emde	125	2	Dr	....	4.1
21cdd	do	220	2	Dr	1945	60
21dcd1	John Meyer	160	2	Dr	1941	11
21dcd2	do	125	2	Dr	1947	11
22aaa	Test hole 815	280	5	Dr	11-14-53	...
23ddc	Elmer Smith	135	2	Dr	1952	30
24cdc	William Wieser	140	2	Dr	....	30
25aaa	Alois Wieser	180	2½	Dr	1951	12
26cda	Harry Wirtz	180	2	Dr	1932	70
27bbb	Ed Herman	75	3	Dr	....	11
28baa	Anne Kinn	165	2	Dr	1945	20
29bcc	Ed Kuehl	40	...	Dv	....	...
29dcd	do	150	3	Dr	1950	...
30add	Pete Krump	25	...	Dv	....	...
34abb	Max Schmidt	122	2	Dr	1910	11
130-50						
1aaa	Ray Bladow	18	2	Dv	....	5
1bba	T. Steinwehr	20	2	Dv	....	...
2bab	John Pankow	20	2	Dv	1952	3
2bbc	City of Hankinson	60	48	Dr	1954	4.50
2caa	August Pankow	15	1½	Dv	....	9
2cca1	Test hole 803	70	5	Dr	10-16-53	...

Date of measurement	Use of water	Aquifer	Chemical analysis	Elevation of land surface	Remarks
....	...	....	...	1,029	See log.
....	...	....	...	.....	Hardness 435 ppm.
....	...	....	...	1,052	See log.
....	...	....	...	1,046	Hardness 460 ppm. See log.
....	...	....	...	.....	Hardness 1,160 ppm.
....	...	....	...	.....	Hardness 290 ppm.
9-24-53	D,S	Sand	x	.....	Iron precipitates after standing.
9-24-53	S	Sand	...	.....	Hardness 435 ppm.
9-24-53	D,S	Gravel	...	.....	Hardness 325 ppm.
....	...	....	...	.....	Hardness 795 ppm.
12- 2-53	D,S	Sand	...	.....	Soft; adequate supply.
....	...	....	...	1,046	See log.
9-24-53	S	Gravel	x	.....	Temperature 48°F. Flowed before nearby wells were constructed.
12- 2-53	D,S	Sand	x	.....	Hard; adequate supply.
12- 3-53	D,S	Sand	...	.....	Soft; inadequate supply.
12- 3-53	D,S	Sand	...	.....	do
....	...	....	...	996	See log.
12- 2-53	D,S	Sand	...	.....	Soft; adequate supply.
12- 2-53	D,S	Sand	...	.....	do
12- 2-53	D,S	Sand	...	.....	Hard; adequate supply.
12- 2-53	D,S	Sand	...	.....	Soft; adequate supply.
12- 2-53	D,S	Sand	...	.....	Medium soft; adequate supply.
12- 2-53	D,S	Sand	...	.....	Reddish color; inadequate supply.
....	...	....	...	.....	Hardness 435 ppm.
....	D,S	Sand	...	.....	Hardness 215 ppm.
....	...	....	...	.....	Hardness 180 ppm.
12- 3-53	D,S	Sand	...	.....	Soft; adequate supply.
10- 6-53	D	Sand	...	.....	Hardness 410 ppm.
....	D	Sand	...	.....	Hardness 507 ppm.
9-25-53	D,S	Sand	x	.....	400 gpd for stock.
10-28-54	PS	Sand	x	.....	
9-24-53	S	Sand	x	.....	
....	...	....	...	1,070	See log.

TABLE 2.--RECORDS OF WELLS

Location no.	Owner or name	Depth of well (feet)	Diameter (inches)	Type of well	Date or year completed	Depth to water (feet below land surface)
130-50 -- Continued						
2cca2	Soo Line Railroad	42	108	Du,Dv	....	10
3aac1	L. Prochnow	52	2	Dv	1953	11.3
3aac2	do	54	2	Dv	1933	...
3cba1	T. Prochnow	22	1¼	Dv	1952	6.7
3cba2	do	48	1¼	Dv	1952	...
3cbb	Test hole 818	80	5	Dr	11-19-53	...
4acd	Sheyenne Valley Land Grazing Association	25	1¼	Dr,Dv	....	5
5ada	do	20	2	Dv	....	5
6dcd	W. F. Vedder	20	1¼	Dv	1918	7
8ada	Edwin Staack	100	2	Dr	....	...
8bab	Mrs. L. Vedder	35	...	Dv	....	15
9ada	August Mueller	40	...	Dv	....	8
9bbc	Emma Hartleben	20	2	Dv	....	8.9
9da	C. Klawitter	143	...	Dr	....	...
11bab	Test hole 806	400	5	Dr	10-20-53	...
11cac	Kenneth Jones	45	2	Dr	....	...
11dbb	Test hole 807	110	5	Dr	10-23-53	6.00
11ddc	Test hole 808	110	5	Dr	10-24-53	5.65
13abc	Paul Milbrandt	80	2	Du	....	8.5
13acb	Gus Winfeldt	30	...	Dv	....	9
13acc	Richard Winfeldt	12	...	Dr,Dv	....	8
13acd	William Gollnick	23	36	Dr,Dv	....	8
13bbb	Martin Wolfe	24	36	Dr,Dv	....	9
13bbc	Clem Brunkhorst	46	2	Dv	....	9
13bcb1	Robert Dumpke	20	36	Dr	....	8
13bcb2	Jim Fallon	22	...	Dr,Dv	....	8
13bcc	Wilbur Chapin	21	1¼	Du,Dr	....	8.1
13bda	Alfred Bellen	26	2	Dr	....	9
13bdb	Gilbert Miller	25	36	Dr,Dv	....	7.55
13bdd	Test hole 819	100	5	Dr	11-23-53	...
13cab1	Hankinson Creamery	165	4	Dr	....	...
13cab2	Lewis Store	35	2	Dv	....	8
13cad	Art Hanson	20	24	Dr,Dv	....	9
13cba	Clem Meide	25	...	Du	....	8
13cda1	Henry Erb	30	...	Du	....	8

AND TEST HOLES -- Continued

Date of measurement	Use of water	Aquifer	Chemical analysis	Elevation of land surface	Remarks
9-24-53	RR	Sand	x	.....	Seven sand points below dug well.
9-24-53	D	....	...	.....	
....	D	Sand	...	.....	Temperature 49°F. Hardness 180 ppm.
9-24-53	S	Sand	x	.....	
....	...	....	...	.....	
....	...	....	...	1,076	See log.
9-25-53	S	....	x	.....	
9-20-53	S	Sand	x	.....	Temperature 49°F.
10- 6-53	D	Sand	...	.....	Temperature 50°F. Adequate supply. Hardness 480 ppm.
....	D,S	....	x	.....	
10- 6-53	S	Sand	x	.....	Temperature 49°F.
9-13-53	...	....	...	.....	Hardness 470 ppm.
9-25-53	D,S	....	...	.....	
....	...	....	...	.....	Hardness 580 ppm.Reddish color.
....	...	....	...	1,072	See log.
....	D,S	Sand	x	.....	
10-24-53	...	....	...	1,063	Hardness 975 ppm. See log.
10-25-53	...	....	x	1,062	See log.
9-53	D	Sand	...	.....	Hardness 752 ppm.
11-19-53	...	Sand	...	.....	Hardness 1,230 ppm.
11-19-53	[illegible]	Sand	...	.....	Hardness 1,320 ppm.
11-19-53	D	Sand	x	.....	
9- 9-54	D	Sand	x	.....	
7- 8-53	D	Sand	...	.....	Hardness 872 ppm.
11-18-53	D	Sand	x	.....	
7- 8-53	D	....	...	.....	Hardness 667 ppm.
11-18-53	...	Sand	...	.....	Hardness 1,760 ppm.
7- 8-53	D	Sand	...	.....	Hardness 257 ppm.
11-18-53	D	Sand	x	.....	
....	...	....	x	1,063	See log.
....	Ind	Gravel,sand	...	.....	Dark-red color.Hardness 1,090 ppm.
7-53	D	Sand	...	.....	Hardness 513 ppm.
11-19-53	...	Sand	...	.....	
9-53	D	Sand	...	.....	Hardness 718 ppm.
9-54	D	Sand	...	.....	Hardness 616 ppm.

TABLE 2.--RECORDS OF WELLS

Location no.	Owner or name	Depth of well (feet)	Diameter (inches)	Type of well	Date or year completed	Depth to water (feet below land surface)
130-50 -- Continued						
13cda2	Mrs. Tom Bisek	15	2	Du,Dv	....	8
13dca3	R. Medenwaldt	20	36	Dr	....	7.85
13dcc	Test hole 812	250	5	Dr	11- 4-53	...
13dda	F. Boomersbach	35	1¼	Du,Dv	....	...
14aaa	Art Lewis	37	...	Dr	....	...
14ada	Test hole 809	190	5	Dr	10-29-53	...
14add	City of Hankinson	161	10	Dr	1947	...
14cac	A. Medenwaldt	73	...	Dr	....	...
14dad	Test hole 810	100	5	Dr	10-31-53	7.32
14ddc	Art Graive	136	...	Dr	....	...
14ddd	Test hole 811	180	5	Dr	11- 2-53	...
15bba	Hankinson Nursery	60	...	Dv	....	...
15dac	Albert Buckhause	171	2	Dr	....	...
16aba	Art Hartleben	74	...	Dv	....	...
16acb	Soo Line Railroad	78	10	Du,Dr	1908	...
18cda	A. Medenwaldt	55	2	Dr	....	...
18ddc	Oscar Prachnow	...	2	Dr	....	12
19baa	Gustave Muehler	105	2	Dr	....	10
19cdc	Rudolph Miller	38	2	Dr	....	...
19dcc	William Westphal	47	2	Dr	....	...
21dab	Elroy Muehler	21	3	Dr	....	8
21dda	F. E. Coppin	40	36 by 36	Du	....	27.4
22ddd	H. O. Medenwaldt	86	2	Dr	1945	...
23aaa	Witts Standard Service	30	...	...	....	4
23abc	G. Buckhause	60	...	Dr	....	...
24aaa	Alfred Miller	45	...	Dv	....	10
24acc	Test hole 820	60	5	Dr	11-25-53	...
24baa	Harry Nulph	30	...	Dv	....	8
24bbb	John R. Scheller	27	...	...	....	8

AND TEST HOLES -- Continued

Date of measurement	Use of water	Aquifer	Chemical analysis	Elevation of land surface	Remarks
11-19-54	D	Sand	x	.....	
11-18-53	...	Sand	...	.....	
....	...	....	...	1,064	See log.
....	D	Sand	x	.....	
....	...	....	...	.....	Water becomes slightly red after standing; hardness 838 ppm.
....	...	....	...	1,065	See log.
....	PS	Gravel	x	.....	Has odor.
....	...	....	...	.....	Water becomes red after standing; hardness 940 ppm.
11- 2-53	...	....	...	1,072	See log.
....	...	....	...	.....	Hardness 872 ppm.
....	...	....	x	1,073	See log.
....	...	.....	...	.....	Dark red color;hardness 470 ppm.
....	D,S	Gravel	...	.....	Hardness 718 ppm.
....	...	....	...	.....	Hardness 540 ppm.
....	RR	Gravel,sand	...	.....	Hardness 498 ppm.
....	D,S	Sand	...	.....	Unfit for laundry,very hard; temperature 47°F. Hardness 870 ppm.
10-53	D,S	....	x	.....	Temperature 48°F.
10- 7-53	D,S	Gravel	x	.....	Adequate supply, temperature 47°F.
....	...	....	...	.....	Hardness 580 ppm.
....	D,S	....	...	.....	Hardness 735 ppm.
9-23-53	D,S	....	...	.....	Hardness 325 ppm.
9-18-53	D,S	Gravel	x	.....	Temperature 49°F.
9-17-53	D,S	Sand	x	.....	Temperature 51°F.
9-23-53	...	....	...	.....	Hardness 462 ppm.
....	...	....	...	.....	Hardness 940 ppm.
9-24-53	...	....	...	.....	Becomes red after standing; hardness 400 ppm.
....	...	....	x	1,073	See log.
9-24-53	...	....	...	.....	Hardness 435 ppm.
9-18-53	...	....	x	.....	

TABLE 2.--RECORDS OF WELLS

Location no.	Owner or name	Depth of well(feet)	Diameter (inches)	Type of well	Date or year completed	Depth to water(feet below land surface)
130-50 -- Continued						
25aab	Otto Buckhause	27	...	Dv	....	...
26bcd	R. C. Bladow	66	2	Dr	....	Flows
26ccd	Hillview Farms, Inc.	48	...	Dr	....	...
27bbb	do	160	2	Dr	....	...
27dcd	do	80	3	Dr	....	...
29bdc	Henry Milbrandt	30	...	Du	....	...
34aa	C. F. Buckhause	15	30	Dv	....	8.16
34dba	Emil Wallman	18	...	Du	....	10
36abb	Fred Buckhause	130	$2\frac{1}{2}$	Dr	....	20
131-48						
32ada	Francis Hermes	184	3	Dr	....	6
34daa	Carrie Daman	250	4	Dr	....	...
131-49						
7c	Mrs. Mike Kinn	52	$2\frac{1}{2}$	Dr	....	8
31bac	R. C. Bladow	24	$1\frac{1}{4}$	Dv	....	10
31cca	do	20	$1\frac{1}{4}$	Dv	....	9
33dda	Walter Pasberg	60	3	Dr	....	10
34aba	Reuben Bladow	...	2	Dr	....	3
34abb	do	62	2	Dr	....	4
35aaa	Elroy Stein	135	3	Dr	....	5
35bbc1	Mary Boelke	96	3	Dr	....	Flows
35bbc2	do	105	...	Dr	....	...
35d1	Mrs. Grace Rossow	98	2	Dr	1916	3
35d2	do	98	2	Dr	1951	9
36dda	A. Stoltenow	68	2	Dr	1947	10
131-50						
31bbc	Alfred Witt	28	$1\frac{1}{4}$	Dv	1949	...
31daa	do	25	$1\frac{1}{4}$	Dv	....	6.5

AND TEST HOLES -- Continued

Date of measurement	Use of water	Aquifer	Chemical analysis	Elevation of land surface	Remarks
....	...	Gravel	...	.....	Hardness 435 ppm.
9-23-53	D	....	x	.....	
....	D,S	....	x	.....	Temperature 47°F.
....	D,S	....	x	.....	Temperature 48°F.
....	D,S	....	...	.....	Temperature 47°F. Hardness 320 ppm.
....	D,S	....	...	.....	Very hard.
9-23-53	...	....	...	.....	
9-23-53	D,S	....	...	.....	Hardness 290 ppm.
9-23-53	D,S	....	x	.....	Becomes brown after standing; temperature 49°F.
10- 8-53	D,S	Gravel	...	.....	Hardness 325 ppm.
....	D,S	Sand	x	.....	Salty taste.
12- 2-53	D,S	Sand	...	.....	Hard.
12- 1-53	D	Sand	...	.....	do
12- 1-53	D,S	Sand	...	.....	do
12- 1-53	D,S	Sand	...	.....	Soft.
9-17-53	D,S	....	...	.....	Hard.
12- 1-53	D,S	Sand	...	.....	Soft.
12- 1-53	D,S	Sand	...	.....	do
9-17-53	S	Gravel	...	.....	Hard.
....	D	Gravel	...	.....	
12- 1-53	D,S	Sand	...	.....	Hard.
12- 1-53	D	Gravel	...	.....	do
12- 2-53	D,S	Sand	...	.....	do
....	D,S	Sand	x	.....	Adequate supply.
10- 6-53	S	Sand	...	.....	Hardness 215 ppm; temperature 50°F.

Location no.	Owner or name	Depth of well(feet)	Diameter (inches)	Type of well	Date or year completed	Depth to water(feet below land surface)
131-50 -- Continued						
33bca	Sheyenne Land Grazing Association	...	2	Dv	....	...
34ddd	Test hole 817	110	5	Dr	....	...
35bab	E. Medenwaldt	32	$1\frac{1}{4}$	Dv	....	...
35ccb	do	Spring	...	...	....	...
35dca	August Pankow	20	2	Dv	....	7
36ccb	Test hole 816	60	5	Dr	11-18-53	...

AND TEST HOLES -- Continued

Date of measurement	Use of water	Aquifer	Chemical analysis	Elevation of land surface	Remarks
....	S	....	...	.....	Hardness 145 ppm.; temperature 49°F.
11-18-53	...	....	x	1,063	See log.
....	D	....	...	.....	Soft.
....	...	....	...	.....	Flows all year; 75-100 gpm (est); till-delta sand contact.
9-25-53	D	Sand	x	.....	
....	...	....	...	1,076	See log.

TABLE 3.--LOGS OF TEST HOLES

130-49-17aaa
Test hole 821

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Sand, very fine, light-gray	6	6
	Clay, light-gray	3	9
	Sand, very fine to fine, some clay	46	55
	Sand, very fine, much clay	43	98
Till and associated melt-water deposits:			
	Till,* light-gray	63	161
	Sand and gravel	2	163
	Till, light-gray to medium-gray	37	200

*Till refers to an unsorted mixture of clay, sand, and gravel. In the Hankinson area it is predominantly clay and usually will not yield water readily.

130-49-17ccc
Test hole 813

Lake Agassiz deposits (deltaic):			
	Clay, silt, and sand, very fine	7	7
	Sand, very fine to fine, light-gray	43	50
	Sand, very fine, and considerable amounts of clay and silt	22	72
Till and associated melt-water deposits:			
	Till, soft, light-gray	30	102
	Sand	3	105
	Till, light-gray	27	132
	Sand and gravel	4	136
	Till, light-gray to medium-gray	105	241
	Sand, fine to coarse	8	249
	Till, hard, medium-gray	25	274
Benton(?) shale:			
	Shale, clayey, very dark-gray to black	109	383
Granite, decomposed:			
	Clay, white; grading downward into green, probably kaolinitic	17	400

TABLE 3.--LOGS OF TEST HOLES -- Continued

130-49-17ddd
Test hole 814

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Clay, sandy, orange	4	4
	Clay, light-gray	4	8
	Silt and sand, very fine	46	54
Till and associated melt-water deposits:			
	Till, light-gray	78	132
	Sand, coarse to very coarse, small amount of clay	8	140
	Sand and gravel, boulders at bottom	39	179
Benton(?) shale:			
	Shale, silty, very dark-gray	11	190

130-49-20ddd
Test hole 822

Lake Agassiz deposits (deltaic):			
	Clay, silty, limonitic concretions, grayish-orange	16	16
	Silt and sand, very fine, light-gray	49	65
Till and associated melt-water deposits:			
	Till, light-gray	61	126
	Sand, gravel, and clay	23	149
	Till, light-gray to medium-gray	51	200

130-49-22aaa
Test hole 815

Lake Agassiz deposits:			
	Clay, silty, grayish-orange	16	16
Till and associated melt-water deposits:			
	Till, light-gray	66	82
	Sand	3	85
	Till, light-gray	4	89
	Sand, gravel, and clay	13	102
	Till, light-gray	4	106
	Sand and clay	3	109
	Till, hard, medium-gray	119	228
Benton(?) shale:			
	Clay, fine-grained; hard-drilling, very dark-gray	52	280

TABLE 3.--LOGS OF TEST HOLES -- Continued

130-50-2cca1
Test hole 803

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Sand, very fine and silt	18	18
	Sand, very fine to fine, light-gray	17	35
	Sand, very fine to fine, yellowish-gray	5	40
	Sand, very fine to fine, light-gray	30	70

130-50-3cbb
Test hole 818

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Sand, fine, brown	6	6
	Clay, gray	5	11
	Sand, very fine; clayey	9	20
	Sand, very fine; small amount of clay	46	66
Till and associated melt-water deposits:			
	Till, light-gray	14	80

130-50-11bab
Test hole 806

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Sand, very fine to fine; much carbonaceous material	17	17
	Sand, light-gray, very fine to fine	91	108
Till and associated melt-water deposits:			
	Till, sandy; light-gray, becoming darker gray with increasing depth	257	365
Benton(?) shale:			
	Clay, very fine-grained, very dark-gray to black	35	400

130-50-11dbb
Test hole 807

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Sand, very fine to fine, yellowish-gray	9	9
	Sand, very fine to fine, light-gray	93	102
Till and associated melt-water deposits:			
	Till, medium-gray	8	110

TABLE 3.--LOGS OF TEST HOLES -- Continued

130-50-11ddc
Test hole 808

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Sand, very fine to fine	7	7
	Sand, very fine to fine, much carbonaceous material	2	9
	Sand, very fine, silty, light-gray	61	70
	Sand, very fine; considerable amounts of clay and silt; small snail shells	27	97
Till and associated melt-water deposits:			
	Till, light-gray	13	110

130-50-13bdd
Test hole 819

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Sand, very fine, brown. Abundant small snail shells	6	6
	Sand, very fine to fine, light-gray	48	54
	Sand, very fine, clayey, light-gray	32	86
	Clay, sandy, light-gray	8	94
Till and associated melt-water deposits:			
	Till, light-gray	6	100

TABLE 3.--LOGS OF TEST HOLES -- Continued

130-50-13dcc
Test hole 812

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Sand, very fine to fine, yellowish-gray..	6	6
	Sand, very fine to fine, light-gray......	13	19
	Sand, fine..............................	8	27
	Sand, very fine, clayey..................	69	96
	Clay, silty, sandy, medium-gray..........	6	102
	Clay, silt, and much partly carbonized wood; one small conifer branch recognizable..........................	18	120
Till and associated melt-water deposits:			
	Clay and sand............................	20	140
	Till (?) weathered; samples consist of yellowish-gray clay, sand, and gravel, and pieces of decayed wood............	15	155
	Till, medium-gray........................	28	183
	Sand, and gravel.........................	4	187
	Till, medium-gray........................	6	193
	Sand and gravel..........................	3	196
	Till, medium-gray........................	52	248
Benton(?) shale:			
	Clay, very fine-grained, very dark-gray..	2	250

130-50-14ada
Test hole 809

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Clay, sandy, yellowish-gray..............	8	8
	Sand, very fine to fine, light-gray......	42	50
	Sand, very fine, and silt................	22	72
	Clay and silt, light-gray................	33	105
Till and associated melt-water deposits:			
	Till, medium-gray........................	33	138
	Sand and gravel..........................	2	140
	Till, medium-gray........................	50	190

TABLE 3.--LOGS OF TEST HOLES -- Continued

130-50-14dad
Test hole 810

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits: (deltaic)*			
	Clay and silt, yellowish-gray	10	10
	Sand, very fine, clayey	11	21
	Sand, very fine to coarse, clayey	9	30
	Sand, very fine, clayey	20	50
	Sand, very fine, clayey; probably cleaner than above	35	85
Till and associated melt-water deposits:			
	Till, light-gray	15	100

*The delta sands from this site are finer and dirtier than from test hole sites farther north.

130-50-14ddd
Test hole 811

Lake Agassiz deposits (deltaic):			
	Clay, yellowish-gray	4	4
	Clay, light-gray	3	7
	Sand, very fine to fine	33	40
	Sand, mostly fine	5	45
	Sand, very fine to fine	36	81
	Clay, (?); samples contain mostly sand but drill hard	16	97
	Sand, fine to very coarse, clayey	23	120
	Sand, very coarse, and gravel	15	135
	Gravel, fine to medium	31	166
Till and associated melt-water deposits:			
	Till, light-gray	14	180

130-50-24acc
Test hole 820

Lake Agassiz deposits (deltaic):			
	Clay, sandy, light-brown	4	4
	Sand, very fine to fine, light-brown	16	20
	Sand, very fine to fine, light-gray	10	30
	Sand, mostly fine (coarser than above)	15	45
	Sand, very fine to coarse, and gravel, very fine; composed of shale	7	52
Till and associated melt-water deposits:			
	Till, light-gray	8	60

TABLE 3.--LOGS OF TEST HOLES -- Continued

131-50-34ddd
Test hole 817

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Clay, sandy, light-gray..................	13	13
	Sand, very fine to fine, light-gray......	79	92
	Clay, soft, light-gray...................	18	110

131-50-36ccb
Test hole 816

Formation	Material	Thickness (feet)	Depth (feet)
Lake Agassiz deposits (deltaic):			
	Clay and sand; very fine, carbonaceous, dark-brown............................	7	7
	Sand, very fine to fine..................	35	42
Till and associated melt-water deposits:			
	Till, soft-drilling, light-gray..........	18	60

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