PROGRESS REPORT ON THE GEOLOGY AND GROUND-WATER RESOURCES OF THE WESTHOPE AREA BOTTINEAU COUNTY, NORTH DAKOTA

(example)

BY
J. E. POWELL, ENGINEER
GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

NORTH DAKOTA GROUND-WATER STUDIES NO. 27

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

1959

PROGRESS REPORT ON THE GEOLOGY AND GROUND-WATER RESOURCES OF THE WESTHOPE AREA, BOTTINEAU COUNTY, NORTH DAKOTA

By
J. E. Powell
Engineer, Geological Survey
United States Department of the Interior

North Dakota Ground-Water Studies No. 27

Prepared cooperatively by the United States Geological Survey, the North Dakota State Water Conservation Commission, and the North Dakota State Geological Survey

- 1959 -

CONTENTS

ILLUSTRATIONS

TABLES

PROGRESS REPORT ON THE GEOLOGY AND GROUND-WATER RESOURCES OF THE WESTHOPE AREA, BOTTINEAU COUNTY, NORTH DAKOTA

By
J. E. Powell

ABSTRACT

The area described in this report is in Bottineau County in north-central North Dakota and consists of approximately 81 square miles in the vicinity of the city of Westhope.

The geologic units in the area, from the land surface down, are as follows: Alluvium of Recent age; glacial deposits of Pleistocene age, consisting of deposits of glacial Lake Souris, deposits in the valley of the Souris River, and till and associated meltwater deposits of sand and gravel; and bedrock consisting of the Cannonball(?) member of the Fort Union formation of Paleocene age, the Fox Hills(?) sandstone of Late Cretaceous age, and the Pierre shale of Late Cretaceous age. Older Cretaceous formations include the Niobrara formation, Benton shale equivalents, and the Dakota sandstone.

Glacial deposits in the area probably originated during the Wisconsin stage of the Pleistocene epoch. Thirty-nine test holes drilled completely through the glacial drift indicate a range in thickness of 86 to 195 feet and an average of 140 feet.

Surface deposits in the area consist almost entirely of lake clay deposited by the waters of glacial Lake Souris. The glacial-lake deposits range in thickness from 12 feet to 57 feet and average 27 feet. A few wells in the area obtain water from a sandy and gravelly zone near the base of the lake deposits. Generally wells of this type are less than 30 feet deep and supply only small amounts of water.

Older and more permeable alluvial deposits are found in the valley of the Souris River beneath the Recent alluvium and the deposits of glacial Lake Souris. These deposits are largely discontinuous, interbedded, and gradational and consist of sand, gravel, and clay in varying proportions. The older alluvial deposits range in thickness from 12 feet to 39 feet and average 23 feet.

Glacial till is present throughout the report area. It underlies the deposits of glacial Lake Souris in the uplands and occurs immediately below the deposits of older alluvium in the Souris River valley. The till is composed of heterogeneous material ranging in size from clay to large boulders. The glacial till ranges in thickness from 36 feet to 152 feet and averages 113 feet.

Either the Cannonball(?) member of the Fort Union formation or the Fox Hills(?) sandstone, or both, are believed to be present below the glacial till at some locations in the Westhope area. Cuttings from test holes that penetrated these deposits consisted of smooth gray clay or grayish-green sandy clay. As no fossils were recovered, the deposits could not be positively identified.

The Pierre shale is the oldest formation penetrated by test drilling. In the report area it consists of medium-light- to dark-gray clay and siltstone. Cuttings from most test holes contained fragments of bentonite and selenite (gypsum). The thickness of the Pierre shale in the Westhope area is believed to approximate 1,200 feet.

Ground water in sufficient quantity to supply a city or other large user is difficult to obtain in the Westhope area. Small amounts of water sufficient for individual farm and domestic use are obtained at the base of the deposits of Lake Souris and from aquifers in the glacial till.

Water of satisfactory quality to meet U. S. Public Health Service standards probably is not present in the report area. In most of the area the ground water has high concentrations of dissolved solids (more than 1,000 ppm) and, except in a few places, is very hard. Chemical analyses of water from six wells in the area show that it is generally unsuitable for irrigation.

The deposits of older alluvium in the valley of the Souris River 2 miles east of Westhope may be sufficiently permeable to yield larger amounts of water. However, additional test drilling and aquifer tests would be necessary to determine whether the alluvial deposits are sufficiently permeable and widespread to yield substantial water supplies.

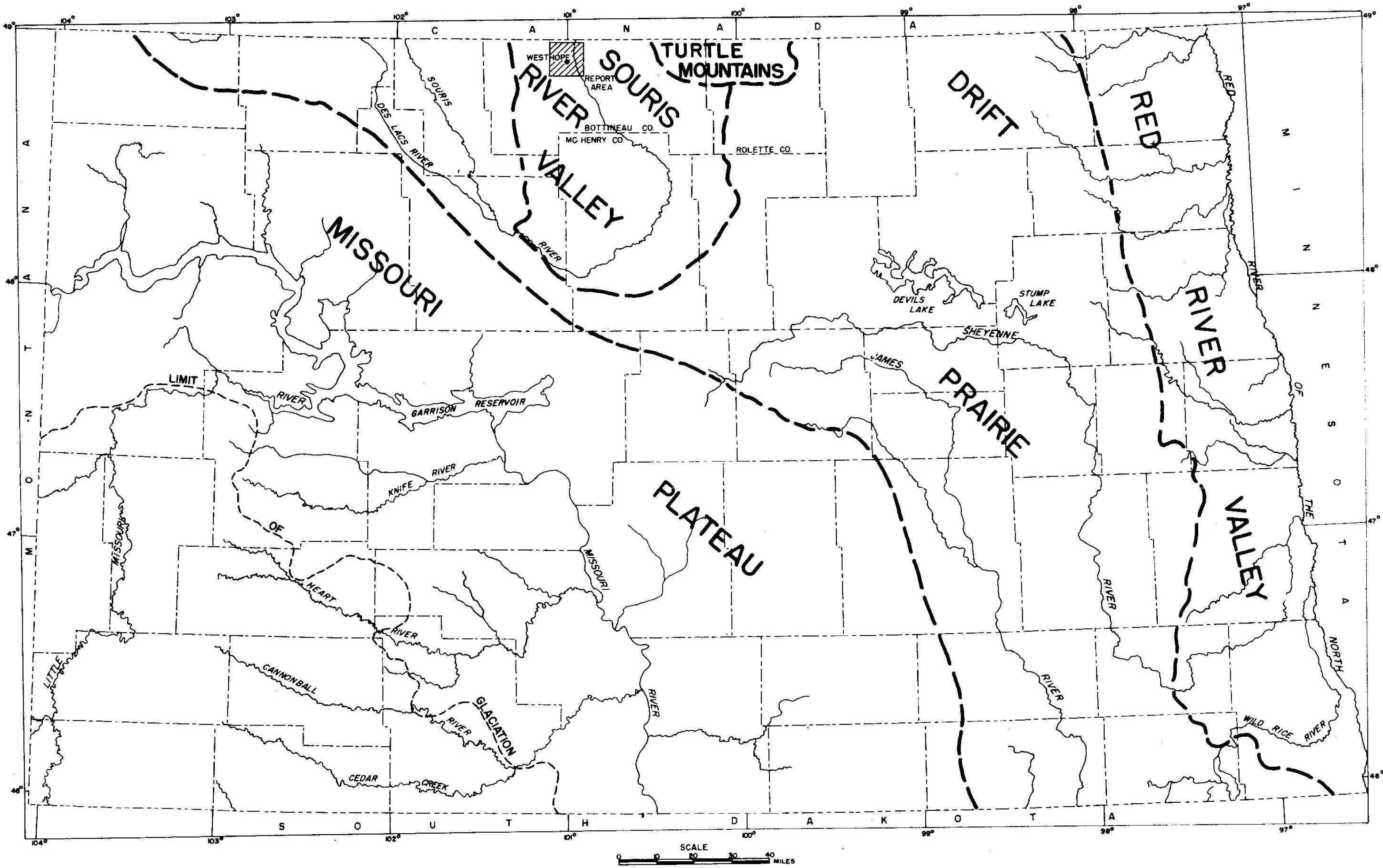


FIGURE I--PHYSIOGRAPHIC PROVINCES IN NORTH DAKOTA (MODIFIED FROM. SIMPSON,1929) & LOCATION OF THE WESTHOPE AREA

INTRODUCTION

Location and General Features of the Area

The Westhope area in north-central Bottineau County is approximately 81 square miles and is in the following townships: the western half of T. 163 N., R. 79 W., sections 4 through 9 and 16 through 18 of T. 162 N., R. 79 W., all of T. 163 N., R. 80 W., and sections 1 through 18 of T. 162 N., R. 80 W. Westhope, the only city in the area had a population of 575 in 1950. It is served from the north and south by U. S. Highway 83 and from the east and west by a branch of the Great Northern Railroad. The average annual precipitation recorded by the U. S. Weather Bureau at Westhope from 1891 to 1954 was 14.55 inches. The mean annual temperature during the same period was 37.9 degrees. The principal occupation in the area is farming; the main crops are wheat, flax, barley, oats, and corn.

Purpose and Scope of the Investigation

This is a progress report on a study of the geology and ground-water resources of Bottineau County, N. Dak., which is being made by the U. S. 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, discharge, and recharge of the ground water, and the quantity and quality of ground water available for municipal, domestic, industrial, and irrigation purposes. The most critical need in the State is for adequate and perennial water supplies 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 towns that have requested aid from the State Water Conservation Commission and the State Geologist.

Progress reports are released when enough data are accumulated to be helpful in the solution of water-supply problems of the towns and other water users. This investigation was made in 1953 and 1954 under the general supervision of A. N. Sayre, former chief of the Ground Water Branch, Water Resources Division, U. S. Geological Survey, and under the direct supervision first of P. D. Akin, district engineer, and then of Joseph W. Brookhart, district geologist, Grand Forks, N. Dak. The fieldwork and test drilling were done by or under the direct supervision 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 Bottineau County was made by Simpson (1929, p. 79-88),[1/] who included in his report a discussion of the log of a test hole drilled by the North Dakota Gas Co. 9 miles south of Westhope. Abbott and Voedisch (1938, p. 48) made an investigation of the municipal water supplies of North Dakota, and their report includes a well description and chemical analysis of water from Westhope city well 1.

1/See References at end of this report.

The first investigation of the geology of the area was made by Upham (1895), who described the surface features of the glacial Lake Souris basin in the vicinity of Westhope.

The cooperation of residents of the Westhope area was of great help during the present investigation. Valuable assistance was given by members of the city council, who supplied general information and otherwise facilitated the investigation. Thanks are due to C. A. Simpson and Sons, well drillers, who supplied logs and considerable information concerning depth and performance of wells in the area.

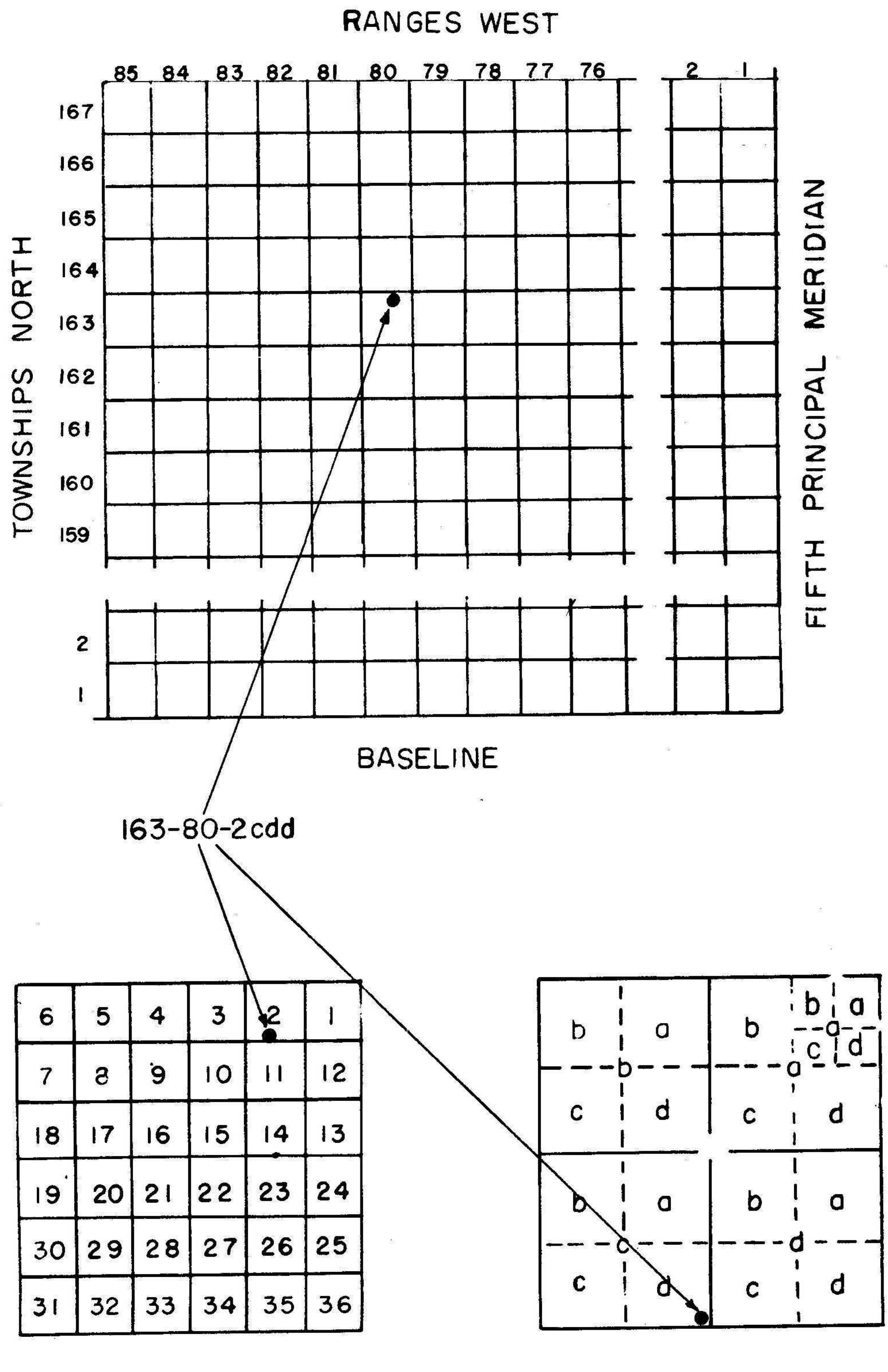


Figure 2 --Sketch illustrating well-numbering system.

Well-Numbering System

The well-numbering system used in this report is illustrated in figure 2 and is based upon the location of the well within the public land classification of the U. S. Bureau of Land Management. 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 listed within a given 10-acre tract. Thus, well 163-80-2cdd is in the southeast quarter of the southeast quarter of the southwest quarter of section 2, T. 163 N., R. 80 W. Similarly, well 163-79-2cca2 is the second well located in the northeast quarter of the southwest quarter of the southwest quarter of section 2, T. 163 N., R. 79 W.

Physiographic Features

The area is a part of the Western Young Drift section of the Central Lowland province of Fenneman (1938, p. 599) and is in the Souris River valley as designated by Simpson (1929, p. 4). The Souris River valley is a broad glacial-lake basin which slopes gently northward toward the long axis of the basin. The basin was occupied by the waters of glacial Lake Souris probably during the latter part of the Mankato substage of the Pleistocene epoch.

The Westhope area is a depositional lake plain. Relief in the area is for the most part very gentle and seldom exceeds 10 feet in a square mile. Sharper relief can be seen in the valley of the present day Souris River, where in places the valley floor is 100 feet below the lake plain.

The area is drained by the northward-flowing Souris River, which is a part of the Hudson Bay drainage system. Reservoirs impounded by dams constructed across the valley by the U. S. Fish and Wildlife Service serve as refuges for migratory waterfowl.

Numerous small, shallow coulees dissect the otherwise flat surface of the lake plain. The coulees form the secondary drainage network for the area and gradually deepen and broaden as they near the main river valley.

GEOLOGY AND OCCURRENCE OF GROUND WATER

Principles of Occurrence of Ground Water

Practically all ground water is derived from precipitation. Water enters the ground by direct penetration of rain or melting snow or by percolation from streams and lakes that lie above the water table. Ground water generally moves downward and then 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 where the water table is near the land surface, by seepage into streams, by pumping from wells, and by discharge from springs.

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 rock 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 pores, 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, relatively impermeable 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 relatively 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. When water is yielded from the well, the aquifer remains saturated and water is yielded because the water expands and the aquifer is compressed as the pressure is decreased. Gravity drainage does not occur under 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.

The water released from or taken into storage in a water-table aquifer in response to a change in head is attributed partly to gravity drainage or refilling of the zone through which the water moves and partly to compressibility of the water and of the material in the saturated zone. The volume of water attributable to compressibility is a negligible part of the total volume of water released from or taken into storage, however, and can be disregarded. Thus, for a water-table aquifer, the coefficient of storage is practically 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 such 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 such material is said to be relatively impermeable or to have low permeability. The "coefficient of 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 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 of a small part. It is the average field permeability of the aquifer multiplied by its thickness, in feet.

The suitability of an aquifer as the source of water supply is governed by its permeability, its volume, and 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 which are highly permeable but small in areal extent and which are surrounded by relatively impermeable material can be pumped dry in a comparatively short time. The rather high initial yield of a well may give an erroneous impression that a great volume of water is available from the aquifer indefinitely. Thus, before any substantial ground-water development is made, sufficient test drilling, aquifer tests, and related studies should be undertaken to determine the capabilities and recharge conditions of the aquifer being considered.

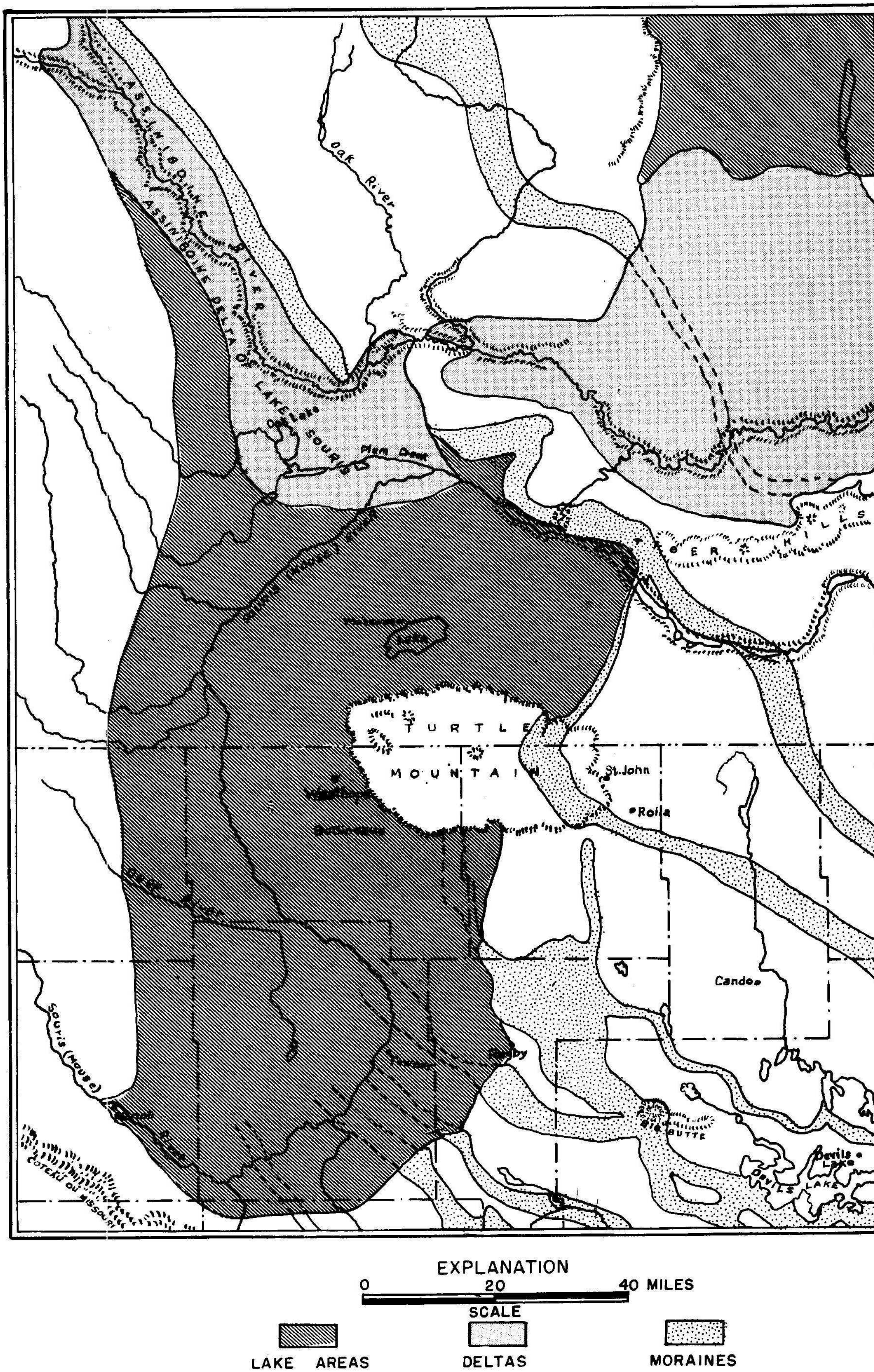


FIGURE 3 - MAP OF THE GLACIAL LAKE SOURIS
(AFTER UPHAM, 1896)

Geologic History

During the last substages of the Wisconsin stage of the Pleistocene epoch, glacial Lake Souris was formed in the northward-sloping Souris River basin. The lake was formed in front of the ice margin during the last retreat of the glacier; consequently, the configuration of the surface of the basin is essentially the same as it was when covered by the water of the glacial lake. At its maximum stage, Lake Souris was approximately 175 miles long and 75 miles wide, and extended from the southern loop of the Souris River in North Dakota to the point in the province of Manitoba, Canada where the river turns sharply north through the Tiger Hills. (See fig. 3.)

The outflow of Lake Souris during its early stages was southward via the Sheyenne River to the southern part of glacial Lake Agassiz in eastern North Dakota. When the ice had retreated far enough north to uncover the Turtle Mountains, the outflow passed north of the Turtle Mountains and thence to the northern part of Lake Agassiz via the Pembina River (Upham, 1896, p. 268).

After the last major retreat of the Dakota ice lobe it is quite probable that minor advances and recessions of the ice in parts of the Souris basin caused fluctuations in the level of the lake. Inasmuch as there are no prominant beaches or other evidence of extensive wave or lake-ice action in the area, it is doubtful that the lake remained at fixed stages for long periods. During at least a part of its history Lake Souris was probably broken into several segments and contained numerous islands.

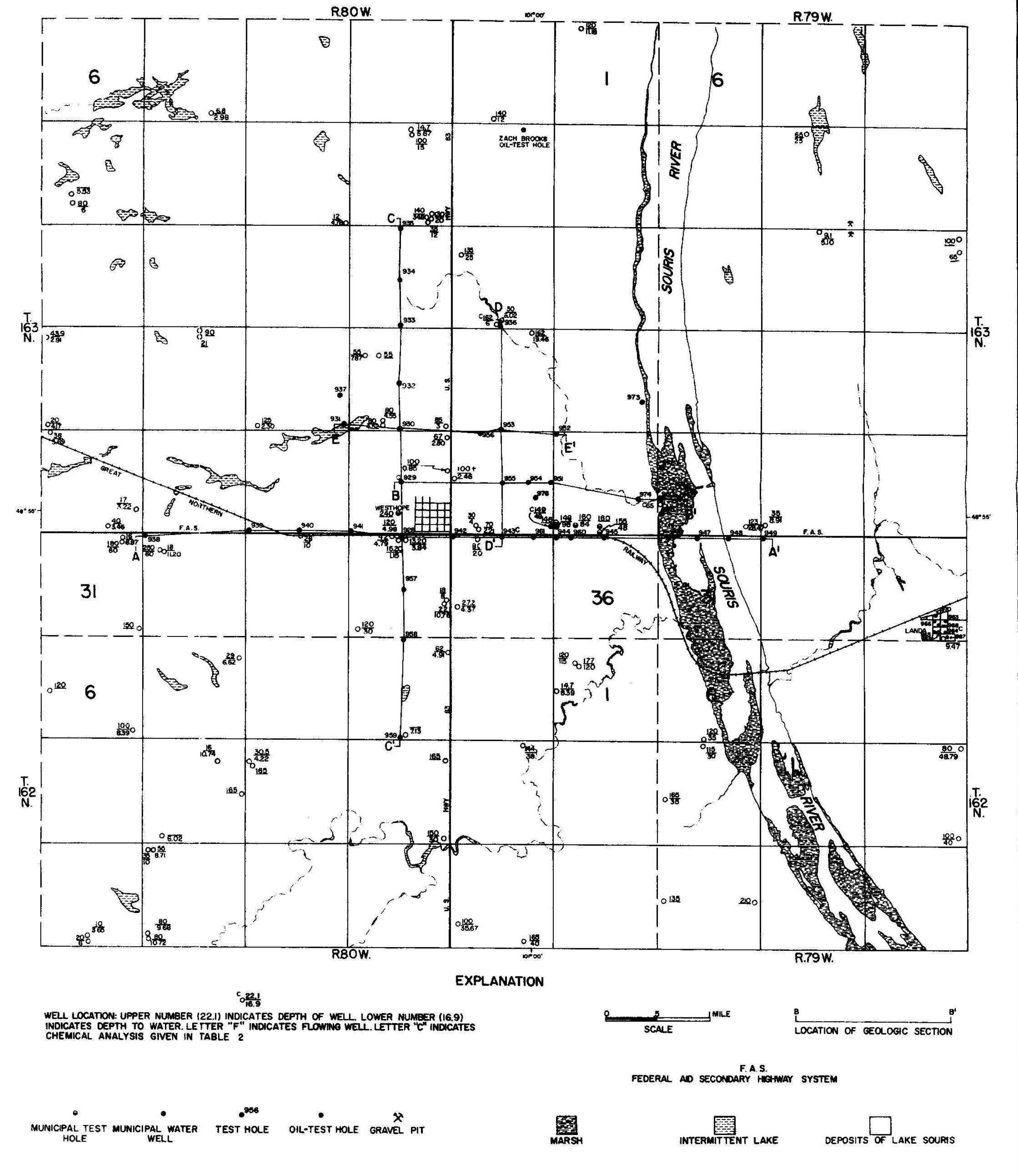
The part of the Souris River that flows through the report area is approximately in the middle of the basin formerly occupied by glacial Lake Souris. Therefore, as the lake was drained and its borders retreated slowly to the north with the retreat of the ice, there probably was little or no flow of water in the Souris River valley, inasmuch as it was itself a part of the lake beds being slowly uncovered as the lake receded. Because of the position of the valley in relation to the borders of the lake it is doubtful that the waters of glacial Lake Souris were involved to any great extent in the deposition of alluvium in the Souris River valley. More likely the alluvium was deposited by glacial meltwater from a source outside the Souris River Basin.

The Cannonball(?) member of the Fort Union formation and the Fox Hills(?) sandstone, both of which may be present in the area, were deposited in a marine environment. The Cannonball(?) member was deposited by the Tertiary sea during its only invasion of the area in early Tertiary time. The Fox Hills(?) sandstone was deposited by the Cretaceous sea during its last advance in Late Cretaceous time.

UNITED STATES
GEOLOGICAL SURVEY

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
NORTH DAKOTA STATE GEOLOGICAL SURVEY

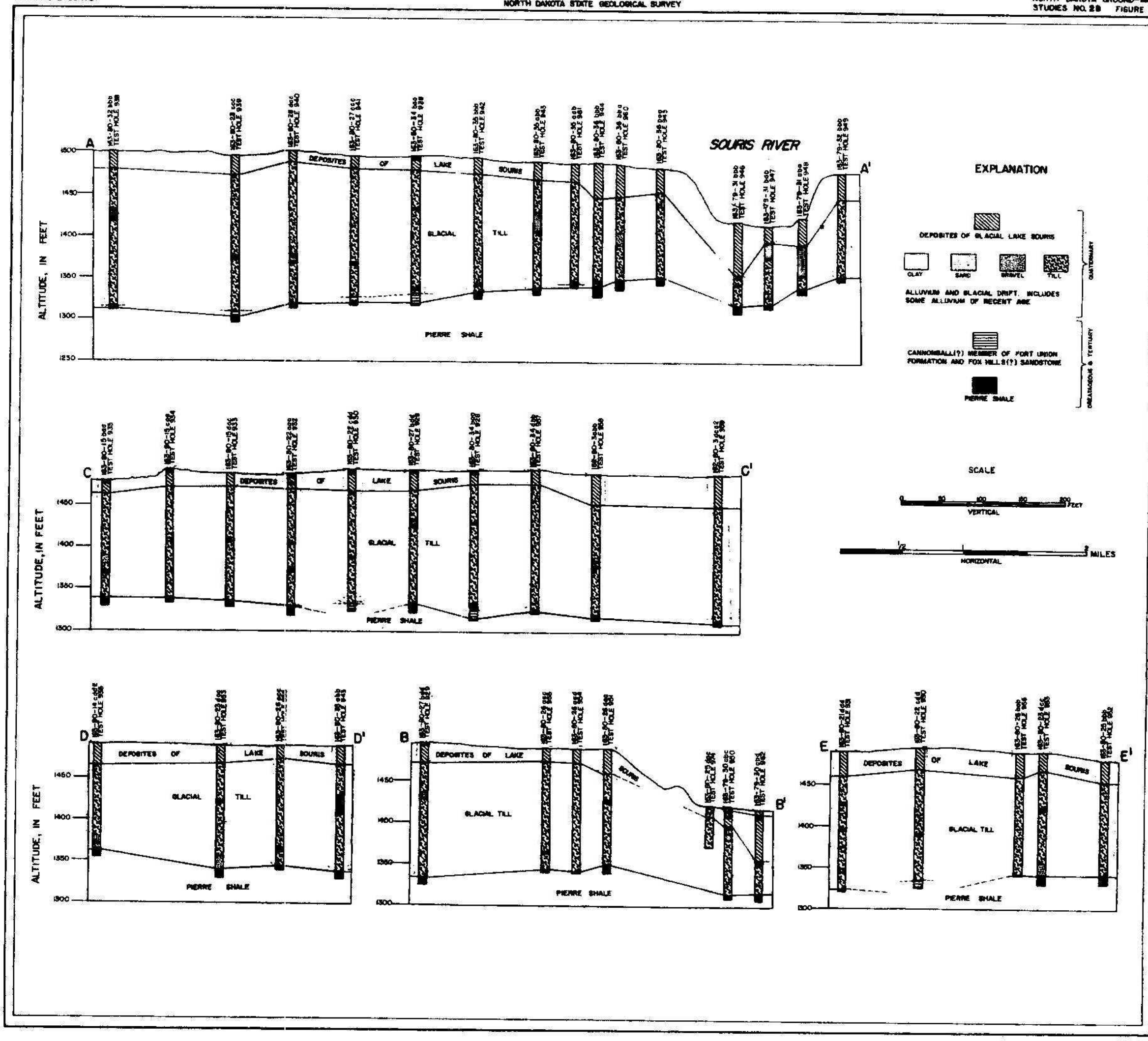
NORTH DAKOTA GROUND-WATER STUDIES NO. 28 FIG. 4



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

General Stratigraphic Relationships

Information regarding the stratigraphy in the Westhope area was obtained in part from a study of the cuttings from 49 test holes and in part from published information. The locations of test holes drilled in the area are shown on figure 4, and the logs are listed on pages 44 to 67. The test holes were drilled with a hydraulic-rotary drilling machine owned by the North Dakota State Water Conservation Commission. The depths of the test holes ranged from 50 to 200 feet and averaged 119 feet. Samples were taken of each 5-foot interval. Geologic cross sections based upon logs of test holes are shown on figure 5. Information concerning the deeper formations in the area was obtained from logs of oil-test holes supplied by the North Dakota Geological Survey. The logs of other wells and test holes also were available for study. The following partial stratigraphic section was determined by examination of samples from test holes drilled in the area and by extrapolation of information from logs of oil-test borings in nearby areas.



GEOLOGIC SECTIONS IN THE WESTHOPE AREA

Table 1 - Quaternary, Tertiary, and Cretaceous stratigraphy in the Westhope area

Cenozoic era
- Quaternary system
  - Recent series
    - Alluvium
  - Pleistocene series
    - Wisconsin stage
      - Deposits of glacial Lake Souris
      - Deposits of alluvium in the valley of the Souris River
      - Till and associated sand and gravel deposits
    - Pre-Wisconsin(?) stage
- Tertiary system
  - Paleocene series
    - Cannonball(?) member of Fort Union formation

Mesozoic era
- Cretaceous system
  - Upper Cretaceous series
    - Fox Hills(?) sandstone
    - Pierre shale
    - Niobrara formation
    - Benton shale equivalents
    - Dakota sandstone

Recent alluvium

Thin deposits of Recent alluvium consisting of clay, silt, and very fine sand are present in the Souris River valley and in the valleys of its tributaries. The contact between these deposits and underlying deposits is gradational and their thickness varies considerably from point to point in short distances. Generally the Recent alluvium is thin and discontinuous. The deposits range in thickness from a few inches to a maximum of 8 feet. They are extremely lenticular and contain no important aquifers. Near the valley edges the deposits of Recent alluvium grade into deposits of slopewash.

Glacial drift

The glacial drift in the Westhope area probably originated during the Wisconsin stage of the Pleistocene epoch. There are three types of drift: (1) lake clays deposited in glacial Lake Souris, (2) alluvium deposited by glacial meltwater in the valley of the Souris River, and (3) glacial till and associated sand and gravel deposits.

Thirty-nine test holes penetrated the entire thickness of the glacial drift. The thickness of the drift averaged 140 feet and ranged from 86 feet in test hole 948 (163-79-31aba) to 185 feet in test hole 940 (163-80-28dcc). An examination of drill cuttings from the test holes did not reveal the presence of an oxidized zone that might indicate an older drift. However, the number of test holes drilled through the drift was small in relation to the size of the area and was not sufficient to establish definitely whether more than one sequence of glacial deposition was involved. Portions of the till and associated deposits may have originated during an earlier stage of the Pleistocene epoch.

Deposits of glacial Lake Souris.--Surface deposits in the Westhope area, except for scattered deposits of Recent alluvium in the valley of the Souris River, consist entirely of lake clay deposited by the waters of glacial Lake Souris. The clay is generally well sorted and in drill cuttings exhibits the laminations characteristic of lake deposits. At many locations the clay contains small amounts of sand and gravel, especially near its base, immediately above the glacial till. As determined by test drilling, the thickness of the lake deposits averaged 27 feet and ranged from 12 feet at the site of test hole 974 (163-80-25dac) to 57 feet at the site of test hole 946 (163-79-31bbb). The most common color of the lake-clay deposits is yellow-brown. However, at some locations it is gray, dark brown, or green.

Inasmuch as the lake clay is relatively impermeable, recharge to deeper glacial-drift aquifers by percolating surface waters is considerably inhibited, resulting in greater surface runoff and evaporation that would occur from more permeable materials. A few wells obtain water from the sandy and gravelly zone near the base of the glacial deposits of Lake Souris. Generally wells of this type are less than 30 feet deep and yield only small amounts of water.

Alluvium in the valley of the Souris River.--Older and more permeable alluvial deposits underlie the Recent alluvium and deposits of glacial Lake Souris in the valley of the Souris River. These deposits are largely interbedded, discontinuous and gradational, and consist of sand, gravel, and clay in varying proportions. Test drilling failed to disclose any places where the deposits of alluvium are underlain by deposits of glacial Lake Souris; hence, it is probable that the alluvium was deposited by the Souris River prior to the formation of glacial Lake Souris. However, it is possible that the early deposits of Lake Souris were completely removed from the valley by stream erosion and were later replaced by alluvial deposits.

The alluvial deposits vary considerably in thickness as well as in their proportion of component materials. Ten test holes were drilled in the valley of the Souris River and six of these penetrated deposits that could positively be identified as alluvial in origin. The alluvial deposits range in thickness from 12 feet to 39 feet and average 23 feet.

A large part of the valley of the Souris River is occupied by water which has been impounded to provide refuges for migratory waterfowl. As a result, only one well in the area is known to produce water from the deeper alluvial deposits. However, it is believed that these deposits, though discontinuous, may be hydraulically connected and thus may constitute a potentially productive aquifer.

Till and associated sand and gravel deposits.--Glacial till is present throughout the report area. It underlies the deposits of glacial Lake Souris in the uplands and occurs immediately below the deposits of older alluvium in the Souris River valley. The till was deposited directly from the melting ice and was subjected to little or no subsequent sorting by wind or water. Because the till is composed of unsorted material and because the spaces between the larger particles tend to be filled with finer materials, till does not ordinarily yield water readily to wells.

In general, glacial till is composed of heterogeneous materials ranging in size from clay to large boulders, but clay is the predominant constituent. The till in the Westhope area is dark- to light-gray calcareous, silty clay and contains varying amounts of sand, gravel, and boulders. The gravel is composed principally of shale fragments and irregular amounts of limestone, dolomite, and igneous-rock fragments. The small bodies of sand and gravel in the till were penetrated by many of the test holes (see table 4). These deposits vary considerably in thickness and in the area they underlie. They are alluvial in origin and were deposited by streams of glacial meltwater.

The thickness of glacial till as determined by test drilling averaged 113 feet and ranged from 36 feet in test hole 946 (163-79-31bbb) to 152 feet in test hole 957 (163-80-34dbb).

The permeability of the till varies from place to place with the proportion of sand and gravel it contains, so that a well finished in till at one location will yield water, whereas a similar well a short distance away will yield little or no water.

Wells of rather high initial yield may be developed in sand and gravel deposits within the till. However, the production of wells penetrating aquifers that are lenticular- that is, aquifers that are completely surrounded by dense till decreases rapidly as the aquifers become unwatered. Recharge through the glacial till to these aquifers is slow, and pumping rates must be correspondingly low if production is to be maintained. Water for farm and domestic use is obtained from the till throughout the Westhope area. Wells that have higher production are probably finished in lenticular sand and gravel deposits.

The Westhope municipal water-distribution system was installed in 1948. Before this time supplies were obtained from shallow wells in and near the city and from a public-supply well half a mile east of the city. In 1958 the city supply was obtained from two wells. City well 1 (163-80-26ddal) is 150 feet deep and is approximately a mile east of Westhope. City well 2 (163-80-25ccc) is 145 feet deep and is approximately 500 feet east of city well 1. Both wells obtain water from a sand and gravel zone at or near the base of the glacial drift and immediately above the Pierre shale. City well 1 was drilled in May 1946, when the water level was reported to be 49 feet below the land surface. When city well 2 was completed in the same aquifer in December 1954 the measured water level was 103.09 feet below the land surface. It was observed that pumping of city well 1 caused almost immediately a lowering of the water level in city well 2.

Bedrock

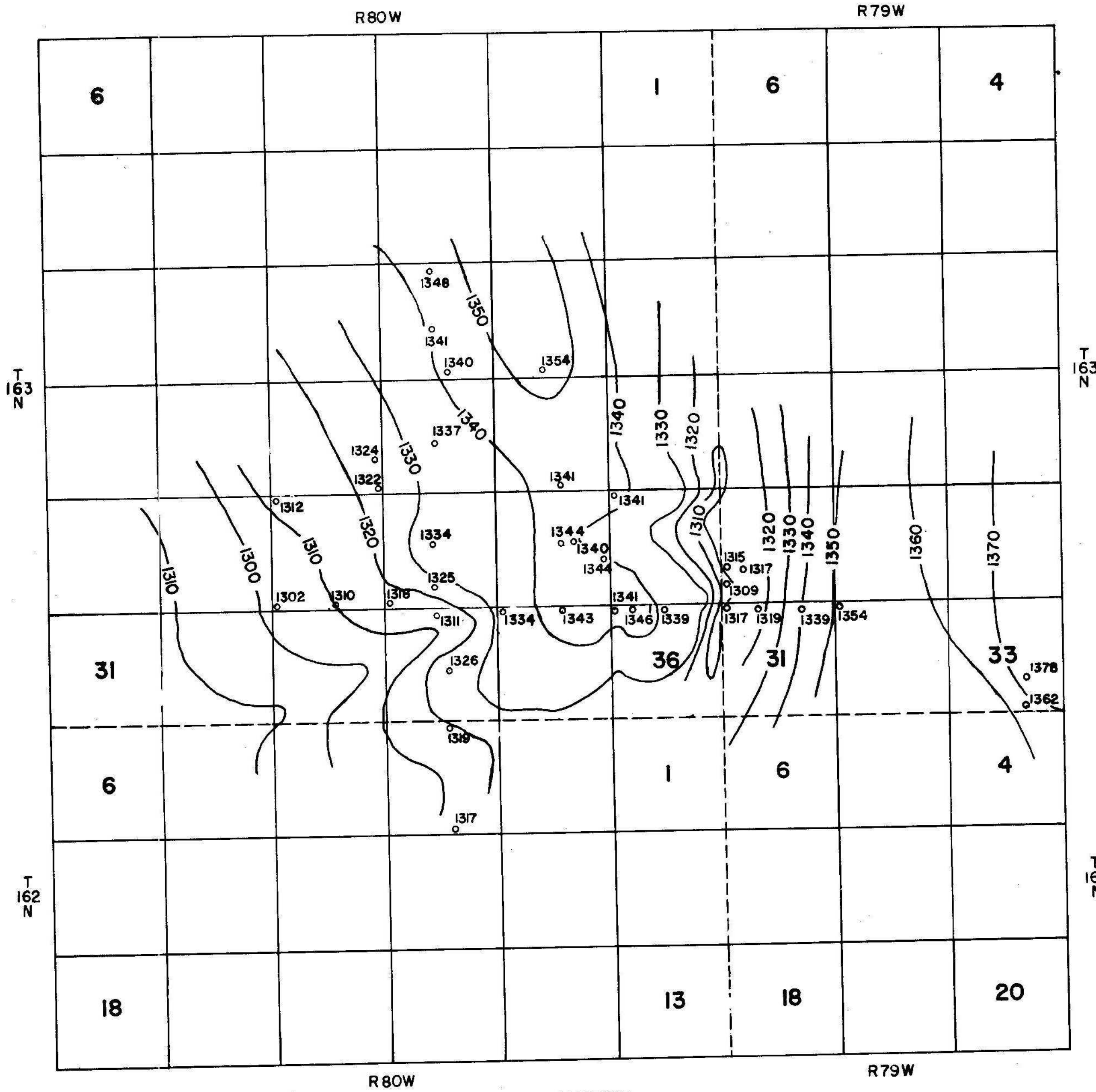
Cannonball(?) member of Fort Union formation.--The presence of the Cannonball(?) member in the report area has not been definitely established but the Cannonball(?) member may be represented by smooth gray clay which immediately underlies the glacial drift in places. This clay was penetrated by test holes 930 (163-80-22cdd), 939 (163-80-28ccc), 941 (163-80-27ccc), and 962 (163-79-30cbd). The gray clay averaged $3\frac{1}{4}$ feet in thickness in the four test holes in which it was identified. It ranged in thickness from 1 foot at test hole 962 to 5 feet at test hole 939. Possibly the gray clay was penetrated by other test holes in the area but was not recognized in the drill cuttings. Except for the absence of sand and gravel it does not differ markedly from glacial till in composition or color. Lack of sand, gravel, or other coarse rock debris in the gray clay indicates that it is not of glacial origin.

The closest outcrop of the Cannonball(?) member is reported (Brown and Lemke, 1948, p. 624-625) to occur near the towns of Velva and Sawyer, approximately 76 miles south of Westhope.

None of the wells inventoried in the Westhope area produce water from the Cannonball(?) member, and it is not considered to be an aquifer.

Fox Hills(?) sandstone.--The presence of the Fox Hills(?) sandstone in the Westhope area has not been definitely established; however, the formation is believed to be present in several places in the form of a grayish-green sandy, gravelly clay immediately below the gray clay of the Cannonball(?) member. It was penetrated in test holes 928 (163-80-34baa4), 930 (163-80-22cdd), 938 (163-80-32bbb), 939 (163-80-28ccc), 941 (163-80-27ccc), 961 (163-80-35aab), and 968 (163-79-33dca2). The thickness of the green sandy clay averaged approximately 3½ feet and ranged from 1 foot in test hole 930 to 12 feet in test hole 928. Possibly this material was penetrated by test drilling in other parts of the report area but was not recognized in the drill cuttings.

Although the Fox Hills(?) sandstone does not underlie the whole of the report area, it is believed to be present in scattered patches at many places. These patches may be interconnected in parts of the area by narrow, elongate zones of the same formation. This situation is believed to exist in the vicinity of the Westhope city wells as the analysis of water from city well 1 is similar to analyses of water known to have been produced from the Fox Hills(?) sandstone in other parts of the State (Abbott and Voedisch, 1938, p. 35).



EXPLANATION

CONTOUR INTERVAL 10 FEET

0 1/2 1 2 3 MILES

SCALE

FIGURE 6 — CONTOUR MAP SHOWING APPROXIMATE ALTITUDE OF THE TOP OF THE PIERRE SHALE IN THE WESTHOPE AREA.

Pierre shale.--During the field investigation test drilling was continued no farther than the top of the Pierre shale. This formation underlies the whole area and constitutes the bedrock immediately below the glacial drift where the Cannonball(?) member and the Fox Hills(?) sandstone are not present. The Pierre shale was reached by 41 test holes. In the Westhope area it consists of medium-light-gray to medium-dark-gray clay and siltstone. Cuttings from most of the test holes that penetrated the Pierre shale contained fragments of bentonite and selenite (gypsum). As the Pierre shale is relatively impermeable, water percolating downward through the glacial drift is confined at the top of the Pierre; thus, moderate supplies of water may be obtained from sandy and gravelly zones where they are present at the base of the glacial till. Small amounts of moderately mineralized water are obtained from fractured zones of brittle clay at the top of the Pierre shale in other parts of North Dakota; however, similar zones were not evident in the Westhope area. The log of the Zach Brooks Drilling Co., Herman Haugen No. 1 oil-test well (163-80-11abb), approximately $1\frac{1}{2}$ miles northeast of test hole 935 (163-80-15baa), lists the top of the Niobrara formation, which immediately underlies the Pierre shale, as being 1,335 feet below the land surface. No elevation was listed for the top of the Pierre shale.[2/] Test hole 935 penetrated the top of the Pierre shale at a point 142 feet below the land surface.

2/Oral communication, S. B. Anderson, North Dakota Geological Survey.

Inasmuch as the altitudes of the land surface at the two test holes are approximately equal, the thickness of the Pierre shale can be estimated at 1,200 feet in the Westhope area. This figure could be in error by about 100 feet, owing to irregularities in the surface of the formation. Figure 6 shows the approximate altitude of the top of the Pierre shale in the Westhope area.

No wells in the Westhope area are known to obtain water from the Pierre shale and it is not considered to be an aquifer.

Older rocks.--The Pierre shale is underlain in the Zach Brooks oil-test well by older rocks of Cretaceous age and by rocks of Jurassic, Triassic, and Mississippian age. The test well was drilled to a depth of 3,757 feet and did not penetrate rocks older than Mississippian; however, it is probable that older Paleozoic rocks occur beneath the Mississippian.

The Dakota sandstone of Late Cretaceous age is the only deep-lying formation of potential importance as an aquifer in the Westhope area. According to the log of the Zach Brooks well, the Dakota sandstone occurs 2,113 feet below the land surface and is 350 feet thick. Large amounts of highly mineralized water are obtained from the Dakota sandstone in other parts of North Dakota, and in some localities the water is under sufficient hydrostatic pressure to cause it to flow at the land surface. However, it is doubtful that pressure in the Westhope area would be sufficient to produce flow from wells penetrating that formation. The water may be moderately to highly mineralized.

QUALITY OF THE GROUND WATER

Ground water dissolves a part of the soluble mineral constituents of the rock particles as it moves into and through an aquifer. The amount of mineral matter dissolved depends principally on the amount of soluble materials in the aquifer and the length of time the water is in contact with them. Therefore, in any aquifer, water that has been stored underground a long time or has traveled a long distance from the recharge area generally is more mineralized than water that has been stored a short time and recovered relatively near the recharge area of the same aquifer.

Six samples of water were collected in the Westhope area. The wells from which samples were taken produce from glacial drift and range in depth from 65 to 170 feet. Chemical analyses of the samples are listed in table 2. Water from five of the wells is similar to water from glacial drift in other parts of North Dakota. However, water from the Westhope city well (163-80-26ddal) is much softer than water from the other wells. It may be that the Westhope well obtains water directly or by leakage from the Fox Hills(?) sandstone rather than entirely from glacial drift. Low hardness is typical of water in the Fox Hills(?) sandstone in other parts of the State (Robinove, 1956, p. 23). Constituents typical of water from the Fox Hills(?) sandstone and also present in relatively large concentrations in the Westhope city water are sodium (490 ppm), sulfate (220 ppm), bicarbonate (712 ppm), and chloride (179 ppm).

The U. S. Public Health Service (1946) has established standards for drinking water used on common carriers in interstate traffic. Listed below are the concentration limits for some of the chemical substances commonly present in drinking water.

Chemical constituent	Concentration (ppm)
Iron (Fe) plus manganese (Mn)	0.3
Magnesium (Mg)	125
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	1.5
Dissolved solids	500

Dissolved-solids concentrations of 1,000 ppm are permitted if water of better quality is not available.

Water of satisfactory quality to meet U. S. Public Health Service standards probably is not present in the report area. In most of the area the ground water has high concentrations of dissolved solids (above 1,000 ppm) and, except in a few places, is very hard. Four of the six samples contained sufficient hydrogen sulfide to impart a disagreeable odor to the water, and one of the six had a high concentration of nitrate. All the samples analyzed had relatively high concentrations of iron.

The chemical analyses of ground water in the Westhope area given in table 2 show that the recommended limits of some chemical constituents are exceeded in water from all the wells sampled. However, water containing more than the recommended concentration of certain chemical constituents has been used in some areas, including North Dakota, for many years without noticeable ill effects.

High concentrations of nitrate in ground water may be due to the presence of decaying organic matter in the well, in the aquifer, or on the ground surface in the vicinity of the well. It may be due also to such inorganic material as mineral fertilizers. Water containing more than about 44 ppm of nitrate may cause cyanosis in infants when used in feeding formulas and for drinking (Comly, 1945; Silverman, 1949).

The consumption of water containing fluoride in concentrations of 0.8 to 1.5 ppm isbelieved to lessen the incidence of tooth decay, especially in children. However, during the period of calcification of the teeth the consumption by children of water having concentrations higher than about 1.5 ppm may cause mottling of tooth enamel (Dean, 1936). Fluoride in excess of the recommended limit was not present in any of the six samples.

Practically all ground water contains at least small amounts of minerals causing hardness. Hardness of water is caused principally by calcium and magnesium and to a lesser extent by iron, aluminum, manganese, copper, strontium, barium, zinc, and free acid. Hardness in water is generally undesirable, especially if the water is used for cleansing purposes, because it causes increased soap consumption as well as soap scum. Water having a hardness of about 100 ppm as $CaCO_3$ generally is considered to be moderately hard; water having a hardness of 200 ppm or more is considered very hard and generally requires softening to be satisfactory for most uses.

Water having a high concentration of sodium relative to the total cation concentration (high percent sodium) is unsuitable for irrigation because it may cause soils to become relatively impermeable. The relative proportion of sodium, expressed as a percentage, may be calculated using the following equation:

$$\text{Percent Na} = \frac{\text{Na} \times 100}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}}$$

where the concentrations of all cations are in equivalents per million.

The continued use of irrigation water in which the percent sodium is in excess of 50 may cause damage to the soil. However, the amount of damage to soil that will result from the continued use of a particular type of water depends also on other factors, such as salinity of the water, porosity of the soil, drainage, irrigation practices, and crop management. In general, the higher the percent sodium the less suitable the water is for irrigation.

Water having a high salinity also is unsuitable for irrigation. The salinity of water is determined by the quantity of dissolved salts it contains. Salinity is closely related to electrical conductivity. The value for electrical conductivity, therefore, may be used to indicate the salinity of water. A close approximation of the value for electrical conductivity may be obtained by using the following formula: Dissolved solids, in parts per million $\div$ 0.65 = electrical conductivity in micromhos per centimeter at 25° C. Nearly all irrigation waters that have been used successfully for a considerable time have conductivity values less than 2,250 micromhos per centimeter. Waters of higher conductivity are used occasionally, but crop production, except in unusual situations, has not been successful (U. S. Salinity Laboratory Staff, 1954, p. 70).

Chemical analyses of the 6 water samples collected in the area showed that 5 samples had more than 50 percent sodium and 4 samples had conductivity values greater than 2,250 micromhos per centimeter. The remaining 2 samples had conductivity values greater than 2,000 micromhos per centimeter. It may be concluded, therefore, that water from all the 6 wells sampled is of poor quality for irrigation.

Because downward drainage is slow in the clay and silt which constitute the surface deposits over most of the area, considerable caution should be used in applying water having a high percent sodium or a high salinity.

SUMMARY OF GROUND-WATER CONDITIONS

Ground water in sufficient quantity to supply a city or other large user is difficult to obtain in the Westhope area. Test drilling failed to disclose the presence of an aquifer of even modest extent. However, scattered deposits of sand and gravel within or at the base of the glacial till supply small amounts of hard water which are generally adequate for individual farm or ranch use during times of normal precipitation.

Recharge to the aquifers in the glacial drift is restricted throughout the area by the surface deposits of lake clay. This clay, because of its low permeability, acts as a barrier to the downward percolation of water from precipitation and further limits the amount of ground water available to wells penetrating the small glacial-drift aquifers.

The two Westhope city supply wells which penetrate sand and gravel at the base of the glacial drift, furnish about 100 gpm. The very low hardness of the water from these wells (58 ppm) and the high percent sodium (94) in comparison with other wells in the area suggests the possibility that the Westhope city wells obtain some of their water from a bedrock source which is probably the Fox Hills(?) sandstone. Test holes 976 (163-80-26dac), 961 (163-80-35aab), and 944 (163-80-36bbb) all were drilled within a quarter of a mile of the city wells and all penetrated zones immediately below the glacial drift which were thought to be bedrock, either the Fox Hills(?) sandstone or the Cannonball(?) member of the Fort Union formation. However, attempts to core the material were unsuccessful and positive identification was not possible. Moderate additional amounts of water may be available from this bedrock(?) source in the vicinity of the Westhope city-supply wells.

Larger supplies of ground water may be available from the deposits of older alluvium in the valley of the Souris River 2 miles east of Westhope. The alluvial deposits are gradational and discontinuous and consist of varying proportions of sand, gravel, and clay. Although the permeability of the alluvium probably varies considerably at different locations in the valley, the deposits may be hydraulically connected throughout their extent. However, additional test drilling and aquifer tests would be necessary to determine whether the alluvial deposits are sufficiently permeable to constitute a promising future source of ground-water supply.

Aquifer: D, glacial drift
Fh, Fox Hills(?) sandstone
Results in parts per million except as indicated

Location number	Owner or name	Aquifer	Depth of well (feet)	Date of collection	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
163-79-30cbc1	U. S. Fish & Wildlife Service	D	65	8- 9-54	1.9	137	71	312
163-79-33ddc1	Test hole 964	D	110	8-30-54	.3	72	57	530
163-80-14cdd1	John Frazier	D	162	8-15-54	.4	215	101	445
163-80-26ddd1	City of Westhope well No. 1	D and (or) Fh	149	8-16-54	.6	7	10	490
163-80-27bdd	Test hole 929	D	170	7-14-54	3	162	66	338
163-80-35abb	Test hole 943	D	160	7-31-54	3	245	94	362

Analyses by State Laboratories, Bismarck

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardnes as $CaCO_3$	Dissolved solids (sum of determined constituents)	Percent sodium
45	774	42	341	187	0	6	637	1,520	74
14	463	12	708	291	0	13	413	1,930	52
10	742	0	809	242	0	104	954	2,290	44
3.2	712	47	220	179	0.3	16	58	1,320	94
10	411	0	508	95	.2	11	672	1,400	50
13	580	0	1,150	40	0	9	996	2,200	51

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

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

Location number	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed	Depth to water below land surface (feet)
162-79						
6cdd	Alex Boucher	120	18	Dr	....	35
7baa	R. O. Hegen	115	18	Dr	....	30
7cbb	Jacob Jacobson	165	4	Dr	1940	35
9aaa	Arnold Bangs	80	18	Dr	1900	48.79
9ddd	J. L. Solsang	100	24	Dr	1900	40
18cbb	Alfred Hagen	135	3	Dr	....	......
18daa	Oscar Krogen	210	4	Dr	....	......
162-80						
1bca1	Elmer Damstrom	177	4	Dr	1946	120
1bca2	Do	120	4	Dr	....	......
1cbb	Chris J. Jensen	14.7	48 x 48	Du	....	8.39
3aad	Walter McKechnie	62	24	Dr	....	4.91
3abb	Test hole 958	175	5	Dr	8-54	......
3dcc1	Unknown	...	...	Dr	....	7.13
3dcc2	Test hole 959	180	5	Dr	8-54	......
5aad	Anton Nesting	29	18	Dr	....	6.62
6cbb	A. Bowchen	120	12	Dr	....	......
6ddd	H. VanNewkirk	100	24	Dr	....	8.39
8abd	S. J. Acheson	16	48 x 48	Du	1898	10.74
8ccd	Unknown	...	24	Dr	....	8.02
8daa	Do	165	4	Dr	....	......
9bbc1	A. Helgeson	30.5	8	Dr	....	4.22
9bbc2	Do	165	4	Dr	....	......
10aad	B. Broen	165	4	Dr	....	......
10ddd	Axel Houmann	150	18	Dr	....	30
11aba	Almon Lee	144	4	Dr	1946	38
14ccb	Unknown	100	18	Dr	....	35.67

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

Use of water: D, domestic; N, none; Obs, observation; PS, public supply; S, stock; T, test hole.

Date of measurement	Use of water	Aquifer	Depth to shale (feet)	Altitude of land surface (feet)	Remarks
6-10-49	D,S	....	....	1,473	
6-10-49	D,S	....	....	1,472	
6-10-49	D,S	....	....	1,483	Soft.
6-14-55	D,S	Sand	....	.....	
6-14-55	N	do	....	.....	
....	D,S	....	....	1,482	
....	D,S	....	....	1,476	Soft.
6- 8-49	D,S	....	....	1,484	Soft.
6- 8-49	N	....	....	1,485	
6- 8-49	D,S	Sand	....	1,435	Hard, adequate.
6- 8-49	N	....	....	1,491	
....	T	....	171	1,491	See log.
6- 8-49	N	....	....	1,491	
....	T	....	178	1,490	See log.
6- 8-49	D	....	....	1,506	
....	N	....	....	1,505	
6-12-49	D,S	....	....	1,505	
6- 8-49	D,S	Clay	....	1,501	
6-12-49	N	....	....	1,495	
....	N	....	....	1,500	Soft.
6- 8-49	Obs	....	....	1,501	
....	N	....	....	1,501	Soft.
....	N	....	....	1,492	
6- 8-49	D,S	Gravel	....	1,488	Hard.
6- 8-49	D,S	....	....	1,480	Soft.
6- 8-49	N	....	....	1,496	

Location number	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed	Depth to water below land surface (feet)
162-80 (Cont.)						
14dcd	Leo Weber	165	4	Dr	....	40
17bbb1	S. S. Kelley	35	24	Dr	....	10
17bbb2	Do	55	24	Dr	....	8.71
17ccc1	Frank Armer	80	24	Dr	....	10.72
17ccc2	Do	80	24	Dr	....	9.68
18cdd1	Archie DeMars	20	18	Dr	....	6
18cdd2	Do	10	18	Dr	....	3.65
163-79						
8baa	Peter Severtson	65	18	Dr	....	25
16aaa	Clara Lindseth	100	2	Dr	1925	......
16aad	Do	65	12	Dr	....	......
17abb	Gilbert Severson	9.1	12	Du	....	5.10
29ccc	Unknown	35	12	Dr	....	8.91
30bcb	Test hole 972	60	5	Dr	9-54	......
30cab	Test hole 971	70	5	Dr	9-54	......
30cbc1	U. S. Fish & Wildlife Service	65	3	Dr	....	......
30cbc2	Test hole 950	110	5	Dr	8-54	......
30cbd	Test hole 962	110	5	Dr	8-54	......
30ccb	Test hole 975	110	5	Dr	9-54	......
30ddc	A. C. Anderson	123	14	Dr	1925	28.47
31aba	Test hole 948	90	5	Dr	8-54	......
31bab	Test hole 947	100	5	Dr	8-54	......
31bbb	Test hole 946	110	5	Dr	8-54	......
32bbb	Test hole 949	130	5	Dr	8-54	......
33dbd	Test hole 970	110	5	Dr	9-54	......
33dca1	Test hole 966	120	5	Dr	9-54	......
33dca2	Test hole 968	110	5	Dr	9-54	......
33dcd1	Test hole 965	130	5	Dr	9-54	......
33dcd2	Test hole 969	120	5	Dr	9-54	......
33ddb	Test hole 963	110	5	Dr	8-54	......
33ddc1	Test hole 964	100	5	Dr	8-54	......
33ddc2	Test hole 967	110	5	Dr	9-54	......

Date of measurement	Use of water	Aquifer	Depth to shale (feet)	Altitude of land surface (feet)	Remarks
6-11-49	D,S	....	....	1,491	Soft.
6-12-49	D	....	....	1,506	
6-12-49	S	....	....	1,506	
6-12-49	N	....	....	1,500	
6-12-49	D	....	....	1,500	
6-12-49	D	....	....	1,501	
6-12-49	N	....	....	1,501	
6-14-55	S	....	....	.....	Hard.
....	D	....	....	.....	Hard, adequate.
....	D	....	....	.....	Hard.
6-14-55	D,S	Gravel	....	.....	Soft.
6-14-55	...	....	....	.....	
....	T	....	....	1,415	See log.
....	T	....	....	1,415	Do.
....	D	Gravel	....	1,415	See chemical analysis.
....	T	....	105	1,421	See log.
....	T	....	101	1,416	Do.
....	T	....	105	1,425	Do.
6-14-55	S	Gravel	....	.....	Hard.
....	T	....	86	1,425	See log.
....	T	....	96	1,415	Do.
....	T	....	101	1,420	Do.
....	T	....	126	1,482	Do.
....	T	....	102	1,482	Do.
....	T	....	108	1,482	Do.
....	T	....	....	1,482	See log. Green clay 101-110 feet.
....	T	....	118	1,482	See log.
....	T	....	....	1,482	Do.
....	T	....	101	1,482	Do.
....	T	....	96	1,482	See log and chemical analysis.
....	T	....	110	1,482	See log.

Location number	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed	Depth to water below land surface (feet)
163-79 (Cont.)						
33ddc3	Wanda School	...	24	Dr	1954	9.47
163-80						
1bba	David Henderson	120	18	Dr	....	11.18
2cdd	Frank Deschampe	140	18	Dr	1910	12
5dcd	Virgil Fredrickson	6.8	48 x 72	Du	....	2.98
7cac	Unknown	...	18	Dr	....	5.53
7cdb	Chas. Patalas	80	24	Dr	....	6
9ddd	Rod Deschamp	12	24	Du	....	4.78
10abb1	E. Deschamp	100	24	Dr	....	15
10abb2	Do	14.7	24	Du	....	5.67
10ddc1	Oscar Hulse	35	18	Dr	....	12
10ddc2	Do	140	5	Dr	....	34.80
10ddc3	Do	130	18	Dr	1943	20
11aba	Zach Brooks Drilling Company	3,760	...	Dr	1952	......
14bcb	Darrell Hulse	135	24	Dr	....	25
14cdd1	John Frazier	162	24	Dr	1912	6
14cdd2	Test hole 936	140	5	Dr	7-54	......
14cdd3	John Frazier	30	12	Dr	....	6.02
15baa	Test hole 935	150	5	Dr	7-54	......
15caa	Test hole 934	160	5	Dr	7-54	......
15dcc	Test hole 933	158	5	Dr	7-54	......
19bbb	Henry Robillard	43.9	24	Dr	....	2.91
19ccc	Unknown	20	24	Dr	....	4.17
20abb1	Orville Deschamp	90	24	Dr	....	......
20abb2	Do	21	48	Du	....	......
21ccc	Mr. Berentson	125	18	Dr	....	2.30
21dad	Test hole 937	180	5	Dr	7-54	......
21ddd	Test hole 931	170	5	Dr	7-54	......
22bca	Andrew Nielson	55	18	Dr	....	7.87
22bdb	Do	55	18	Dr	....	......
22caa	Test hole 932	170	5	Dr	7-54	......

Date of measurement	Use of water	Aquifer	Depth to shale (feet)	Altitude of land surface (feet)	Remarks
6-14-55	D	Sand	....	.....	
6- 7-49	D,S	....	....	1,492	
6- 7-49	S	....	....	1,492	Alkali taste; unfit for drinking.
6- 7-49	D,S	....	....	1,493	
6- 8-49	N	....	....	1,496	
6- 9-49	D,S	....	....	1,496	
6-25-49	D	....	....	1,500	
6- 7-49	S	....	....	1,500	
6- 7-49	D	....	....	1,500	
6- 7-49	D	....	....	1,493	
6- 7-49	N	....	....	1,493	
6- 7-49	S,Obs	....	....	1,490	
....	T	....	....	1,490	
6- 7-49	D,S	....	....	1,489	
6- 7-49	S	....	....	1,485	Gas; blackish color. See chemical analysis.
....	T	....	....	1,492	See log.
6- 7-49	D	....	....	1,485	
....	T	....	142	1,480	See log.
....	T	....	154	1,496	Do.
....	T	....	152	1,490	See log. Green clay at 153 feet.
6- 9-49	D,S	....	....	1,503	
6- 9-49	N	....	....	1,497	
....	N	Sand	....	1,497	
....	D,S	....	....	1,497	
6- 7-49	D,S	....	....	1,495	
....	T	....	166	1,492	See log.
....	T	....	168	1,492	Do.
6-25-49	D,S	....	....	1,491	
....	S	....	....	1,495	
....	T	....	158	1,490	See log.

Location number	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed	Depth to water below land surface (feet)
163-80 (Cont.)						
22cdc1	Melvin Tolstad	80	18	Dr	....	4.52
22cdc2	Do	80	18	Dr	....	4.55
22cdd	Test hole 930	170	5	Dr	7-54	......
22ddd	Chester Hulse	85	18	Dr	....	3
23aab	John Frazier	162	18	Dr	1937	19.46
23dcc	Test hole 953	160	5	Dr	8-54	......
24dac	Test hole 973	50	5	Dr	9-54	......
25bbb	Test hole 952	150	5	Dr	8-54	......
25ccc1	City of Westhope	146	6	Dr	1953	......
25ccc2	Westhope well #2	148	6	Dr	1954	98
25ccd	City of Westhope	160	6	Dr	1953	84
25cdd1	Do	160	6	Dr	1946	......
25cdd2	Do	155	6	Dr	1946	48
25dac	Test hole 974	50	5	Dr	9-54	......
26acc	Test hole 955	150	5	Dr	8-54	......
26acd	Test hole 954	151	5	Dr	8-54	......
26bab	Test hole 956	150	5	Dr	8-54	......
26bcc	Unknown	100 +	18	Dr	....	2.46
26cdc1	C. A. Matthews	70	18	Dr	....	2.21
26cdc2	Do	30	24	Dr	....	4
26daa	Test hole 951	150	5	Dr	8-54	......
26dac	Test hole 976	150	5	Dr	8-54	......
26ddd	Westhope well #1	149	6	Dr	1946	49
27aaa	Chester Hulse	67	24	Dr	....	2.80
27add	Unknown	100	18	Dr	....	.85
27bdd	Test hole 929	170	5	Dr	7-54	......
27ccc	Test hole 941	180	5	Dr	7-54	......
27cda	City of Westhope	240	6	Dr	1953	......
28ccc	Test hole 939	200	5	Dr	7-54	......
28dcc	Test hole 940	190	5	Dr	7-54	......
30bbb	Chas. McDougal	38	24	Dr	....	3.69

Date of measure-ment	Use of water	Aquifer	Depth to shale (feet)	Altitude of land surface (feet)	Remarks
6-25-49	D	....	....	1,496	
6-25-49	N	....	....	1,496	
....	T	....	160	1,496	See log. Sandy green clay at 162 feet.
6- 7-49	D	....	....	1,491	
6- 7-49	N	....	....	1,470	
....	T	....	160	1,492	See log.
....	T	....	....	1,430	Do.
....	T	....	139	1,481	See log. Green clay at 139 feet.
....	T	....	....	.....	See log.
12 -54	PS	....	....	.....	Do.
9 -53	T	....	....	.....	Do.
....	T	....	157	.....	Do.
5 -53	T	....	....	.....	Do.
....	T	....	....	1,422	Do.
....	T	....	146	1,489	See log. Green shale at 146 feet.
....	T	....	151	1,490	See log. Green shale at 151 feet.
....	T	....	150	1,490	See log. Green shale at 150-160 feet.
6- 7-49	N	....	....	1,495	
6- 8-49	N	....	....	1,489	
6- 8-49	N	....	....	1,489	
....	T	....	150	1,490	See log.
....	T	....	150	1,490	Do.
....	PS	....	....	.....	See log. Chemical analysis.
6- 7-49	S	....	....	1,491	
6- 7-49	N	....	....	1,494	
....	T	....	161	1,496	See log. Chemical analysis.
....	T	....	172	1,497	See log. Sandy green shale at 172-177 feet.
....	T	....	165	.....	Gas at 150 feet. See log.
....	T	....	193	1,497	
....	T	....	185	1,502	
6- 9-49	D,S	....	....	1,498	

Location number	Owner or name	Depth of well (feet)	Diameter or size (inches)	Type	Date completed	Depth to water below land surface (feet)
163-80 (Cont.)						
30dcd	Alfred Hulse	40	18	Dr	....	3.46
30dda	Unknown	17	48 x 48	Du	....	3.22
31aab1	Don Cameron	16	24	Dr	....	6.87
31aab2	Do	180	4	Dr	1945	60
31ddd	M. Moum	150	4	Dr	....	......
32bbb	Test hole 938	190	5	Dr	7-54	......
32bbd1	Clarence Lodoen	18	8	Dr	....	11.20
32bbd2	Do	250	2.5	Dr	1928	60
33abb	E. A. Trimble	26	24	Dr	....	10
34abb	Great Northern Railroad	13.2	18	Dr	....	3.84
34baa1	Collin Seiffert	42	18	Dr	....	4.79
34baa2	Do	120	18	Dr	....	4.98
34baa3	Do	16.2	24	Dr	....	1.15
34baa4	Test hole 928	180	5	Dr	7-54	......
34ccc	Roger Conway	120	24	Dr	....	30
34dad1	Albert Madsen	18	8	Dr	....	8
34dad2	Do	22	24	Dr	....	10.76
34dbb	Test hole 957	170	5	Dr	8-54	......
35aab	Test hole 961	150	5	Dr	8-54	......
35abb	Test hole 943	160	5	Dr	7-54	......
35bab	L. Rosendahl	80	24	Dr	....	20
35bbb	Test hole 942	170	5	Dr	7-54	......
35cbc	Unknown	27.2	48	Du	....	4.37
36baa	Test hole 945	140	5	Dr	8-54	......
36bba	Test hole 960	150	5	Dr	8-54	......
36bbb	Test hole 944	161	5	Dr	8-54	......

Date of measurement	Use of water	Aquifer	Depth to shale (feet)	Altitude of land surface (feet)	Remarks
6- 9-49	S	....	....	1,497	
6- 9-49	D,S	....	....	1,496	
6- 9-49	D	....	....	1,501	
6- 9-49	S	....	....	1,501	Soft.
....	S	....	....	1,504	
....	T	....	186	1,500	See log. Sandy green shale at 186-188 feet.
6- 9-49	D	....	....	1,505	
6- 9-49	S	....	....	1,504	Soft.
6- 7-49	D	....	....	1,499	
5-27-50	Obs	....	....	1,497	
6- 8-49	D	....	....	1,495	
6- 8-49	N	....	....	1,495	
6- 8-49	S	....	....	1,495	
....	T	....	179	1,498	See log. Sandy green shale at 178-179 feet.
6- 8-49	D,S	....	....	1,498	
6- 8-49	D	....	....	1,495	
6- 8-49	S	....	....	1,496	
....	T	....	166	1,495	See log.
....	T	....	....	1,490	See log. Green clay 145-147 feet.
....	T	....	155	1,490	See log. Chemical analysis.
6- 8-49	S	....	....	1,496	
....	T	....	161	1,496	See log.
6- 8-49	N	....	....	1,496	
....	T	....	131	1,485	See log.
....	T	....	139	1,487	Do.
....	T	....	149	1,491	Do.

TABLE 4.--LOGS OF WELLS AND TEST HOLES

162-80-3abb
Test hole 958

Formation	Material	Thickness (feet)	Depth (feet)
Glacial Lake Souris deposits			
	Topsoil, sandy, black	2	2
	Clay, yellow, fine to medium gravel	35	37
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	67	104
	Gravel, fine, clean	3	107
	Clay, gray, and fine to medium gravel	3	110
	Gravel, fine to medium	2	112
	Clay, gray, and fine gravel	56	168
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, smooth, gray	3	171
Pierre shale			
	Shale, gray	4	175

162-80-3dcc2
Test hole 959

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	2	2
	Clay, yellow; fine to medium gravel	36	38
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	138	176
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, smooth, gray	2	178
Pierre shale			
	Shale, gray	2	180

163-79-30bcb
Test hole 972

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, yellow, oxidized; fine to medium gravel and shale pebbles	15	16
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel and shale pebbles	44	60

163-79-30cab
Test hole 971

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, sandy, brown	1	2
	Clay, yellow, and fine to medium gravel and shale pebbles	3	5
Alluvium			
	Sand, coarse, and fine to medium gravel	5	10
	Sand, medium to coarse, silty, contains shell fragments	10	20
	Clay, plastic, gray, and fine gravel and shale pebbles	25	45
	Sand, medium to coarse, silty; fine gravel	10	55
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel and shale pebbles	15	70

163-79-30cbc2
Test hole 950

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	1	1
	Clay, sandy, brown	2	3
	Sand, fine to coarse, silty	8	11
	Clay, yellow, oxidized	10	21
Alluvium			
	Sand, fine to coarse, silty	4	25
	Gravel, coarse, silty	5	30
	Sand, fine to coarse; fine to medium gravel	10	40
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	65	105
Pierre shale			
	Shale, gray	5	110

163-79-30cbd
Test hole 962

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits(?)*			
	Clay, gray; fine to medium gravel......	5	5
	Sand, fine to medium; fine gravel......	5	10
	Clay, gray; fine to coarse sand; fine gravel..............................	10	20
	Clay, gray-brown; fine to medium gravel and shale pebbles....................	15	35
	Clay, smooth, gray....................	27	62
	Sand, fine to medium, gray, silty......	3	65
Till and associated sand and gravel deposits			
	Clay, gray, and fine gravel and coarse sand................................	35	100
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, smooth, gray....................	1	101
Pierre shale			
	Shale, gray...........................	9	110

*Possibly intermixed with alluvium

163-79-30ccb
Test hole 975

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black........................	2	2
	Clay, yellow; medium to coarse sand.....	8	10
Alluvium			
	Gravel, fine; medium to coarse sand....	5	15
	Sand, medium to coarse; clay, yellow; fine gravel..........................	15	30
Till and associated sand and gravel deposits			
	Clay, gray, and medium to coarse sand and fine gravel.....................	25	55
	Clay, gray, and fine sand.............	15	70
	Clay, gray, and medium to coarse sand and fine gravel.....................	39	109
Pierre shale			
	Shale, gray...........................	1	110

163-79-31aba
Test hole 948

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Road fill	12	12
	Clay, smooth, light-gray	9	21
	Clay, sandy, gray	10	31
Alluvium			
	Sand, fine to coarse, clayey	4	35
	Sand, fine to medium, clayey	35	70
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	16	86
Pierre shale			
	Shale, gray	4	90

163-79-31bab
Test hole 947

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Road fill	8	8
	Clay, yellow; fine to medium gravel	2	10
	Clay, gray-green	10	20
Alluvium			
	Sand, fine to medium, silty	17	37
	Clay, sandy, gray	11	48
	Sand, coarse; fine gravel	7	55
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	27	82
	Sand, medium to coarse; fine gravel	4	86
	Clay, gray, and fine to medium gravel	10	96
Pierre shale			
	Shale, gray	4	100

163-79-31bbb
Test hole 946

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Road fill	8	8
	Clay, smooth, gray	18	26
	Clay, smooth, light-gray	22	48
	Clay, smooth, gray	17	65
Till and associated sand and gravel deposits			
	Sand, medium to coarse; fine gravel	3	68
	Clay, gray, and fine gravel	8	76
	Sand, coarse, and fine to medium gravel	2	78
	Clay, gray, and fine to medium gravel	23	101
Pierre shale			
	Shale, gray	9	110

163-79-32bbb
Test hole 949

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, smooth, light-gray	3	4
	Clay, yellow, oxidized; fine to medium gravel	27	31
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	95	126
Pierre shale			
	Shale, gray	4	130

163-79-33dbd
Test hole 970

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, yellow; fine to medium gravel	15	16
Till and associated sand and gravel deposits			
	Clay, gray; fine to medium gravel and shale pebbles	86	102
Pierre shale			
	Shale, gray	8	110

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

163-79-33dca1
Test hole 966

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, smooth, gray	1	2
	Clay, yellow, oxidized; fine to medium gravel and shale pebbles	15	17
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel and shale pebbles	44	61
	Sand, coarse; fine gravel and shale pebbles	5	66
	Clay, sandy, gray, and fine gravel and shale pebbles	42	108
	Clay, gray, and fine gravel and angular shale pebbles	12	120

163-79-33dca2
Test hole 968

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, yellow; fine to medium gravel and shale pebbles	25	26
Till and associated sand and gravel deposits			
	Clay, gray; fine gravel; coarse to very coarse sand, some thin fine sand beds	75	101
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, sandy, green; fine gravel	8	109
	Clay, hard, green; medium sand	1	110

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

163-79-33dcd1
Test hole 965

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Road fill	2	2
	Clay, yellow, oxidized; fine to medium gravel and shale pebbles	36	38
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel and shale pebbles	19	57
	Gravel, fine to medium	3	60
	Clay, gray, and fine gravel, and medium to coarse sand	58	118
Pierre shale			
	Shale, gray	12	130

163-79-33dcd2
Test hole 969

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, light-gray	3	4
	Clay, yellow; fine to medium gravel and shale pebbles	32	36
Till and associated sand and gravel deposits			
	Clay, gray; fine to medium gravel and shale pebbles	32	68
	Sand, medium to coarse; fine gravel and shale pebbles	10	78
	Clay, gray, and fine gravel and coarse sand	34	112
	Clay, gray, and medium to coarse sand.	8	120

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

163-79-33ddb
Test hole 963

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Road fill.............................	2	2
	Clay, yellow; fine to medium gravel and shale pebbles......................	41	43
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel..	17	60
	Sand, fine to medium, silty...........	10	70
	Clay, gray, and fine to medium gravel..	31	101
Pierre shale			
	Shale, gray...........................	9	110

163-79-33ddc1
Test hole 964

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Road fill.............................	2	2
	Clay, yellow, oxidized; fine to medium gravel.............................	36	38
Till and associated sand and gravel deposits			
	Clay, gray; fine to medium gravel......	28	66
	Gravel, fine to medium, silty..........	8	74
	Clay, gray, hard at base...............	26	100

163-79-33ddc2
Test hole 967

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black........................	2	2
	Clay, yellow; fine to medium gravel and shale pebbles..................	13	15
	Clay, brown; fine to medium gravel and shale pebbles......................	26	41
Till and associated sand and gravel deposits			
	Clay, gray, and fine gravel and shale pebbles............................	17	58
	Gravel, fine; medium to coarse sand...	2	60
	Sand, gray; gravel, silty.............	5	65
	Sand, medium to coarse; fine gravel, silty..............................	10	75
	Clay, gray, and coarse sand, fine gravel and shale pebbles............	31	106
	Clay, gray-green; coarse sand.........	3	109
Pierre shale			
	Shale, gray..........................	1	110

163-80-14cdd2
Test hole 936

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black........................	2	2
	Clay, yellow; fine to medium gravel...	24	26
Till and associated sand and gravel deposits			
	Clay, gray; fine to medium gravel.....	91	117
	Gravel, fine; coarse sand, clean......	11	128
	Clay, gray, and fine to medium gravel.	8	136
Pierre shale			
	Shale, gray..........................	4	140

163-80-15baa
Test hole 935

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	2	2
	Sand, fine to medium, silty	1	3
	Clay, gray	1	4
	Clay, yellow; fine to medium gravel	12	16
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	74	90
	Gravel, fine; coarse sand	10	100
	Clay, gray, and fine to medium gravel	8	108
	Gravel, fine, silty	3	111
	Clay, gray, and fine to medium gravel	31	142
Pierre shale			
	Shale, gray	8	150

163-80-15caa
Test hole 934

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, gray	2	2
	Sand, fine to medium, silty	3	5
	Clay, yellow; fine to medium gravel	16	21
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	133	154
Pierre shale			
	Shale, gray	6	160

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

163-80-15dcc
Test hole 933

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	3	3
	Clay, smooth, yellow	2	5
	Clay, yellow; fine to medium gravel	9	14
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	61	75
	Sand, medium to coarse; fine gravel, silty	6	81
	Clay, gray, and fine to medium gravel	69	150
Pierre shale			
	Shale, gray	8	158

163-80-21dad
Test hole 937

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, sandy, yellow	2	3
	Clay, yellow; fine to medium gravel	20	23
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	43	66
	Sand, medium coarse; fine gravel	2	68
	Sand, coarse; fine gravel, silty	21	89
	Clay, gray, and fine to medium gravel	35	124
	Sand, coarse; fine gravel and shale pebbles	2	126
	Clay, gray, and fine to medium gravel	30	156
	Sand, fine to coarse; fine gravel	2	158
	Clay, gray, and fine to medium gravel	4	162
	Sand, fine to coarse; fine gravel	4	166
Pierre shale			
	Shale, gray	14	180

163-80-21ddd
Test hole 931

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	2	2
	Clay, smooth, yellow	2	4
	Clay, yellow; fine to medium gravel	26	30
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	32	62
	Sand, medium to coarse; fine to medium gravel, silty	3	65
	Clay, gray, and fine to medium gravel	28	93
	Sand, medium to coarse; fine gravel, silty	3	96
	Clay, gray, and fine gravel	22	118
	Sand, medium to coarse; fine gravel	2	120
	Clay, gray, and fine to medium gravel	22	142
	Sand, coarse; fine to medium gravel	4	146
	Clay, gray, and fine gravel	22	168
Pierre shale			
	Shale, gray	2	170

163-80-22caa
Test hole 932

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Sand, fine; clay, gray	5	5
	Clay, yellow; fine to medium gravel	6	11
	Sand, medium to coarse; clay, yellow; fine to medium gravel	2	13
	Clay, yellow; fine to medium gravel	5	18
Till and associated sand and gravel deposits			
	Clay, gray and fine to medium gravel	64	82
	Sand, fine to coarse; fine to medium gravel, silty	3	85
	Clay, gray, and fine to medium gravel	28	113
	Sand, coarse; fine to medium gravel, clean	5	118
	Clay, gray, and fine to medium gravel	40	158
Pierre shale			
	Shale, gray	12	170

163-80-22cdd
Test hole 930

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	3	3
	Gravel, fine; shale pebbles	1	4
	Clay, yellow; fine to medium gravel	22	26
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	78	104
	Sand, coarse; fine to medium gravel, silty	2	106
	Clay, gray, and fine to medium gravel	54	160
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, smooth, gray	2	162
	Clay, sandy, gray-green	8	170

163-80-23dcc
Test hole 953

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	2	2
	Clay, yellow, oxidized; fine to medium gravel	20	22
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	45	67
	Sand, medium to coarse; fine gravel, silty	3	70
	Clay, gray, and fine to medium gravel	64	134
	Gravel, fine to medium	15	149
Pierre shale			
	Shale, gray	11	160

163-80-24dac
Test hole 973

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, yellow, oxidized; fine to medium gravel	15	16
Till and associated sand and gravel deposits			
	Clay, gray; fine gravel	14	30
	Clay, gray; coarse sand and fine to medium gravel	20	50

163-80-25bbb
Test hole 952

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Clay, yellow, oxidized; fine to medium gravel	27	27
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel.	112	139
Pierre shale			
	Shale, gray	11	150

163-80-25ccc1
Municipal test hole
(Log furnished by C. A. Simpson and Sons, Bisbee, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Clay, yellow	25	25
Till and associated sand and gravel deposits			
	Clay, sandy, blue	38	63
	Sand and clay, blue	59	122
	Sand, silty	12	134
	Sand and gravel	11	145
	Clay with gravel, blue	1	146

163-80-25ccc2
Westhope City well #2
(Log furnished by C. A. Simpson and Sons, Bisbee, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, yellow	34	35
Till and associated sand and gravel deposits			
	Clay, blue	25	60
	Clay, sandy, blue	23	83
	Clay, very sandy, blue	17	100
	Clay and sand	20	120
	Gravel and clay	15	135
	Gravel	11	146
Pierre shale			
	Shale, blue	2	148

163-80-25ccd
Municipal test hole
(Log furnished by C. A. Simpson and Sons, Bisbee, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, sandy, light-yellow	2	3
	Clay, yellow	19	22
Till and associated sand and gravel deposits			
	Clay, sandy, blue	36	58
	Clay, gravelly	48	106
	Sand, fine to coarse	5	111
	Clay, gravelly	11	122
	Clay, gray	6	128
	Clay, sandy, gray	2	130
	Sand, fine to coarse, silty	1	131
Pierre shale			
	Shale, blue	29	160

163-80-25cdd1
Municipal test hole
(Log furnished by C. A. Simpson and Sons, Bisbee, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	2	2
	Clay, yellow	23	25
Till and associated sand and gravel deposits			
	Clay, blue	35	60
	Clay, sandy, blue	60	120
	Clay, very sandy	5	125
	Sand, coarse	2	127
	Clay, sandy, blue	15	142
	Sand, (escaping gas)	1	143
	Sand and clay, interbedded, water and gas in the sand layers	10	153
	Clay, blue	4	157
Pierre shale			
	Shale, blue	3	160

163-80-25cdd2
Municipal test hole
(Log furnished by C. A. Simpson and Sons, Bisbee, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, sandy, yellow	29	30
Till and associated sand and gravel deposits			
	Clay, sandy, blue	35	65
	Clay, very sandy, blue	55	120
	Clay, sandy, blue	4	124
	Gravel	2	126
	Clay, very sandy, blue	29	155

163-80-25dac
Test hole 974

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium			
	Sand, fine to coarse; yellow clay; fine gravel	8	8
	Sand, very coarse to medium; fine gravel	4	12
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	38	50

163-80-26acc
Test hole 955

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, sandy, brown	2	3
	Clay, yellow; fine to medium gravel	13	16
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	108	124
	Sand, coarse; fine to medium gravel, silty	3	127
	Clay, gray, and fine gravel	19	146
Pierre shale			
	Shale, gray	4	150

163-80-26acd
Test hole 954

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Clay, sandy, brown	2	2
	Clay, sandy, dark-gray	3	5
	Clay, smooth, yellow	12	17
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	133	150
Pierre shale			
	Shale, gray	1	151

163-80-26bab
Test hole 956

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	2	2
	Clay, sandy, brown	2	4
	Clay, yellow, oxidized; fine gravel	26	30
Till and associated sand and gravel deposits			
	Clay, gray, and fine gravel	119	149
Pierre shale			
	Shale, gray	1	150

163-80-26daa
Test hole 951

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Clay, sandy, gray	2	2
	Clay, light-gray; fine gravel	2	4
	Clay, yellow; fine to medium gravel	24	28
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	34	62
	Sand, fine, silty	3	65
	Clay, gray, and fine to medium gravel	50	115
	Clay, gray, and fine to medium gravel, hard drilling	26	141
Pierre shale			
	Shale, gray	9	150

163-80-26dac
Test hole 976

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, yellow	40	41
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel and shale pebbles	29	70
	Clay, gray; medium to very coarse sand	10	80
	Gravel, fine; medium to coarse sand, silty	15	95
	Clay, gray, and fine to medium gravel and shale pebbles	49	144
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Sand, medium to coarse, silty, gray	5	149
Pierre shale			
	Shale, gray	1	150

163-80-26ddd1
Westhope City well #1
(Log furnished by C. A. Simpson and sons, Bisbee, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Clay, yellow	35	35
Till and associated sand and gravel deposits			
	Clay, blue	25	60
	Clay, sandy, blue	23	83
	Gravel	4	87
	Clay, sandy, blue	52	139
	Sand, coarse; gravel	10	149

163-80-27bdd
Test hole 929

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black..................	2	2
	Sand, fine, silty......................	1	3
	Clay, light-gray.......................	1	4
	Clay, yellow; fine to medium gravel....	20	24
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel..	35	59
	Sand, medium to coarse; fine to medium gravel, silty......................	9	68
	Clay, gray, and fine to medium gravel..	93	161
Pierre shale			
	Shale, gray............................	9	170

163-80-27ccc
Test hole 941

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black..................	1	1
	Clay, sandy, brown.....................	2	3
	Clay, gray.............................	2	5
	Clay, yellow; fine to medium gravel....	10	15
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel..	112	127
	Sand, fine to medium, silty............	3	130
	Clay, gray, and fine to medium gravel..	40	170
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, smooth, gray.....................	2	172
	Clay, sandy, gray......................	5	177
Pierre shale			
	Shale, gray............................	3	180

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

163-80-27cda
(Log furnished by C. A. Simpson
and Sons, Bisbee, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, sandy, gray	7	8
	Clay, yellow	10	18
Till and associated sand and gravel deposits			
	Clay, blue	36	54
	Clay, sandy, gray	14	68
	Clay, gray; gravel	70	138
	Sand, silty	12	150
	Clay, gray; gravel	15	165
Pierre shale			
	Shale, gray	75	240

163-80-28ccc
Test hole 939

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, brown	2	2
	Clay, light-gray	2	4
	Clay, yellow; fine to medium gravel	20	24
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	98	122
	Sand, fine to coarse, silty	3	125
	Clay, gray, and fine to medium gravel	62	187
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, smooth, gray	5	192
	Clay, sandy, green	1	193
Pierre shale			
	Shale, gray	7	200

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

163-80-28dcc
Test hole 940

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	2	2
	Clay, light-gray	1	3
	Clay, sandy, gray	2	5
	Clay, sandy, yellow	9	14
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	110	124
	Sand, medium to coarse; fine to medium gravel, silty	4	128
	Clay, gray, and fine to medium gravel	6	134
	Sand, medium to coarse; fine to medium gravel	2	136
	Clay, gray, and fine to medium gravel	49	185
Pierre shale			
	Shale, gray	5	190

163-80-32bbb
Test hole 938

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	2	2
	Clay, sandy, yellow	7	9
	Clay, yellow; fine to medium gravel	14	23
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	47	70
	Sand, fine to medium; fine gravel	2	72
	Clay, gray, and fine to medium gravel	3	75
	Sand, medium to coarse; fine gravel	3	78
	Clay, gray, and fine to medium gravel	3	81
	Sand, fine to coarse, silty; fine to medium gravel	2	83
	Clay, gray, and fine to medium gravel	103	186
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, sandy, green	2	188
Pierre shale			
	Shale, gray	2	190

163-80-34baa4
Test hole 928

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	2	2
	Clay, light-gray	1	3
	Sand, fine	2	5
	Clay, yellow	12	17
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	45	62
	Sand, medium to coarse; fine gravel	2	64
	Clay, gray, and fine to medium gravel	96	160
	Sand, medium to coarse; fine gravel, silty	2	162
	Clay, gray, and fine to medium gravel	5	167
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, gray to green; fine gravel	12	179
Pierre shale			
	Shale, gray	1	180

163-80-34dbb
Test hole 957

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	2	2
	Clay, sandy, brown	2	4
	Clay, yellow; fine to medium gravel and shale pebbles	13	17
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	149	166
	Clay, smooth, gray	3	169
Pierre shale			
	Shale, gray	1	170

163-80-35aab
Test hole 961

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	1	1
	Clay, smooth, yellow	2	3
	Clay,yellow; fine gravel	20	23
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	119	142
	Gravel, fine; shale pebbles	3	145
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Clay, gray-green	2	147
Pierre shale			
	Shale, gray	3	150

163-80-35abb
Test hole 943

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	1	1
	Clay, yellow; fine to medium gravel	21	22
Till and associated sand and gravel deposits			
	Clay, gray; fine to medium gravel	38	60
	Sand, coarse; and fine to medium gravel and shale pebbles	23	83
	Clay, gray, and fine to medium gravel	69	152
Pierre shale			
	Shale, gray	8	160

163-80-35bbb
Test hole 942

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	1	1
	Clay, yellow; fine to medium gravel	18	19
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	132	151
	Gravel, fine; shale pebbles	1	152
	Clay, gray, and fine to medium gravel	9	161
Pierre shale			
	Shale, gray	9	170

163-80-36baa
Test hole 945

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, black	1	1
	Clay, light-gray	1	2
	Clay, yellow, oxidized; fine to medium gravel	25	27
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	104	131
Pierre shale			
	Shale, gray	9	140

163-80-36bba
Test hole 960

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	1	1
	Clay, yellow, oxidized; fine to medium gravel	37	38
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel	44	82
	Gravel, fine to medium	6	88
	Gravel, fine to medium, silty	8	96
	Clay, gray, and fine to medium gravel	43	119
Pierre shale			
	Shale, gray	11	150

163-80-36bbb
Test hole 944

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits			
	Topsoil, sandy, black	1	1
	Clay, yellow; fine gravel	42	43
Till and associated sand and gravel deposits			
	Clay, gray, and fine to medium gravel, coarser at base	99	142
Cannonball(?) member of the Fort Union formation or Fox Hills(?) sandstone			
	Sand, fine to medium, silty	3	145
	Clay, gray, and medium to coarse sand	4	149
Pierre shale			
	Shale, gray	12	161

REFERENCES

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

Akin, P. D., 1951, Ground water in the Mohall area, Bottineau and Renville counties, North Dakota: North Dakota Ground-Water Studies No. 17.

Brown, R. W., and Lemke, R. W., 1948, Newly discovered outcrops of the Cannonball formation in North Dakota: Science, v. 107.

Comly, H. H., 1945, Cyanosis in infants caused by nitrates in well water: Am. Med. Assoc. Jour., v. 129, no. 2, p. 112-116.

Dean, H. T., 1936, Chronic endemic dental fluorsis: Am. Med. Assoc. Jour., v. 107, no. 16, p. 1269-1272.

Fenneman, N. M., 1938, Physiography of eastern United States: New York, McGraw-Hill, 599 p.

Lemke, R. W., and others, Preliminary geologic quadrangle maps of parts of the Crosby-Mohall area: U. S. Geol. Survey open-file rept.

Meinzer, O. E., 1923, The occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489.

Robinove, C. J., 1956, Geology and ground-water resources of the Hettinger area, Adams County, North Dakota: North Dakota Ground-Water Studies No. 24.

Silverman, L. B., 1949, Methemoglobinemia: Report of two cases and clinical review: Journal-Lancet, v. 69, p. 94-97, March.

Simpson, H. E., 1929, Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598.

Smith, Carol, 1954, Summary of the Sohio Petroleum Co.-John Nelson #1 oil-test well: North Dakota Geol. Survey Circ. 67.

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

U. S. Public Health Service, 1946, Drinking water standards: Public Health Repts., v. 61, no. 11.

U. S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U. S. Dept. Agriculture, Agriculture Handbook 60.

U. S. Weather Bureau, 1954, Climatological data for North Dakota, annual summary, 1953: v. 63, no. 13, p. 174, 176.

INT.DUP.,D.C.59- 56679