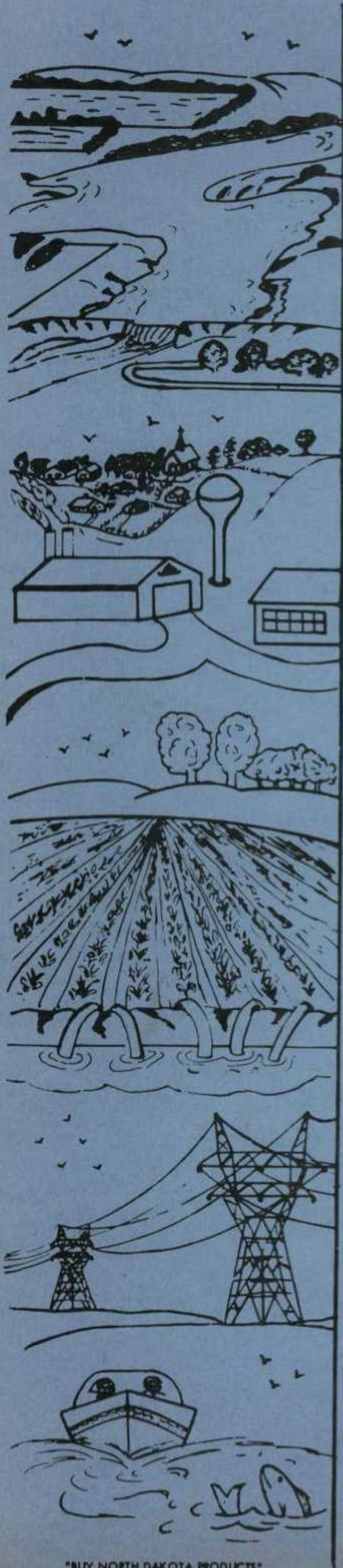


"BUY NORTH DAKOTA PRODUCTS"

Report of

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

1301 State Capitol

BISMARCK, NORTH DAKOTA

GROUND WATER IN THE PORTLAND AREA

TRAILL COUNTY, NORTH DAKOTA

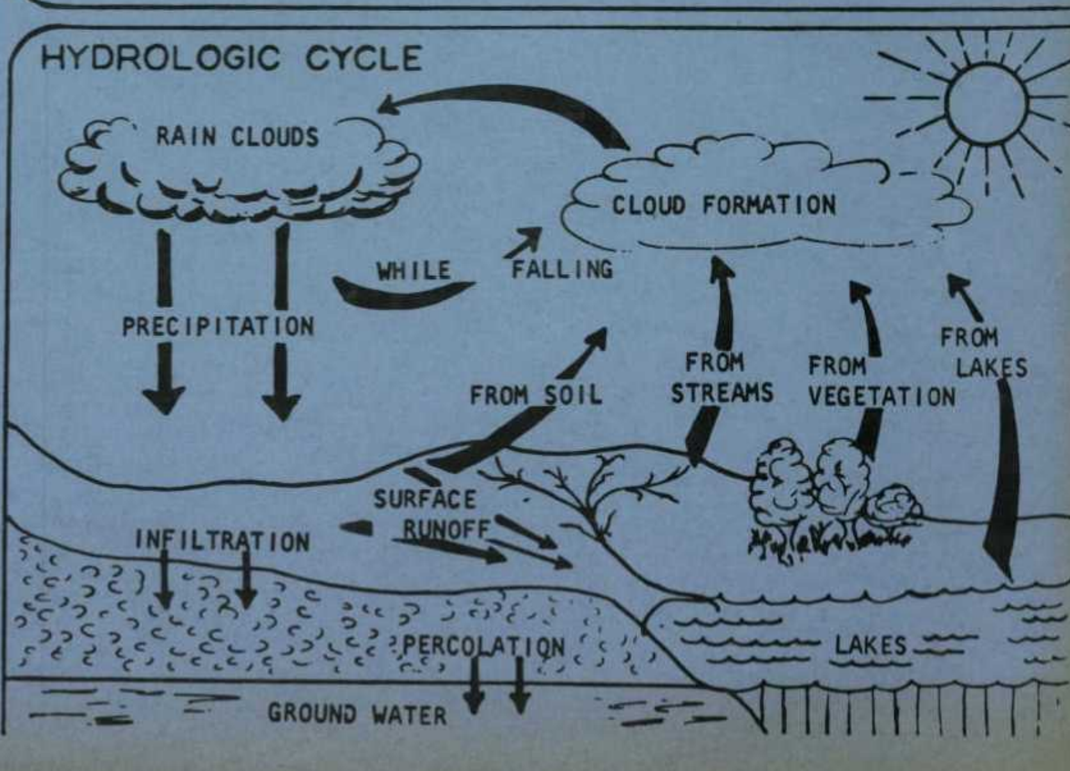
By

P. E. Dennis and P. D. Akin

North Dakota Ground Water Series No. 15

Prepared in Cooperation Between the Geological Society
U. S. Department of the Interior; the North Dakota
Water Commission and North Dakota State
Geological Survey

1950



GROUND WATER IN THE PORTLAND AREA
TRAILL COUNTY, NORTH DAKOTA

BY

P. E. DENNIS AND P. D. AKIN

NORTH DAKOTA GROUND WATER STUDIES NO. 15

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

1950

GROUND WATER IN THE PORTLAND AREA

TRAILL COUNTY, NORTH DAKOTA

By

P. E. Dennis and P. D. Akin

North Dakota Ground-Water Studies No. 15

Prepared in cooperation between the Geological Survey, U. S. Department of the Interior; the North Dakota State Water Conservation Commission; and the North Dakota State Geological Survey

1950

CONTENTS

ILLUSTRATIONS

GROUND WATER IN THE PORTLAND AREA
TRAILL COUNTY, NORTH DAKOTA

By

P. E. Dennis and F. D. Akin

ABSTRACT

The town of Portland is in the west-central part of Traill County, N. Dak, about 2 miles west of Mayville. It has a population of about 550. The town has no public water system at the present time, and it is estimated that 40,000 to 50,000 gallons of water a day would be required for a satisfactory municipal supply.

The Portland area is in the Red River Valley. The Elk Valley delta makes up the western part of the area; the eastern part is characterized by the featureless Lake Agassiz plain. The area is drained by the Goose River, its north and south branches, and minor tributaries.

In descending order, the stratigraphic units in the Portland area are: (1) river alluvium, which floors the valley of the Goose River and its principal tributaries; (2) ice-rafted drift; (3) Lake Agassiz deposits, which consist of a single unit of fine sand comprising the Elk Valley delta and of two units (a basal clay unit and an overlying silt unit) elsewhere; (4) till and associated glacioaqueous deposits; (5) Cretaceous (?) rocks, of which the Benton shale and the Dakota sandstone may be represented in this area; and (6) the pre-Cambrian basement complex of crystalline rocks.

There are a few shallow dug wells in the river alluvium, but no wells of very large capacity are known to tap this material. At least two attempts were made to develop wells in the river alluvium as possible sources of water supply for the town of Portland, and both attempts were unsuccessful. It seems unlikely that wells of capacities suitable for municipal or industrial uses could be developed in the alluvium.

The ice-rafted drift probably contains no important aquifers; this is true also of the clay and silt units of the lake Agassiz deposits in this area.

The sediments of the Elk Valley delta furnish water of relatively low mineral content to many farm wells ranging from 7 to 55 feet in depth, and also supports several significant springs which issue along its eastern margin. A large volume of water is stored in the delta sands, and there is ample opportunity for seasonal recharge to the sands by direct penetration of water from rain and melting snow over their entire area. However, the sands are so fine that ground-water developments practical for municipal and industrial purposes probably would require the use of special methods such as lateral water collectors or batteries of wells.

Only a few thin aquifers were encountered by test drilling in the till and associated glacioaqueous deposits which underlie the Lake Agassiz deposits. None of these aquifers appear to be significant as possible sources of municipal or industrial supplies.

The Dakota (?) sandstone yields highly mineralized water to wells over most of the area, and the wells of highest yield in the area are obtained from this formation. A pumping test made on the new Portland creamery well indicates that the coefficient of transmissibility of the formation in this area is about 16,100 gallons per day per foot, and the coefficient of storage is about 0.00038. The 1-day specific capacity of the new creamery well is estimated to be about $2\frac{1}{2}$ gallons per minute per foot of drawdown.. It seems likely, therefore, that wells yielding several hundred gallons a minute could be obtained in this formation; it also appears that local developments on the order of 500,000 to 1,000,000 gallons a day could be maintained for many years. The formation is deeply buried under relatively impermeable materials and there is little or no opportunity for seasonal recharge from precipitation, so that most or all of the water taken would be derived from storage within the aquifer.

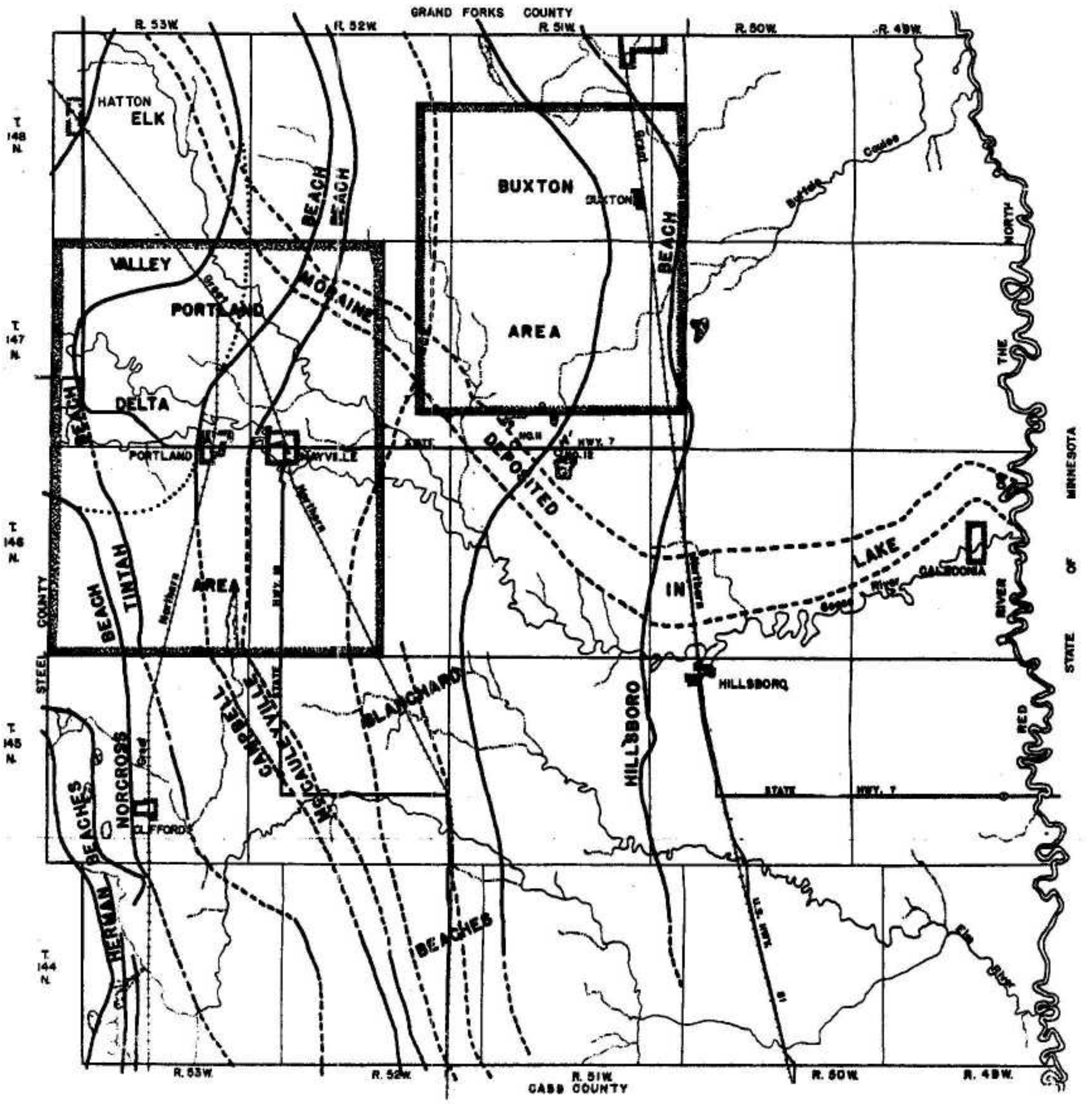
Pre-Cambrian crystalline rocks, locally referred to as granite, underlie the Cretaceous (?) rocks. There are no wells in the crystalline rocks in the Portland area, and it is generally considered useless to drill deeper for water when these rocks are reached.

INTRODUCTION

Purpose and Scope of the Investigation

This progress report on the geology and ground-water resources of Traill County, is a part of the studies being made by the U. S. Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the State Geological Survey. The purpose of these general studies is to determine the occurrence, movement, discharge, and recharge of the ground-water, and the quantity and quality of such water available for all purposes, including municipal, domestic, stock, irrigation, and industrial. At present, the most critical need is for adequate perennial water supplies for many towns and small cities throughout the State wishing to construct municipal water-supply and sewage-disposal systems. For this reason, the county-wide studies are being started in the vicinity of those towns that request the help of the State Water Conservation Commission and the State Geologist in locating suitable ground-water supplies. Progress reports are being released before the completion of the general studies so that the data may be available to the towns as soon as possible and to others concerned with immediate problems. The area described in this report comprises most of the four townships nearest the village of Portland, as that area is of the most immediate interest to the village in its search for an adequate water supply.

Field work in the area was done chiefly in May 1947 and June, July, and September, 1948. It consisted of (1) gathering of information, on many of the existing wells, including measurements of depth and water level where possible, (2) study of the surface geology,



BEACHES AND DELTAS AFTER UPHAM
MORAINE AFTER LEVERETT

EXPLANATION

O - USGS TEST HOLE
A A' LOCATION OF SECTION SHOWN IN FIGURE 2

SCALE

FIGURE 1. MAP OF TRAILL COUNTY SHOWING LOCATION OF PORTLAND AREA, GEOLOGIC FEATURES, AND LOCATION OF TEST HOLES OUTSIDE THE PORTLAND AREA.

(3) establishment of elevations at wells and test holes, (4) drilling of 38 test holes to depths between 12 and 561 feet for a total of 4,460 feet, and taking of ditch samples and cores of the earth materials, (5) collection and submission for chemical analysis of samples of water from the various aquifers encountered by test holes and existing wells, and (6) test pumping of wells to determine the quantitative capacities of the water-bearing materials.

Laboratory and office work connected with the investigation were done chiefly in the winter of 1948-49 and the summer of 1949. It included (1) examination and analysis of cuttings and cores from the test holes, (2) correlation of well logs, (3) laboratory determination of permeability of some samples, (4) interpretation of chemical analyses of the waters, (5) compilation or well, test-hole, and other data, and (6) preparation of illustrations and a report on the investigation.

Location and General Features of the Area

The area covered by this report includes most of four townships: T. 146 N., R. 53 and part of 52 W., and T. 147 N., R. 53 and part of 52 W., in Traill County, N. Dak. Portland and Mayville are the only towns in the area, Portland Junction, Roseville, and Murray being simply stations on the railways (see fig. 1). Portland is near the center of the area about 35 miles southwest of Grand Forks. It has a population of about 550 and lies at an elevation of about 985 feet above sea level. It is on State Highways 7 and 18 and also on a branch of the Great Northern Railway. Mayville, with a population of about 1,350, is on the same highways but on a different branch of the Great Northern Railway. Farming is the main occupation in the area, and the towns serve as shopping centers and as shipping points on the railway.

The climate is rigorous. Summer temperatures are generally pleasantly low but may reach 100° or higher for short periods. Temperatures of 30° below zero and lower are not uncommon during the winter. According to Weather Bureau records, the mean annual temperature at Grand Forks is 38.7°, and the mean annual precipitation is 19.40 inches. About 80 percent of the precipitation occurs as rain during the months of April through September, inclusive.

The area is part of the Western Young Drift section of the Central Lowland province 1/ and is the Red River Valley area of Simpson 2/. The Red River Valley is a broad, flat glacial-lake plain modified chiefly by low beach ridges and deltas. The Portland area is crossed by several beach ridges and includes a part of the southeastern edge of the Elk Valley delta (see fig. 1).

The glacial-lake plain has been only slightly modified by subsequent erosion, there being no integrated drainage across the broad divides between the incised meander channels of the streams. The Goose River, its north and south branches, and minor tributaries constitute the drainage system of the area. The flood plains of the three main branches of the Goose River vary from 500 feet to a quarter of a mile in width and average about 40 feet in depth. The streams, except in flood stage, occupy narrow channels cut about 25 feet into the flood plains.

1/ Fenneman, N. M., Physiography of the eastern United States, p. 559, McGraw-Hill Book Co., 1938.
2/ Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey, Water-Supply Paper 598, p. 4, 1929.

Previous Investigations and Acknowledgments

There are no previous reports on the geology and ground-water resources of the Portland area, but is is described in general studies of larger areas. Simpson 3/ discussed the ground-water resources of Traill County in general terms and listed a few typical wells in the area. The comprehensive study of Lake Agassiz by Upham 4/ includes many details of the Portland area.

This is the second progress report on Traill County, an earlier report on the Buxton area 5/ having been released (see fig. 1). Chemical analyses of water samples from two wells in the Portland area are included in North Dakota Geological Survey Bulletin 11. 6/

The present investigation was made under the general supervision of A. N. Sayre, Geologist in Charge of the Ground Water Branch, Water Resources Division, of the Federal Geological Survey. A part of the well inventory was made by Gilbert Rupp, and examination of the test-hole samples was made by Quentin Paulson. Test drilling was done by Ray Danielson, George McMaster, Keith Hanson, Gilbert Rupp, Quentin Paulson, and Robert Asker. Well records obtained by the county assessors in 1939 as a part of a State-wide well inventory under the Works Projects Administration were made available and many of them are included in this report.

3/ Op. cit.
4/ Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1896.
5/ Dennis, P. E., Ground Water near Buxton, Traill County, N. Dak., U. S. Geol. Survey mimeo. rept., 1947.
6/ Abbott, G. A., and Voedisch, F. W., The municipal ground-water supplies of North Dakota: North Dakota Geol. Survey Bull. 11, 1938.

Work was facilitated by the excellent cooperation of all residents of the area and, particularly, by the interest and assistance of the town officials at Portland.

Present Water Supply and Future Needs

Water for domestic, stock, and industrial uses in the area is obtained chiefly from wells, although the well water is supplemented in some cases by rain water stored in cisterns, by spring water, or by water from the Goose River. Field crops are grown without irrigation and lawns, shrubs, and gardens are watered only infrequently by a few people. Therefore, the chief needs are for domestic and stock water on the farms and for municipal and minor industrial uses in the towns.

Mayville has a municipal water system, the water being obtained chiefly from the river. Deep wells are used to supplement the surface water during dry seasons when there is little or no water in the river. A dam on the river near Portland formerly provided a reservoir from which the railroad obtained water, but an inadequate supply during dry seasons and difficulty in maintaining a watertight dam are said to have been responsible for its abandonment. Records of discharge of the Goose River 6½ miles northwest of Portland have been kept by the Federal Geological Survey since 1939. They show that from about the middle of July to the middle of March there is commonly little or no flow in the river, and that the flow from March to July varies within wide limits. For example, the maximum discharge in 1945 was 340 second-feet, and in 1941 it was 1,130 second-feet. The maximum discharge known was about 4,300 second-feet in 1882, as computed by the Corps of Engineers. 7/ The annual discharge generally ranges

7/ Surface-water supply of the United States, 1943, Pt. 5, Hudson Bay and Upper Mississippi River Basins: U.S. Geol. Survey Water-Supply Paper 975, p. 48, 1945.

between 3,000 and 15,000 acre-feet, equivalent to an average flow of about 4 to 21 second-feet. From these records it appears that the Goose River might provide municipal water supplies for Portland and Mayville if adequate storage facilities were constructed.

The village of Portland has drilled several test holes and wells in and near town, but potable water in sufficient quantity for municipal needs has not been found. Most of the water used for drinking and culinary purposes is hauled from the Theodore Amb well (146-53-29cdd2), which is in an area of springs about 7 miles northwest of Portland.

It is estimated that about 40,000 to 50,000 gallons of water a day probably would be required for a satisfactory municipal water supply for Portland, although probably less than half that amount is used at the present time.

GEOLOGY AND HYDROLOGY

General

Local Physiography

The Portland area is part of the Red River Valley, which is one of the flattest plains in North America. The flatness of the plain and the beach ridges and deltas which constitute its principal relief features are the result of lake sedimentation and shore-line erosion. The general character of the physiographic features of the lake plain and the probable origin of the features have been well presented by Upham 8/ and Leverett. 9/ Only the details noted during the

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

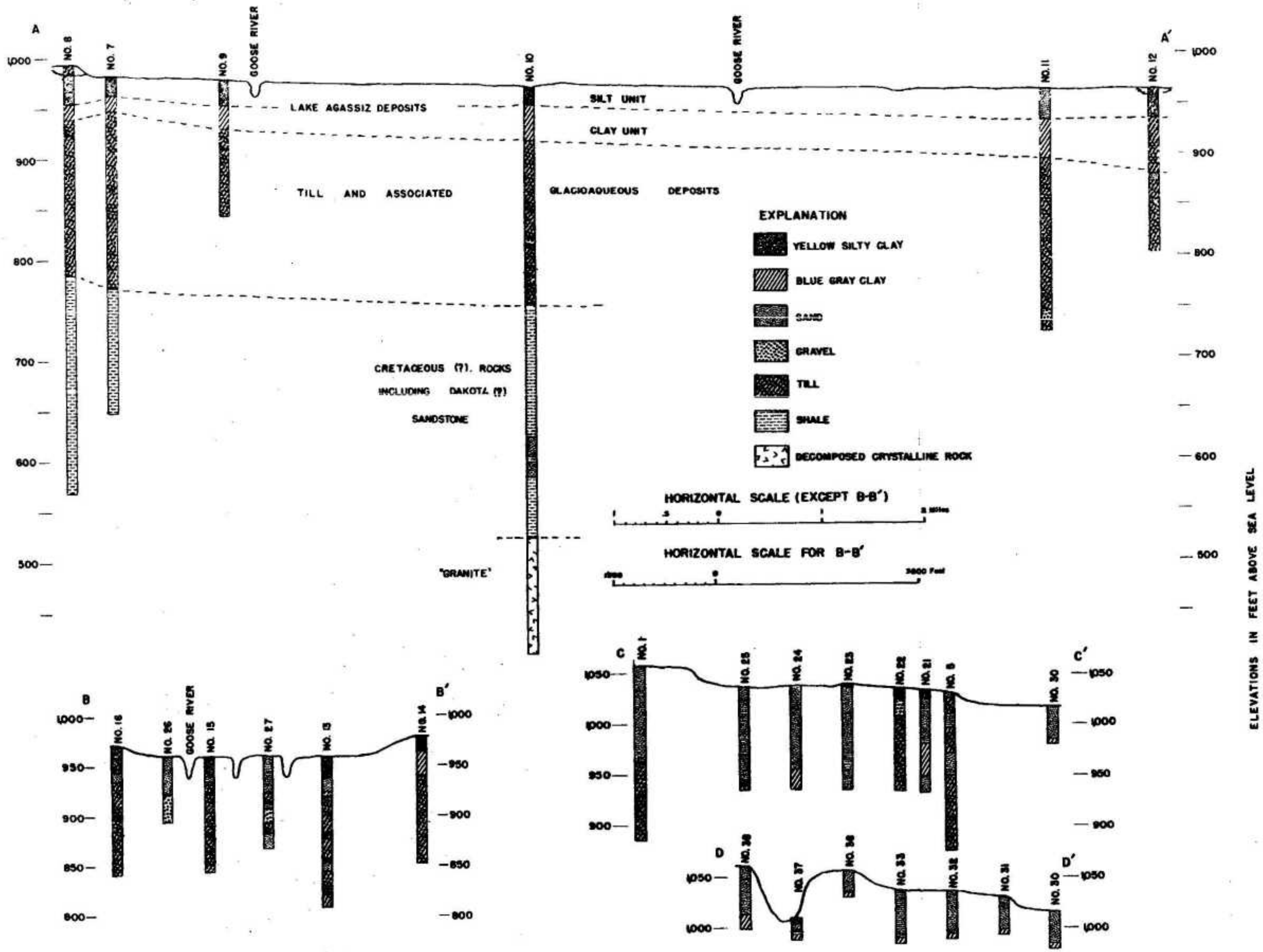


FIGURE 2.—GEOLOGIC SECTIONS IN THE PORTLAND AREA BASED ON U.S.G.S. TEST HOLES.

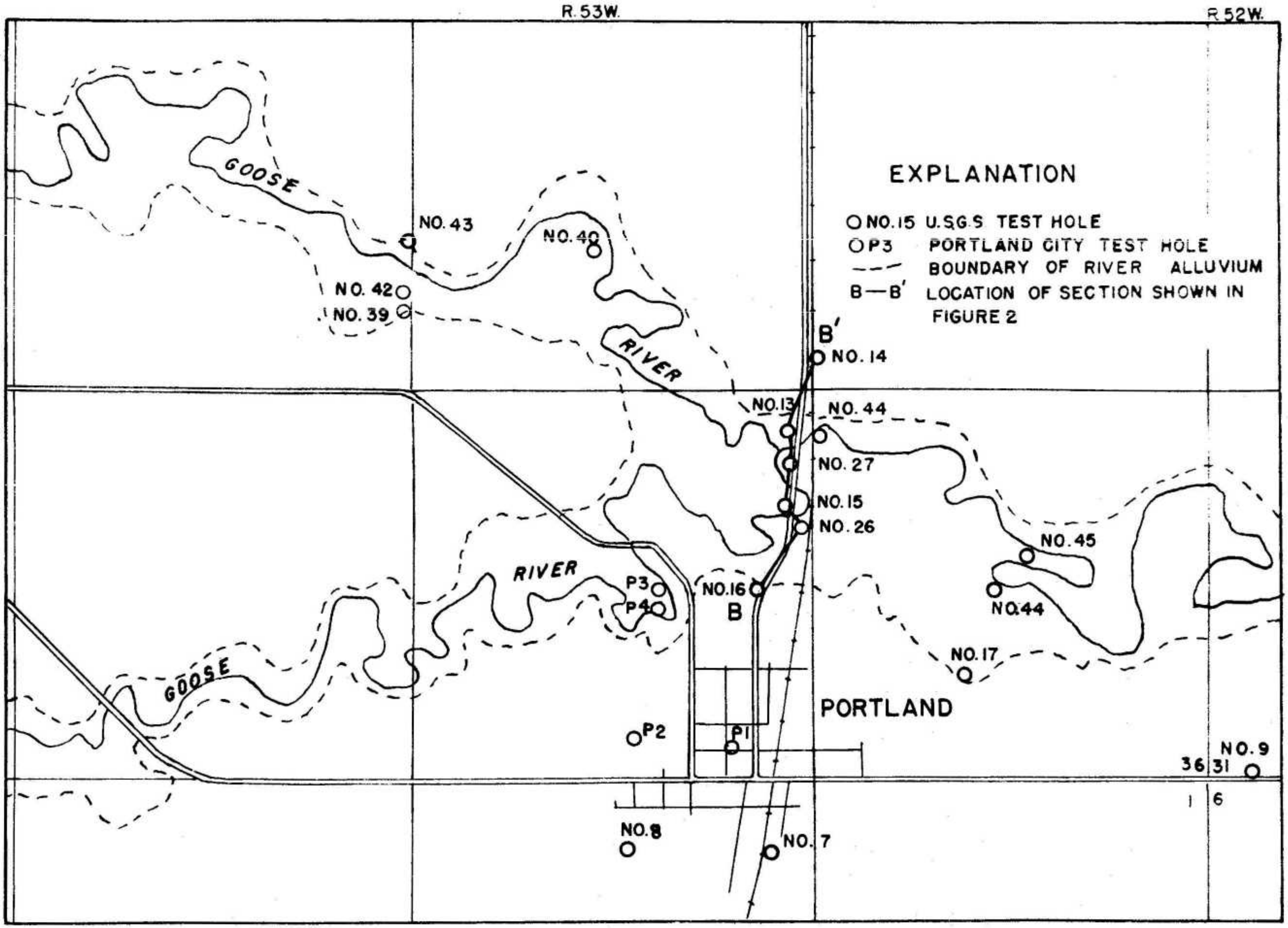
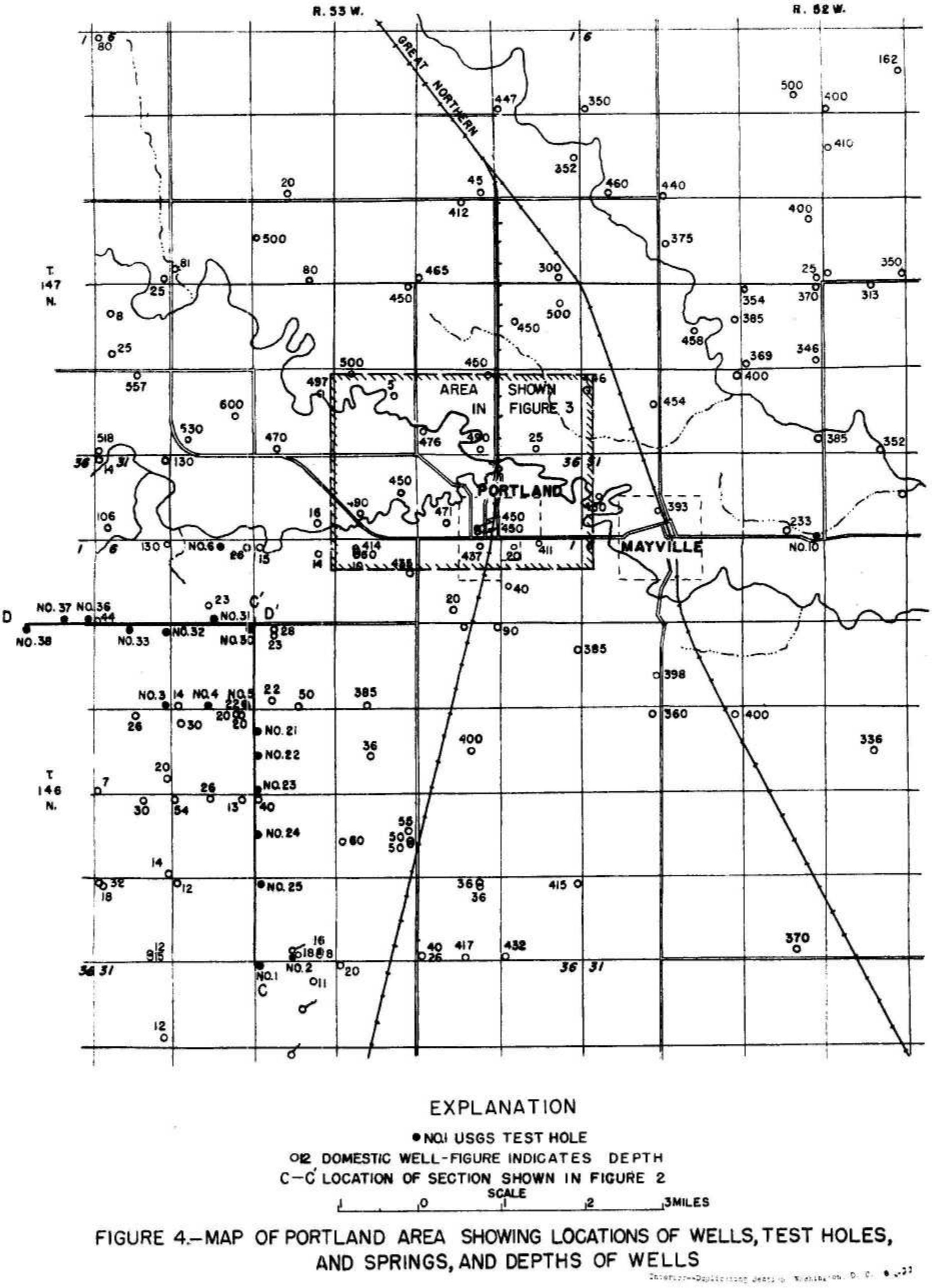


FIGURE 3.

MAP OF PORTLAND AND VICINITY SHOWING LOCATION OF TEST HOLES AND RIVER ALLUVIUM



EXPLANATION

● NO.1 USGS TEST HOLE

O12 DOMESTIC WELL-FIGURE INDICATES DEPTH

C–C' LOCATION OF SECTION SHOWN IN FIGURE 2

SCALE: 1 0 1 2 3 MILES

FIGURE 4.–MAP OF PORTLAND AREA SHOWING LOCATIONS OF WELLS, TEST HOLES, AND SPRINGS, AND DEPTHS OF WELLS

present investigation are presented here.

The beach ridge that is so prominent in the western part of Portland can be followed only a short distance north and south of town. At Portland the ridge has a relief of 12 to 15 feet, the top having an elevation of about 995 feet above sea level. The materials of the ridge are gray clay or till (see fig. 2 and log of USGS test 8, p. 36). It is reported that boulders were encountered in the first 10 feet of drilling in Portland test hole 2 (see fig. 3), which was drilled on the ridge in 1941, suggesting that the ridge may be till. The buff silts that constitute the surficial material generally throughout the lake basin below the Campbell shore line occur beneath the clay of the beach ridge. The beach is considered by Upham to be the Campbell, although it is somewhat lower than that beach farther south where it is more strongly developed. The very strongly developed beach that forms the margin of the Elk Valley delta west of Portland is considered by Upham to be the Tintah. It has a general elevation of about 1,010 to 1,016 feet above sea level. In view of these facts, it appears probable that the prominent beach that marks the east margin of the delta is the Campbell, and that the ridge in Portland is a local feature developed on a till "high." It is further suggested that the material of the ridge may represent a block of ice-rafted till, because part of the materials in it overlie the latest lake sediments.

The boundary of the Elk Valley delta is shown by Upham to extend eastward to the edge of Portland, as shown on figure 1. As shown on figure 4, the prominent escarpment of the delta is 2 to 2½ miles west of Portland. Furthermore, there is very little delta sand east of the escarpment except where the Goose River and its tributaries have cut down the escarpment and redistributed some of the fine sand.

Both Upham 10/ and Leverett 11/ show a moraine crossing the lake plain in the region immediately north of Portland (see fig. 1). The evidence for this moraine according to Upham 12/ is : (1) the presence of till forming the land surface in the central part of the Red River Valley, (2) small boulders and gravel on the surface of this till, (3) slight inequalities of contour of the land surface, and (4) the Goose Rapids, from where, downstream from the mouth of the Goose River, the Red River descends 24 feet in 12 miles, which is about double the fall elsewhere along this part of the river. This part of the channel is obstructed by many boulders.

With the aid of aerial photographs an attempt was made during the present investigation to outline more closely the boundaries of this moraine, which is thought to have been deposited in the lake waters. This was found to be impossible without detailed field work, and might not be pos ible without considerable drilling, because the inequalities of land contour are clearly distinguishable only in isolated areas and not as a continuous belt. Nevertheless, some information obtained during the study lends support to the hypothesis of the occurrence of a water-laid moraine in this area even though its boundaries were not determined. Because this information is largely not physiographic, it is presented in a later section.

10/ Op. cit., pl. 19, p. 212.
11/ Op. cit., fig. 19, p. 128.
12/ Op. cit., p. 165.

Hydrologic Concepts

An "aquifer" is any rock formation or stratum that will yield water in sufficient quantity to be of importance as a source of supply. 13/ The amount of water that can be stored in an aquifer is dependent upon its porosity. The unconsolidated rocks such as clay, sand, and gravel are generally more porous than consolidated rocks such as sandstone and limestone, although in some areas the consolidated rocks are highly pouous. The water-yielding capacity of a rock is generally somewhat less than its porosity, because some water is held in the pore spaces by molecular forces and cannot be removed by gravity drainage.

If the water in an aquifer is unconfined by impervous strata above, the water is said to occur under water-table conditions. In this case water may be obtained from storage in the aquifer with a resultant lowering of the water level. The water is yielded by gravity drainage and the specific water-yielding capacity, called "specific yield," may approach very closely the porosity of the aquifer. If the water is confined in the aquifer by an overlying impermeable stratum so that hydrostatic pressure will cause the water to rise in a well above the top of the aquifer, the water is said to occur under artesian conditions. In this case, the water level in the well is lowered as water is taken from it, but the sodiments adjacent to the well are not dewatered. The water is yielded as a result of the compression of the aquifer due to the

13/ Meinzer, O. E., The occurrence of ground water in the United States, with a discussion of principles: U.S.Geol. Survey Water-Supply Paper 489, p. 52, 1923 lowered pressure rather than by gravity drainage. The specific water-yielding capacity is called the "coefficient of storage" and is generally much smaller than the porosity of the material composing the aquifer.

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

There are, then, two fundamental physical properties of an aquifer that largely control the movement of water through it, the "specific yield" or "coefficient of storage" and the "permeability." The "specific yield" (water table conditions) is defined as the amount of water in cubic feet, that will drain by gravity from a cubic foot of the saturated rock. The "coefficient of storage" (artesian conditions) is defined as the amount of water, in cubic feet, that will be released from storage in each vertical column of the aquifer having a base 1 foot square, when the water level falls 1 foot.

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

Essentially all ground water of economic importance is moving through the ground from a place of intake or recharge to a place of disposal or discharge. Velocities of a few tens or a few hundreds of feet a year probably are most common in aquifers under natural conditions.

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

As ground water moves through an aquifer it dissolves a part of the more soluble mineral constituents of the rock particles. The amount of mineral matter dissolved by the water is dependent upon the soluble materials present in the aquifer and the length of time the water is in contact with them. Therefore, the waters that have been underground longest and have traveled the greatest distances are commonly more highly mineralized than those that are relatively near the recharge areas.

The Rock Materials and their Water-Bearing Characteristics

Stratigraphic Units

Information concerning the geologic formations in the area was obtained principally from 38 test holes drilled by the U. S. Geological Survey during the course of the investigation and from logs of a few privately owned wells. Fifteen test holes were drilled to obtain information concerning the river alluvium; 17 were drilled into the delta sand; and 6 were drilled into the till and deeper aquifers.

In descending order, the stratigraphic units in the Portland area are: (1) river alluvium, which floors the valley of the Goose

River and its principal tributaries; (2) [illegible] drift; ([illegible]) Lake Agassiz deposits, which consist of [illegible] fine sand and silt comprising the Elk Valley delta and of two units (a basal clay unit and an overlying silt unit) elsewhere; (4) till and associated glacioaqueous deposits; (5) Cretaceous (?) rocks, of which the Benton shale and the Dakota sandstone may be represented in this area; and (6) pre-Cambrian crystalline rocks.

River Alluvium

Sediments younger than the Lake Agassiz deposits are not common in the Red River Valley, for the region is in the stage of infancy in the erosion cycle initiated by the disappearance of the lake. In the Portland area only the valleys of the Goose River and its north and south branches contain an appreciable quantity of Recent alluvium. The presence of a considerable thickness of alluvium is a common feature in many of the postglacial stream valleys of North Dakota, and many of the valleys are occupied by present-day streams that are much too small to have excavated the valleys. The valleys probably were eroded during the waning stages of the last glaciation, when large quantities of water were being discharged from the melting ice. The valleys were temporarily overdeepened and subsequently partly refilled by river alluvium.

Information obtained from 15 test holes drilled in the valley bottoms in the Portland area indicates that the alluvial fill is generally about 30 to 40 feet thick. It is composed chiefly of silt and clay, very fine sand, and coarse sand and gravel consisting of particles of shale. There is a rather large percentage of clay and silt in pracitically all the samples from the various test holes and throughout the thickness of the deposits at each locality. Nevertheless, there is generally a higher percentage of sand and gravel in the river alluvium than there is in the till.

A few shallow dug wells obtain water from the river alluvium in the Portland area, but no well of large capacity is known to have been developed in this formation. About 1941 a private drilling company drilled two test holes in the village park, which is in the valley of the South Branch of the Goose River just north of town (see fig. 3). An attempt was made to develop one of the wells, but it is reported that the yield was insufficient to meet the needs of the town.

In USGS test 13 about 16 feet of sand and gravel was penetrated between 26 and 42 feet below the surface. About 3 feet of the gravel appeared to be relatively free of fine material and to warrant a quantitative test of the aquifer. The test hole was cased with perforated 4-inch casing and, after backwashing with clear water, the well was pumped for several days. The maximum yield of water was only a little more than 1 gallon a minute.

It is possible that the drilling mud was not completely washed out of the hole and that an accurate test of the capacity of the aquifer was not obtained. However, the recovery curve indicated a very low permeability, and there was no indication that it was not a true test of the capacity of the aquifer.

There is considerable variation in the materials of the valley fill (see fig. 2), and USGS tests 26 and 27 showed fine sand for the full thickness of the alluvium. It is possible that a test well constructed in this material might yield results different from those obtained from USGS test 1[illegible], but it is not likely that wells of large yield could be obtained in the material.

Ice-Rafted Drift

There is considerable evidence of till at and near the surface in the Portland area. Large erratics of granite and other crystalline rocks and of limestone and dolomite are plentiful at the surface at some localities--for example, along the section-line road that extends westward to the county line from a point a mile south of Portland. Till was encountered in USGS test 5 at a depth of 5 feet below the surface, and in USGS test 2[illegible] and 27 feet. At least one exposure of till along the valley wall of the Goose River extends to within about 6 feet of the surface and is underlain by the silt unit of the Lake Agassiz deposits.

Some of these occurrences may be explained as high hills of till not completely covered or barely covered by the lake waters. However, the till resting on delta sand in USGS test 5 and the till (?) resting on the silt unit of the Lake Agassiz deposits in USGS test 8 cannot be explained in this manner; it appears that these bodies of till as well as the erratics may represent ice-rafted material. The fact that high hills of till probably were present in the area would seem to indicate suitable conditions for the lodgment of debris-laden blocks of ice floating in the lake.

Lake Agassiz Deposits

The principal and most widespread surficial sediments in the Portland area are the Lake Agassiz deposits, which may be conveniently divided into a clay unit, a silt unit, and a delta unit. The clay unit and the delta unit are thought to be different facies of the same time interval, deposited during the earlier and deeper phases of the lake, when the shore line was at the Herman and other high-level beaches. The delta sediments are coarser than either of the other units; they occur chiefly west of a prominent escarpment referred to by Upham as the Tintah beach (see fig. 1). The clay unit was formed lakeward from the delta, and in the Portland area this unit is highly variable in thickness and, in general, is thinner than elsewhere in the lake area because it was deposited over a high morainic ridge. The silt unit was deposited during a later flooding of the lake, and it completely covers the clay unit. As the lake that deposited this unit rose high enough only to lap the delta margin, the silt unit is not present above the delta escarpment. The Lake Agassiz deposits are generally about 50 feet thick near Portland (see fig. 2). In order to present a clear picture of the origin and relationships of the deposits, it appears desirable to review briefly the lake history.

During the waning stages of the Wisconsin glaciation, a marginal glacial lake known as Lake Agassiz was formed in the northward-sloping Red River Valley. Sediment derived mainly from glacial till was deposited in this lake directly from the melting ice front and by streams fed by glacial meltwater. The deeper lake deposits consisted mainly of clay, and the coarser material was concentrated along the shores to form the present beach ridges, bars, deltas, and other shore features. Irregularities of the former land surface were partly to completely obscured by this blanket of sediment. The Portland area lies near the eastern edge of one of the deltas.

The history of Lake Agassiz has been studied and described by Upham, 14/ Tyrell, 15/ Johnston, 16/ Leverett, 17/ and Nikiforoff. 18/ These authors are not in complete agreement, and much additional work will have to be done before the history of the lake is known. The following brief summary utilizes factual data and interpretations from all those authors, coordinated in the light of data obtained during the present study.

The ice appears to have melted first around the thin edges of the lake that occupied the Red River Valley. Thus the first lakes to form were small isolated bodies around the margins of the valley. One or more of these small lakes appears to have formed west of the Red River Valley in northeastern Nelson County and to have emptied into Lake Agassiz through the Golden Valley and Elk Valley when the ice had retreated far enough to leave these valleys free of ice. Although no river now occupies these valleys throughout their length, and only small streams cross them, the glacial stream that originally

14/ Upham, Warren, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 1896.
15/ Tyrell, J. B., The genesis of Lake Agassiz: Jour. Geology, vol. 8, pp. 811-815, 1896.
16/ Johnston, W. A., The genesis of Lake Agassiz: Jour. Geology, vol. 24, pp. 625-638, 1916.
17/ Leverett, Frank, Quaternary geology of Minnesota and parts of adjacent States: U. S. Geol. Survey Prof. Paper 161, 1932.
18/ Nikiforoff, C. C., The life history of Lake Agassiz: Alternative interpretation: Am. Jour. Sci., ser. 6, vol. 245, pp. 205-239, 1947.

occupied them carried sufficient sediments to form a large delta, which Upham 19/ has called the Elk Valley delta. Perhaps a part or all of the delta was formed when the ice margin paused in the latitude of Portland and the postulated water-lain moraines were built. In this case, as the ice melted and the lake occupied a larger part of the valley, the water stood at the height of the Herman beaches and found an outlet to the Mississippi drainage. Cutting down of the outlet channel caused the lake waters to drop by successive stages to the level of the Campbell shore line. As the ice front retreated northward, the lake waters also receded northward until the lake was very nearly or completely drained. Subsequently a readvance of the ice again blocked the northward-flowing drainage, and a final lake was formed in the Red River Valley. It rose only to the level of the outlet (Campbell beach) and then receded.

Below the Campbell shore line two distinct units have been identified as corresponding to the two stages of lake flooding. 29/ The lower and commonly the thicker unit is thinly laminated blue-gray clay; the upper and commonly the thinner unit is more coarsely laminated buff to yellow silt. However, in the Portland area the clay unit in some places is absent or thinner than the silt unit because it was deposited over hills of till. The Elk Valley delta lies above the Campbell shore line, and the waters of the last lake flooding never covered it. (As noted on p. 10-14, it appears probable that the beach referred to in fig. 1 as the Tintah actually is the Campbell beach in the Portland area.)

19/ Op. cit., p. 163.
20/ Dennis, P. E., Akin, P. D., and Worts, G. F., Jr., op. cit., p. 18.

Upham 21/ described the formation of the Elk Valley delta as resulting largely from the sediment carried into the lake by the glacial Elk Valley River, although he recognized the possibility of large contributions of sediment directly from the melting ice front. Leverett 22/ was concerned about the absence of similar deltas at the mouths of larger rivers such as the Red Lake River, and believed that the greater part of the material was contributed directly by the melting ice. The fine-grained character and excellent assortment of the sediments, together with the almost total lack of pebbles, boulders, and unassorted blocks and balls of clayey material which one would expect to find in ice-laid deposits, lead the authors to favor Upham's deltaic origin for the Elk Valley delta.

The delta sediments are dominantly fine sand and silt. Considerable clay is interbedded with some of the silt and some medium sand occurs locally with the fine sand. A little gravel is found near the surface in a few localities, but none of the test holes encountered gravel beneath the water table. On the whole the unit is less compacted, even at depth, than are the clay and silt units. The total thickness of the delta sediments appears to range from about 30 to 90 feet in this area.

So far as known the clay unit and the silt unit in the Portland area consist entirely of fine material and contain no important aquifers. On the other hand, the sand of the delta unit is one of the most important aquifers in the area. Farm wells in the delta area obtain ample supplies of water of low mineral content at depths

21/ Op. cit., p. 333.
22/ Op. cit., pp. 126-127.

ranging from 7 to [illegible] feet. Three springs having flows of 10 to 40 gallons a minute issue at the heads of sapped channels along the delta margin in secs. 28 and 33, T. 146 N., R. 53 W., and sec. 4, T. 145 N., R. 53 W. (see fig. 4). A well on the Theodore Amb farm (146-53-28cdd2) dug in one of these spring areas furnishes much of the drinking and culinary water for Portland.

The sand aquifer of the delta unit extends for many miles north and west of the Portland area. The sands of which it is composed constitute very absorptive surficial material, and the aquifer is therefore subject to recharge from direct penetration of precipitation throughout the area of the delta. The sands average at least 50 feet in thickness, and the water table ranges between 3 and 19 feet below the surface. It is evident from these facts that there is a large volume of water in the aquifer in transient storage, and that discharge from the aquifer is replenished each year by local recharge. However, the sands are generally so fine-grained that wells of large yield cannot be easily constructed in them. Seventeen test holes were drilled through the delta materials during the present investigation in an attempt to locate coarser sediments in which wells of large capacity might be constructed, but without success. This does not demonstrate that coarse sediments are not present in the delta materials below the water table, but it does indicate that a large amount od drilling might be necessary to locate such deposits. The coarsest materials encountered at depth were found in USGS test 23. Even these sands were very fine, but it is possible that wells of sufficient yield for small municipal or industrial supplies could be more easily constructed in this area than elsewhere where test drilling was done.

It appears likely, therefore, that significant ground-water developments in the fine delta sands can be made only by the use of special methods such as infiltration tunnels or other types of collectors, gravel-packed wells, or other means.

Another water-bearing formation not present in the Portland area but possibly present about 9 or 10 miles east of Mayville should be considered in connection with the Lake Agassiz deposits, with which it is intimately associated. The presence of an aquifer or series of aquifers consisting of linear gravel bodies partly to completely buried in the lake sediments and extending from the Kist Bottling Works about midway between Buxton and Hatton to a point about a mile west of Hillsboro was determined in a previous investigation of the Buxton area. 23/ The gravel bodies have a known thickness ranging from 30 to 92 feet and in some places are overlain by strongly developed beach ridges. The beach ridges have a northwest-southeast trend, although the shore lines trend generally north-south in the same area. The buried gravels are thought to be glacio-fluvial deposits of the nature of eskers, crevasse fillings, or kame terraces and to have been modified by subsequent erosion and deposition of the eroded material in the lake waters.

The Buxton study did not extend as far south as State Highway 7 and test drilling during the present study did not extend far enough east to prospect the aquifer in that latitude. The aquifer, if present, would be about 12 miles east of Portland and, therefore, possible too distant to be considered as a possible source of

23/ Dennis, P. E., Ground water near Buxton, Traill County, N. Dak.: U. S. Geol. Survey mimeo. rept., p. 13, 1947.

municipal supply. However, it might be of interest to Mayville and Portland if they should contemplate a joint water supply.

Till and Associated Glacioaqueous Deposits

Till and associated glacioaqueous deposits underlie the Lake Agassiz deposits throughout the area. In the three test holes that penetrated the deposits in and near Portland they were about 150 feet thick. The upper surface of these deposits is much more irregular in the Portland area than it is in the Fargo area, for example. 24/ In USGS test 16 the buff-colored silt unit was found to rest directly upon the till and in other places the clay unit was found to be comparatively thin (see fig. 2). A possible explanation of these facts is suggested by the moraine that both Upham and Leverett show crossing the Red River Valley somewhat north of Portland. It appears that the outer margin, at least, of the moraine may have reached as far south as Portland. The absence of the clay unit in some places and the general thinness elsewhere in the area suggest that the moraine may have been formed during the earliest part of the period in which the clay unit was deposited. However, the same conditions could have been produced by the presence of a high morainic area with hills high enough to project to the lake surface or slightly above it. In this case the moraine may have antedated the lake rather than being, in part, contemporaneous with it.

The till consists largely of dark-gray noncalcareous clay peppered with light-gray to white highly calcareous spots and mixed with varying proportions of pebbles and boulders. The pebbles and

24/ Dennis, P. E., Akin, P. D., and Worts, G. F., Jr., op. cit., p. 22.

boulders consist of limestone and dolomite and crystalline rocks. Beds and lenses of glacioaqueous sand and gravel, which are generally interbedded with the till in other areas, are not common in the Portland area. This fact is indicated by the logs of the test holes and by the scarcity of wells between 100 and 250 feet deep.

A small aquifer at or near the top of the till was encountered by the Frank Ross well in Portland. The aquifer was penetrated at a depth of 105 feet and is reported to have consisted of a sand bed only a few feet thick. The well yields only a few gallons a minute but now furnishes water for several of the business establishments at Portland. Presumably, the same aquifer was encountered between 102 and 108 feet at the new Portland creamery well (147-53-35ddc1) and the Portland school well (147-53-35ddc2). A test of this aquifer at the creamery well was made by the driller, and it is reported that a yield of about 6 gallons a minute could be obtained. This aquifer may also have been encountered by Portland test hole P3, which reportedly encountered sand and gravel, consisting largely of shale particles, between 109 and 112 feet. The aquifer was not encountered by other wells and test holes in the area, and it is not believed capable of supporting wells of large yield.

Cretaceous (?) Rocks

At Portland artesian water is found at depths between 427 and 450 feet, and throughout most of the Portland area at depths ranging between 336 and 560 feet. Some wells on low ground have weak flows, and in most of the wells the water rises to within a few feet of the surface. The quality of the artesian water is rather similar in character and concentration throughout the area. For these reasons it has been generally assumed that the water is derived from the Dakota sandstone of Cretaceous age.

Because the high degree of mineralization of the artesian water makes it unsuitable for drinking and culinary purposes and because considerable information on the aquifer could be obtained from existing wells, only three test holes were drilled into the formation that yields the artesian water; and only one test hole completely penetrated it (see Fig. 2). In the absence of the paleontologist's report on fossils contained in cores from one of these wells, it is not possible to state with certainty that the sediments encountered in these test holes are marine, but they are tentatively considered to belong to the Benton shale and Dakota sandstone of Cretaceous age until such time as a more authoritative report is available.

On the basis of information from three test holes it appears that the top of these sediments occurs at a depth of about 200 feet at Portland and at somewhat greater depths eastward. The total thickness of the deposits in USGS test 10 was about 225 feet. They are underlain by the highly weathered crystalline rocks of the basement complex.

Cores of the sediments from USGS test 8 at Portland consist of shale and siltstone, generally noncalcareous but containing a few thin hard limy beds. Fragments of shells, fish scales, secondary pyrite, and detrital lignite occur in the cores. A search was made for foraminifera, but none were found. The silty layers consist largely of rather uniformly sized but angular quartz grains.

In USGS test 10, coarse, well-rounded quartz grains compose a part of the ditch samples representing depths from 345 to 365 feet and from 370 to 385 feet. Although the total thickness of the sand beds is considerably less than the expected thickness of the Dakota sandstone, they are nevertheless tentatively correlated with that formation (see fig. 2). It was expected that these sands would also be encountered in the lower part of USGS test 8, but no trace of the sand was found in the samples, and the drillers did not recognize its presence in the hole by any of its common drilling characteristics.

Whether the artesian water is derived from the Dakota sandstone or is derived from sand beds of glacioaqueous origin, it nevertheless appears to be present rather generally throughout the area and at least four wells in Portland have been drilled to this aquifer.

In order to obtain some idea of the quantity of water that might be obtained perennially from the artesian aquifer in Portland, a pumping test was made on the new creamery well, as described in the following paragraphs.

The pump installation on the new creamery well at Portland (147-53-35ddc1) was completed on August 18, 1948, and trial pumping runs were made on August 18 and 19. The well was pumped at a rate of 45 gallons a minute on August 18, and during part of the pumping on August 19. In the afternoon of August 19, the pump was adjusted to draw 50 gallons a minute. In the morning of August 20, the pump was started and allowed to pump continually at 50 gallons a minute for approximately 26 hours.

The junior author was notified of the pumping on August 20 and went to Portland, arriving there about 2:30 p.m. No accurate measurement of static water level had been obtained prior to the trial pumping and no water-level measurements had been made during the pumping. The author started water-level measurements in the Portland school well (147-53-35ddc2), 370 feet north of the pumping well. Arrangements were made to permit measurement of water levels in the pumped well and a few measurements were obtained before the well was turned off at 9:03 a. m. on August 21. Water-level measurements were made in the creamery well and in the school well until noon of August 22.

The coefficients of transmissibility and storage were computed from the water-level data obtained from the school well. The water-level trend in this well during pumping was extrapolated over the recovery period, and the difference in the measured water levels and the extrapolated curve was taken as the inverse drawdown caused by the imaginary recharge well involved in the water-level recovery. This inverse drawdown plotted against time since the pump was shut

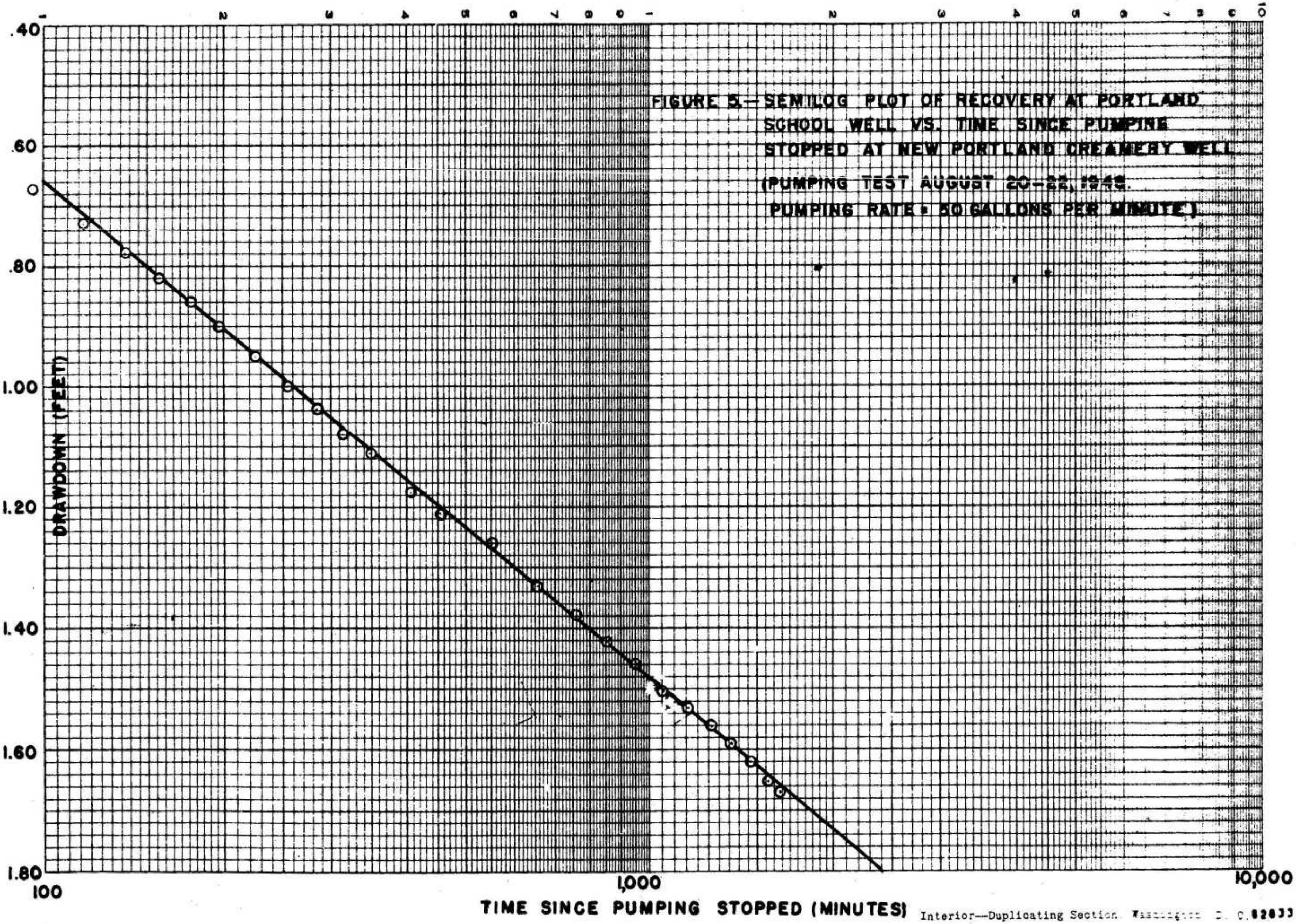


FIGURE 5.—SEMILOG PLOT OF RECOVERY AT PORTLAND SCHOOL WELL VS. TIME SINCE PUMPING STOPPED AT NEW PORTLAND CREAMERY WELL
(PUMPING TEST AUGUST 20–22, 1949. PUMPING RATE = 50 GALLONS PER MINUTE)

Interior—Duplicating Section, Washington, D. C. 62033

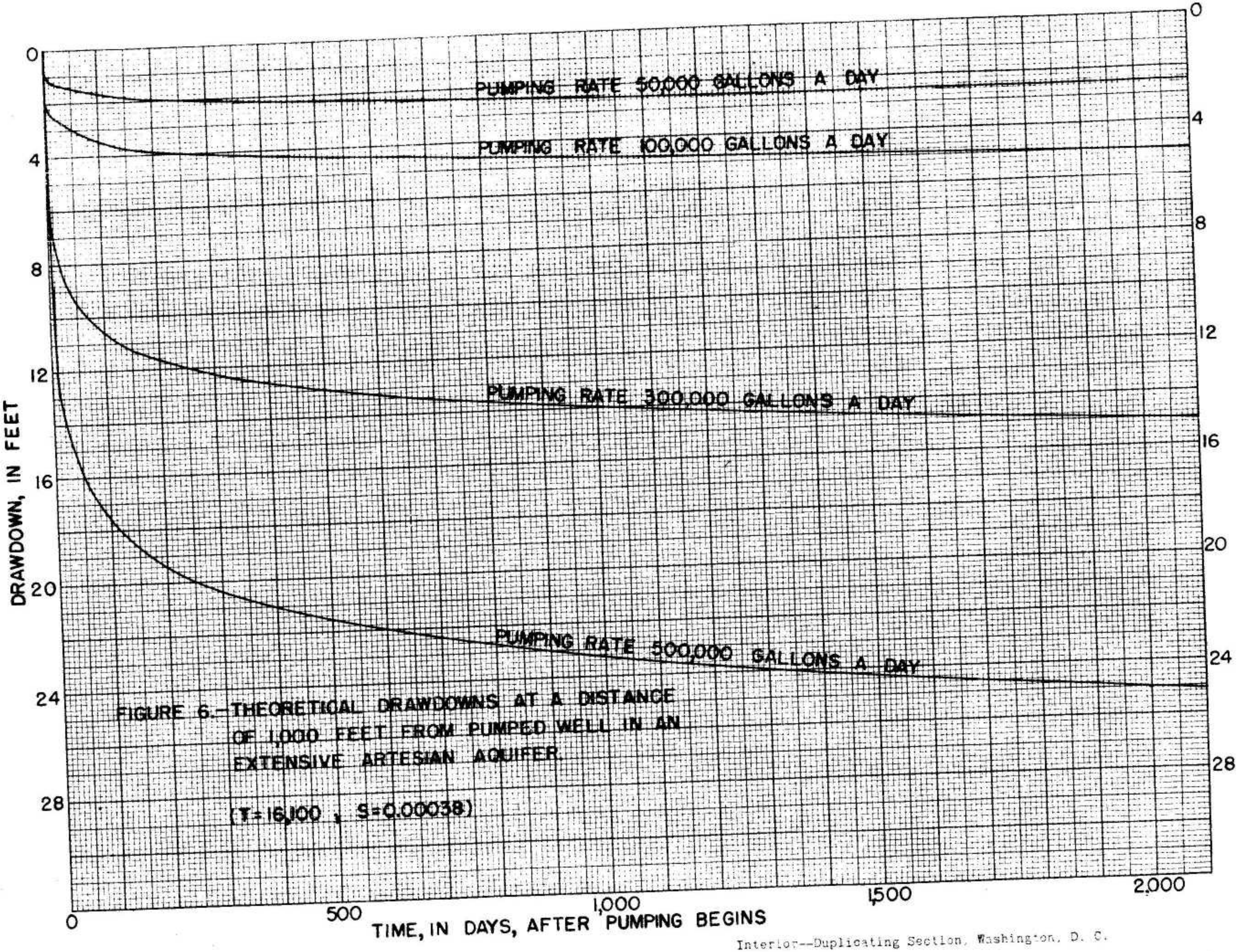


FIGURE 6.–THEORETICAL DRAWDOWNS AT A DISTANCE OF 1,000 FEET FROM PUMPED WELL IN AN EXTENSIVE ARTESIAN AQUIFER.

(T=16,100 , S=0.00038)

off, on semilog coordinates, is shown in figure 5. The coefficient of transmissibility as computed from this plot is 16,100 gallons per day per foot and the computed coefficient of storage is 0.00038.

At the end of the period during which water-level measurements were made, the water level in the new creamery well was 3.37 feet below the land surface and that in the school well was 4.06 feet below the land surface. The pumping water level in the new creamery well was about 24 feet below the land surface just before the pump was turned off. There was some fluctuation of the water level in the well, so that a very accurate measurement of the pumping level could not be made. The 1-day specific capacity of the well (gallons per minute per foot of drawdown) is estimated to be approximately $\frac{50}{20} = 2\frac{1}{2}$ g.p.m./ft.

In order that the reader may more easily visualize the significance of the coefficients of transmissibility and storage, the theoretical drawdown at a distance of 1,000 feet from a pumped well in an extensive aquifer having a coefficient of transmissibility of 16,100 and a coefficient of storage of 0.00038 are shown in figure 6.

Pre-Cambrian Rocks

Pre-Cambrian rocks, locally referred to as granite, were penetrated in the Portland area in only one test hole (USGS 10), where they underlie the Cretaceous (?) sedimentary rocks. The drill encountered the top of the formation at a depth of 447 feet and was still in it at a depth of 561 feet. The drill cuttings from this formation consist of white to greenish-gray clay and angular quartz crystals. A core was taken at a depth of 553 to 561 feet. It was a hard compact mudstone, light greenish gray in color except for thin bands of brick red. It was composed chiefly of clay with abundant angular quartz crystals and somewhat light-colored mica. It appears to have been a fine-grained foliated rock before alteration (weathering ?) and possibly was rhyolitic in composition.

Zones of fracture within or at the surface of the crystalline rocks have been known to yield small supplies of water, but in the Red River Valley area the highly weathered and clayey character of the upper part of these rocks generally prevents fractures from remaining open. No wells derive their water from the crystalline rocks in this area, and drillers generally consider it useless to drill deeper when the zone of decomposed "granite" is reached.

QUALITY OF THE GROUND WATER AND CHEMICAL ANALYSES

Chemical analyses of waters from 15 wells in the Portland area are given in the following table. Of these, four are from wells in the city of Portland, three are from wells in the city of Mayville, five are from wells on farms in the area, and three are from test holes drilled in and near Portland. Two of the samples came from aquifers in the river alluvium, one from sand at the base of the silt unit of the Lake Agassiz deposits, two from sand in the delta unit, two from glacioaqueous deposits interbedded with the till, and eight from the artesian aquifer.

The waters in the Portland area differ widely in chemical composition. The dissolved solids range between 270 and 5,720 parts per million and the total hardness between 153 and 1,610 parts per million. Other constituents also show a wide range in concentrations.

The chemical characteristics of the waters from the river alluvium are represented by samples from the Portland test 3 and USGS test 13. These waters are more highly mineralized than those from the delta sands but less highly mineralized than waters from the artesian aquifers. The sample from the St. Anthony and Dakota Elevator well is believed to come from the silt unit, although that unit is not a common aquifer in the Portland area. The water is quite highly mineralized. The waters from the John Hovland and Theodore Amb wells are derived from the fine sands of the delta, that from the Amb well being perhaps more typical as the Hovland well is at the very edge of the delta area. These waters are much less highly mineralized than those from other sources, being fairly low in dissoled solids and not nearly as hard as most wells in this area. The water from these two wells is the most satisfactory for domestic uses of any well waters encountered in the area.

The sample from the Frank Rose well comes from an aquifer at or near the top of the till and associated glacioaqueous deposits. It is moderately mineralized and are not very hard. On the other hand, the sample from Portland test 1 is reported to have come from a gravel bed at a greater depth in this same formation, and it is the most highly mineralized of the waters encountered. All the other analyses show the chemical composition of the artesian waters These waters are quite similar in chemical character and are uniformly high in mineral content and are very hard.

CHEMICAL ANALYSES OF GROUND WATERS
(PARTS PER

Location number	Owner or name	Date of Analysis	Source of Analysis	Depth of wells (ft.)	Iron (Fe)	Calcium (Ca)
146-52-6a	City of Mayville	1927	a/	365	2.2	177
146-53-1aaa	City of Portland	7-13-36	b/	427	6.0	246
146-53-2aab	Old Creamery	9-17-48	c/	437	2.1	202
146-53-9bab2	John Hovland	7-14-48	c/	23	3.8	62
146-53-28cdd2	Theodore Amb	7-13-48	c/	18	.2	62
147-52-31dad	Mayville Creamery	3-30-49	c/	393	1.4	160
147-52-32c	St. Anthony & Dak. Elev.	1927	a/	20	.2	436
147-53-14abb	D. Lien	7-15-48	c/	412	1.0	237
147-53-26ddc	H. A. Heskin	11-10-48	c/	490	1.2	227
147-53-34cac	Sander Amundson	7-13-48	c/	490	2.2	260
147-53-35aaa	USGS test 13	11-10-48	c/	147	4.0	47
147-53-35dbb1	Portland test 3	8-16-41	c/	135	0	157
147-53-35ddc1	New Creamery	8-17-48	c/	450	1.2	192
147-53-35ddc3	Frank Rose	1947	c/	105	.6	...
147-53-35ddc4	Portland test 1	8- 6-41	c/	300	4.5	135

a/ Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 303, 1929.

b/ Abbott, G. A., and Voedisch, F. W., The municipal ground-water supplies of North Dakota; N. Dak. Geol. Survey Bull. 11, p. 81, 1938.

c/ North Dakota State Health Dept.

IN THE PORTLAND AREA
MILLION)

Magnesium (Mg)	Sodium and Potassium (Na + K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids	Total hardness (as $CaCO_3$)
70	867	.0	254	1,230	790	15	3,370	730
71	875	...	224	1,410	822	11	3,700	918
80	876	...	222	1,380	870	104	3,660	830
30	.0	...	344	.....	...	4.3	402	278
26	.0	...	252	.....	...	0	270	248
87	830	0	242	1,250	755	4.3	3,330	758
126	26	.0	451	1,020	82	144	2,210	1,610
123	804	0	198	1,260	970	10	3,940	1,100
83	...	18	184	1,310	828	6.5	3,740	.....
97	776	.0	206	1,350	...	7.8	3,780	1,050
60	209	.0	428	294	120	4.3	932	240
58	183	.3	628	377	86	...	1,490	631
70	872	...	222	1,330	797	104	3,580	856
62	...	31	432	485	67	...	1,200	153
61	1,570	...	646	3,220	84	...	5,710	581

SUMMARY AND CONCLUSIONS

Test holes and wells drilled in and near Portland, pumping-test data on two wells, and chemical analyses of waters from most of the wells furnish sufficient information to indicate that a municipal water supply, adequate in both quality and quantity, is not likely to be obtained in or immediately adjacent to the town. The aquifer penetrated by the Rose well (147-53-35ddc3) at a depth of about 105 feet consists of a thin bed of sand. The water is more highly mineralized than that being hauled to town from the Theodore Aab well (146-53-28cdd2) but is less mineralized than that from the deeper wells. It is probable that the quantity of water available from this aquifer would be inadequate as a source of municipal supply. The aquifer penetrated at a depth of about 450 feet by the creamery well, school well, and others would yield enough water to meet the needs of the town. However, the water is so highly mineralized as to be undesirable for drinking, culinary, and irrigation purposes.

The construction of a surface-water reservoir on the Goose River from which both Portland and Mayville might obtain municipal supplies appears worthy of consideration, but determining the feasibility of such a project is beyond the scope of the Geological Survey.

The river alluvium along the valleys of the Goose River and its south branch consist largely of clayey sand and gravel and very fine sand, and wells of moderate to large capacities have not been constructed in it in the Portland area. Water from this aquifer appears, from analyses of waters from USGS test 13 (147-53-35aaa) and Portland test 5 (147-53-35dbb1), to be only moderately mineralized. Twelve test holes were drilled through the alluvium during the present investigation, and two wells had been constructed in it previously by a private well-drilling company for the town. At all these locations, except at USGS test 13, the materials appeared to contain too much clay for the construction of satisfactory wells. Although the sand and gravel from USGS test 13, between 26 and 42 feet, was coarse and reasonably free of clay, test pumping indicated a very low transmissibility. The alluvial materials are so variable that beds of sand and gravel relatively free of clay may be present in some part of the valley that was not drilled, although all the evidence thus far obtained makes it appear improbable.

Adequate supplies of ground water of excellent quality are available from the delta sand about 5 to 7 miles southwest of Portland. The sand is generally very fine to fine, and frequently silty, and it probably would be difficult to construct a well in it of sufficient capacity to supply the town. However, a well of very large diameter, a battery of several wells, or an infiltration gallery might be constructed to give the desired yield.

A shallow aquifer or series of aquifers known to be present between Buxton and Hatton is thought to continue southeastward as far as Hillsboro and to cross State Highway 7 about 12 miles east of Portland. Should Mayville and Portland contemplate a joint water supply, the possibility of a large aquifer in that region would seem to be worth further investigation.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based upon the location of the well with respect to the land-survey divisions used in North Dakota. The first number is the township north of the base line running along the Kansas-Nebraska State line. The second number is the range west of the sixth principal meridian. The third number is the section within the designated township. The letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, the quarter-quarter-sections, and the quarter-quarter-quarter sections (10-acre tracts). If more than one well occurs within a 10-acre tract, consecutive numbers are given to them as they are scheduled. This number follows the letters. Thus, well 146-55-4bbb2 is in T. 146 N., R. 55 W., sec. 4. It is in the northwest quarter of the northwest quarter of the northwest quarter of that section and is the second well scheduled in that 10-acre tract. Similarly, well 147-52-55ddd (see USGS Test 10, fig. 2) is in the southeast quarter of the southeast quarter of the southeast quarter of sec. 55, T. 147 N., R. 52 W. Numbers for wells not accurately located within the section in the field may contain one or two letters after the section number, indicating that the locations of such wells are accurate only to the quarter or quarter-quarter section, respectively.

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

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

b a

c d

Date completed: Test holes were drilled and refilled. Date given is date of refilling.
Depth to water: Reported water levels are given in even feet, measured water levels are given to the nearest tenth.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date Completed
145-53-4baa	Goodman Gummer	Spring	......	....	......
146-51-4aaa	USGS test 12	160	5	Drilled	7-9-48
146-52-2	Peter Ulland	354	2	Jetted	1944
146-52-7d	Gilbert Elkin	398	2	..do..	1944
146-52-14ad	N. D. Nelson Estate	152	2	..do..	1945
146-52-15d	John Setwedt	336	2	Drilled	1935
146-52-17a	D. C. Ewen	400	3 to 2	..do..	1936
146-52-18aaa	Otto E. Jordet	360	3	..do..	1898
146-52-28d	C. A. Ulland	370	2	..do..	1936
146-53-1baa	Henry Klavo	411	2	Bored	1942
146-53-1bb	Stockyard well	20	36	Dug	....
146-53-1cbb	Melvin Lucken	40	3	Drilled	....
146-53-2aab	Old Creamery	437	4½ to 2	..do..	1934
146-53-2aad	USGS test 7	335	5	..do..	5-13-47
146-53-2abc	USGS test 8	427	5	..do..	6-12-48
146-53-2cda	Clarence Klabo	20	24	Dug	....
146-53-3add	Emma Harstad	435	3	Drilled	1943
146-53-3bac1	S. Sanderson	414	2	..do..	1944
146-53-3bac2	Hiram Sanderson	60	24	Dug	Old
146-53-3bac3	...do...	10	48	..do..	1936
146-53-4aac	Mrs. S. Stenerson	14	48	..do..	1926
146-53-4bbb1	Albert Hovde	509	3 to 1¼	Jetted	1943
146-53-4bbb2	...do...	15	36	Dug	1931
146-53-5aaa	James Strand	26	42	..do..	1926
146-53-5abb	USGS test 6	117	5	Drilled	5-12-47
146-53-5cdb	Joe Armbrust	23	48	Dug	1948
146-53-5dcc	USGS test 31	37	5	Drilled	9-2-48
146-53-6aaa	Carl Evanson	130	3	Bored	1945
146-53-6ccc1	Roy Peterson	44	24	..do..	1944
146-53-6ccc2	...do...	12	24	Dug	....
146-53-7aaa	USGS test 32	47	5	Drilled	9-3-48
146-53-7baa	USGS test 33	52	5	..do..	9-3-48
146-53-7ddd	USGS test 3	169	5	..do..	5-9-46
146-53-8aaa	USGS test 30	37	5	Drilled	9-2-48
146-53-8ccc	Lewis Holkesvig	14	36	Dug	1936
146-53-8cdd	USGS test 4	161	5	Drilled	5-9-47
146-53-8d	A. O. Anderson	22	48	Dug	1920
146-53-8ddd	USGS test 5	156	5	Drilled	5-10-47
146-53-9bab1	John Hovland	28	...	Bored	1945
146-53-9bab2	...do...	23	24	..do..	1941
146-53-9c	A. O. Anderson	22	36	Dug	1915
146-53-9dcc	O. A. Thompson	50	24	Bored	1908
146-53-10dcc	Spencer Wallen	385	2	Drilled	1910
146-53-11aaa	G. L. Elken	90	24	Bored	1900
146-53-11abb	Joe Kjos	...	2	Drilled	....
146-53-12ada	Ole Syverson	385	..	..do..	1934

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

Depth to water (ft. below land surface.)	Date of Measurement	Use of Water	Remarks
....	....	S	Flow 12 to 18 g.p.m.
....	....	U	Log
Flow	....	S	
..do..	....	S	
..do..	....	D, S	
..do..	....	S	
..do..	....	S	
..do..	....	S	
..do..	....	D, S	
3.9	7-14-48	S	Rainwater used for domestic purposes.
5.2	7-14-48	S	Do.
7	1948	S	
2	1934	Ind	Reported yield 35 gallons a minute.
....	....	U	Log.
....	....	U	Do.
14.1	7-14-48	S	Rainwater used for domestic purposes.
0.5	7-14-48	S	Do.
12	1948	S	Do.
59	1939	D	Reported inadequate.
6	1936	S	Do.
3	1926	U	On river flood plain.
12	1943	S	
....	....	D, S	
24	1939	D, S	
....	....	U	Log.
8.6	7-14-48	D, S	Water formerly hauled to Portland.
....	....	U	Log.
....	....	S	Rainwater used for domestic purposes.
....	....	S	Quality reported poor.
....	....	D	Quality reported good.
....	....	U	Log
....	....	U	Do.
....	....	U	Do.
....	....	U	Log
9	1936	D, S	
....	....	U	Do.
17	1939	D	Reported adequate.
....	....	U	Log.
4	1948	S	Rainwater used for domestic purposes.
4.9	7-14-48	S	Analysis.
16	1939	...	
2.6	5-9-47	S	
15	1947	S	Rainwater used for domestic purposes.
....	....	U	
25	1948	S	Reported salty.
....	....	D.S	

Location number	Owner or Name	Depth of well (feet)	Diameter (inches)	Type	Date Completed
146-53-14dbb	L. Tyre	400	2	..do..	1933
146-53-15caa	Edwin Holkesvig	36	24	Bored	1934
146-53-16bbc	USGS test 21	102	5	Drilled	6-14-48
146-53-16cbb	USGS test 22	102	5	..do..	6-17-48
146-53-16ccc	USGS test 23	102	5	..do..	6-24-48
146-53-17aab1	O. G. Holkesvig	20	48	Dug	1927
146-53-17aab2	...do....	20	72	..do..	1902
146-53-17bb	E. N. Amundson	30	48	..do..	1904
146-53-18abb	Fed. Farm Mtge. Corp.	26	...	..do..	....
146-53-18ccc	Arthur Domier	7	30	..do..	....
146-53-18dda	Hjalmer Hovland	20	72	..do..	1931
146-53-19abb	Leonard Domier	30	48	..do..	1915
146-53-19ddd	Clarence Domier	14	...	..do..	1931
146-53-20aab	O. P. Nelson	13	36	..do..	....
146-53-20baa	Oscar Domier	26	48	..do..	1900
146-53-20bbb	Arthur Stavedal	54	30	Bored	1935
146-53-21bbb	Hjalmer Hovland	40	30	..do..	1941
146-53-21bcc	USGS test 24	102	5	Drilled	6-26-48
146-53-22add	J. Grinde	55	32	Bored	1935
146-53-22cbb	Cora Nelson	60	24	..do..	1920
146-53-22daa1	J. R. Grinde	50	48	..do..	1900
146-53-22daa2	...do.....	50	48	..do..	1935
146-53-25aaa	Paul Babee	415	3	Drilled	1937
146-53-25ccc	...do....	432	3	..do..	1937
146-53-26aab1	C. Koppang	36	24	Bored	1920
146-53-26aab2	...do....	36	24	..do..	1927
146-53-26ccc1	Bernhard Grinde	40	24	..do..	....
146-53-26ccc2	...do....	26	36	Dug	1928
146-53-26dcc	Inga Larson	417	3	Drilled	1939
146-53-28bbb	USGS test 25	102	5	..do..	6-30-48
146-53-28cdd1	Theodore Amb	Spring			
146-53-28cdd2	...do....	18	120	Dug	1946
146-53-28cdd3	USGS test 2	216	5	Drilled	5-7-47
146-53-28ddc1	C. M. Aasen	16	48	Dug	1928
146-53-28ddc2	...do....	8	84	..do..	1933
146-53-29bbb	F. W. Warren	12	96	..do..	1914
146-53-30bbb1	Arthur Kvemen	18	30	..do..	1914
146-53-30bbb2	...do....	32	42	..do..	....
146-53-30dcd1	Betsy Knudson	12	36	..do..	1933
146-53-30dcd2	...do....	15	36	..do..	1946
146-53-31d	C. J. Evanson	12	48	..do..	1930
146-53-33abd	Ray Young	11	48	..do..	1931
146-53-33bbb	USGS test 1	202	5	Drilled	5-5-47
146-53-33dbb	Eanar Krug	Spring			
146-53-34bbb	Joseph Amb	20	24	Dug	....
146-54-1dcc	USGS test 37	22	5	Drilled	9-9-48

Depth to water (ft. below land surface.)	Date of measurement	Use of Water	Remarks
Flow	1939	D,S	
15	1939	D,S	
......	......	U	Log.
......	......	U	Do.
......	......	U	Do.
12	1927	D,S	Reported good, adequate .
15	1939	D,S	Do.
25	1939	D,S	Do.
20	1939	D,S	Do.
1	1939	D,S	Do.
18	1939	S	
23	1939	D,S	Do.
10	1931	...	Do.
10	1939	D,S	Do.
16	1900	D,S	Do.
25	1939	...	Do.
22	1947	D,S	Do.
......	......	U	Log.
35	1939	S	
......	......	D,S	
......	......	S	Reported inadequate.
10	1935	S	
Flow	1937	...	F.S.A. unit 112
..do..	1937	...	Do. 111
20	1920	S	
20	1927	S	
......	......	...	Reported inadequate.
20	1939	D,S	
Flow	1939	D,S	
....	......	U	Log.
Flow	......	...	Sapped channel in beach ridge. Surface discharge about 10 g.p.m.
Flow	......	PS	Hauled to Portland.
....	......	U	Log.
14	1939	D,S	Reported inadequate.
4	1933	S	
10	1939	D,S	Reported good, adequate.
16	1914	D	Do.
28	1939	S	Do.
8	1939	D	Do.
6.0	5-8-47	S	
8	1939	...	
7	1931	D,S	
....	......	U	Log.
Flow	......	...	Flow 30 to 42 g.p.m.
10	1939	D,S	
....	......	U	Log.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date Completed
146-54-1ddd	USGS test 36	27	5	Drilled	9-8-48
146-54-12bbb	USGS test 38	62	5	..do..	9-10-48
147-51-32ddd	USGS test 11	190	5	..do..	7-7-48
147-52-3ccc	Olaf osland	400	4 to 2	..do..	1926
147-52-3daa	Gilbert Aasen	162	2	..do..	1934
147-52-4dca	G. N. Burnsdale	500	3 to 2	..do..	1920
147-52-6ccc	Louis Larson	350	2	..do..	1912
147-52-7cdd	F. B. Dennie Estate	460	2	..do..	1889
147-52-8ccc	Oscar Haugen	440	4 to 2	..do..	1934
147-52-10bcc	Gunder Carlson	410	3 to $1\frac{1}{4}$	..do..	1929
147-52-15ccc	S. N. Rosevold	....	2	..do..	1889
147-52-15ddd	Elmer Evenson	350	2	..do..	1889
147-52-16adb	Eddie Osland	400	3 to 2	..do..	1927
147-52-16ddd	John Hella	25	48	Dug	1927
147-52-17cbb	Karl Brunsdale	375	2 to $1\frac{1}{2}$	Drilled	1914
147-52-20add	Carrie Frigstad	385	4 to 2	..do..	1918
147-52-20caa	David Osland	458	2	..do..	1889
147-52-21aaa	Farm Sec. Admin.	370	3	..do..	1937
147-52-21bbb	..do..	354	3	..do..	1937
147-52-21ccc	..do..	369	3	..do..	1937
147-52-21ddd	..do..	346	3	..do..	1937
147-52-22abb	J. C. Larson Estate	313	3 to 2	..do..	1930
147-52-27dcd	C. M. Nelson	352	2	..do..	1934
147-52-28dda	Eddie Lindaas	385	2	..do..	1898
147-52-29aaa	C. F. Enger	400	2	..do..	1889
147-52-30add	Geo. Osland	454	3 to 2	..do..	1931
147-52-30bbc	Even Evenson	446	4 to 2	..do..	1936
147-52-31cba	Martin Kalstad	480	3	..do..	1898
147-52-31ccc	USGS test 9	135	5	..do..	6-10-48
147-52-31dad	Mayville Creamery	393	4	..do..	1944
147-52-33dcc	K. E. Brunsdale	233	2	..do..	1918
147-52-33ddd	USGS test 10	561	5	..do..	7-5-48
147-52-34daa	Carl Solcott	...	2	..do..	......
147-53-1ccc	Bennie Grandalen	447	3 to 2	..do..	1935
147-53-6bbb	Ole Nelson	80	18	Bored	1936
147-53-9cdd	Andrew Olson	20	48	Dug	1934
147-53-11ddc	C. J. Olson	45	48	..do..	1927
147-53-12daa	O. C. Larson	352	3 to 2	Drilled	1938
147-53-13dcd	C. F. Enger	300	4 to 3	..do..	1942
147-53-14abb	D. Lien	412	2	..do..	1948
147-53-14ccc	C. J. Olson	465	4	..do..	1943
147-53-16bcc	Nels Nerdalere	500	2	..do..	1934
147-53-16dcd	Garvin Braaten	80	3	Jetted	1939
147-53-17ccb	Martin Amb	81	36	Dug	1934
147-53-18ddd	Homer Hovland	25	36	..do..	1932

Depth to water (ft. below land surface	Date of measurement	Use of Water	Remarks
......	......	U	Log.
......	......	U	Do.
......	......	U	Do.
10	1939	S	
26	1939	...	
20	1939	S	
40	1939	S	
18	1939	S	
15	1939	S	
20	1939	S	
20	1939	S	
12	1939	S	
20	1939	S	
23	1939	S	Reported inadequate.
20	1939	S	
16	1939	S	
14	1939	S	Reported to have flowed when drilled.
16	1939	D,S	F. S. A. unit no. 52
16	1939	D,S	Do. no. 50
15	1939	D,S	Do. no. 51
15	1939	D,S	Do. no. 53
12	1939	S	
3	1939	D,S	
8	1939	...	Reported to have flowed when drilled.
20	1939	S	Do.
12	1939	S	
7	1939	...	
Flow	1948	S	Reported salty. On low ground near river.
.....	.....	U	Log.
7	1944	Ind.	Analysis.
17	1939	S	
.....	.....	U	Log.
.....	.....	S	Reported to have flowed when drilled.
25	1939	S	
45	1939	S	
12	1934	S	Reported inadequate.
22.8	7-13-48	S	Rainwater used for domestic purposes.
34	1938	S	Do.
15	1942	S	Do.
Flow	1948	S	Analysis. Reported to flow 8 g.p.m.
.....	.....	S	Salty.
50	1939	S	
6.9	7-13-48	S	Rainwater used for domestic purposes.
8	1939	D	
20	1932	S	Reported inadequate. Dry in 1939.

Depth to water (ft. below land surface)	Date of measurement	Use of Water	Remarks
6	1939	S	Reported inadequate.
22	1932	S	Do.
12	1948	S	Rainwater used for domestic purposes.
15	1948	S	Do.
10	1942	S	Do.
.....	.....	U	Log.
8.1	7-12-48	U	Reported poor quality.
14	1944	D,S	
20	1948	S	Rainwater used for domestic purposes.
.....	.....	U	Log.
Flow	1948	S	Salty. Flow reported as 20 g.p.m.
..do..	1948	S	Analysis. Flow reported as ½ g.p.m.
2	1948	S	Well dug on site of former spring.
.....	.....	S	Salty.
.....	.....	U	Log.
.....	.....	U	Do.
.....	.....	U	Do.
18	1943	U	
7	1948	S	Rainwater used for domestic purposes.
32	1944	S	Do.
15	1948	S	Do.
20	1939	S	
Flow	1939	S	
13	1939	D,S	Reported good, adequate.
12	1939	S	
40	1939	D,S	
15.3	7-14-48	D	
Flow	1948	S	Salty.
..do..	1948	S	Analysis.
......	.....	U	Log. Analysis.
......	.....	U	Log.
......	.....	U	Do.
......	.....	U	Do.
14	1944	S	Rainwater used for domestic purposes.
......	.....	U	Log.
4	1948	Ind.	
......	.....	PS	
......	.....	U	Do.
......	.....	U	Do.
......	.....	U	Do.
......	.....	U	Do.

Location number	Owner or name	Depth of well (feet)	Diameter (inches)	Type	Date Completed
147-53-19bca	Olaf Flaten	8	36	Dug	1939
147-53-19c	Nels Berg	25	36	..do..	1932
147-53-22aaa	George Strand	450	2	Drilled	1913
147-53-24adb	...do....	500	4	..do..	1931
147-53-24bcd	Norman Haugen	450	4	..do..	1942
147-53-25ccc	USGS test 14	126	5	..do..	7-13-48
147-53-25cdd1	Peter Paulson	25	30	Dug	1944
147-53-25cdd2	...do....	430	3	Drilled	1944
147-53-26aaa	Ed Anderson	450	4	..do..	....
147-53-26cad	USGS test 40	37	5	..do..	9-25-48
147-53-26cc	Ed Fyre	475	2	..do..	1945
147-53-26ddc	H. A. Hoskin	490	3 to 1½	..do..	1921
147-53-27aca	Otto Flaten	5	42	Dug	1933
147-53-27bba	Ted Strand	500	3 to 1½	Drilled	1942
147-53-27daa	USGS test 43	27	5	..do..	10-1-48
147-53-27dad1	USGS test 39	12	5	..do..	9-25-48
147-53-27dad2	USGS test 42	37	5	..do..	10-1-48
147-53-28adb	Theo. Strand	497	3 to 1¼	..do..	1943
147-53-28cdc	Albert Hefta	470	4	..do..	1928
147-53-29cca	K. J. Lucken	530	3 to 2	..do..	1944
147-53-29dab	Gordon Houd	600	2	..do..	1910
147-53-30abb	Ingvold Berg	557	3½ to 2	..do..	1933
147-53-30ccc	O. G. Grandalen	518	3 to 1¼	..do..	1934
147-53-31aaa	Alvin Amundson	134	3	..do..	1903
147-53-31bbb	O. N. Berg	14	42	Dug	1931
147-53-31cca	...do....	106	3	Bored	1939
147-53-33ddb	Ludvig Haugen	16	36	Dug	....
147-53-34adc	H. O. Myx	450	2	Drilled	1945
147-53-34cac	Sander Amundson	490	2	..do..	1945
147-53-35aaa	USGS test 13	147	5	..do..	7-10-48
147-53-35aad	USGS test 27	92	5	..do..	7-7-48
147-53-35ada1	USGS test 15	116	5	..do..	7-14-48
147-53-35ada2	USGS test 26	67	5	..do..	7-2-48
147-53-35cda	Gilbert Haagenson	471	3	..do..	1944
147-53-35dab	USGS test 16	130	5	..do..	7-15-48
147-53-35ddc1	Portland Creamery	450	3	..do..	1948
147-53-35ddc2	School well	450	3 to 2	..do..	1948
147-53-36acc	USGS test 45	42	5	..do..	10-10-48
147-53-36caa	USGS test 44	37	5	..do..	10-9-48
147-53-36cad	USGS test 17	120	5	..do..	7-16-48
147-53-36cbb	USGS test 41	42	5	..do..	9-26-48

LOGS OF TEST HOLES IN THE PORTLAND AREA, N. DAK.

No. 1, 146-53-33bbb

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy..........................	2	2
Sand, brown, fine to medium, gravelly...........	18	20
Sand, gray, medium, clayey......................	5	25
Sand, very fine to fine, silty..................	45	70
Sand, fine, some lignite pebbles, silty.........	15	85
Sand, very fine, silty..........................	10	95
Till, very sandy clay...........................	12	107
Till, gray sandy clay with shale pebbles........	44	151
Till, clay, sand and boulders...................	21	172

No. 2, 146-53-28cdd

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy...........................	3	3
Sand, fine, with a very little gravel...........	17	20
Sand, fine......................................	20	40
Sand, very fine to fine, silty..................	15	55
Sand, fine, silty and clayey....................	15	70
Till, sandy clay with shale pebbles,............	35	105
Till, sandy and bouldery clay...................	70	175
Gravel, clayey..................................	10	185
Till, sandy and bouldery clay...................	31	216

No. 3, 146-53-7ddd

Material	Thickness (feet)	Depth (feet)
Gravel, fine to coarse, and sand................	10	10
Sand, and a little gravel.......................	14	24
Till, sandy and gravelly clay...................	46	70
Sand, fine, with a very little gravel...........	35	105
Till (?), sandy clay............................	30	135
Till, sandy and bouldery clay...................	34	169

No. 4, 146-53-8cdd

Material	Thickness (feet)	Depth (feet)
Till (?) gravelly, gray clay....................	5	5
Sand, fine......................................	65	70
Sand, very fine to fine, silty..................	45	115
Till, clay with shale pebbles and limestone boulders....................................	26	141
Sand, gravelly and boulders.....................	7	148
Till, sandy and gravelly clay...................	13	161

No. 5, 146-53-8ddd

Material	Thickness (feet)	Depth (feet)
Sand, mostly fine, with a little gravel.........	4	4
Till (?), yellow gravelly clay..................	9	13
Till (?), gray gravelly clay....................	7	20
Sand, very fine to fine.........................	15	35
Till (?), gray clay with shale and limestone pebbles..	25	60
Sand, fine......................................	20	80
Till, sandy and gravelly clay...................	28	108
Till, bouldery clay.............................	48	156

No. 6, 146-53-5abb

Material	Thickness (feet)	Depth (feet)
Till (?), yellow clay with shale and limestone pebbles..	12	12
Sand, mostly fine, gravelly.....................	9	21
Till (?), yellow gravelly clay..................	8	29
Silt, gray, gravelly............................	60	89
Till, bouldery clay.............................	28	117

No. 7, 146-53-2aad

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy...........................	2	2
Clay, yellow, pebbly............................	18	20
Clay, blue-gray.................................	15	35
Till, light-gray, gravelly and bouldery clay....	75	110
Till, medium-gray, bouldery clay................	45	155
Till, dark-gray, bouldery clay..................	55	210
Clay, dark-brown................................	17	227
Clay or shale, dark-gray........................	63	290
Silt or siltstone and clay or shale.............	30	320
Siltstone, light-gray, fine, sandy..............	15	335

No. 8, 146-53-2abc

Material	Thickness (feet)	Depth (feet)
Topsoil, black..................................	2	2
Till (?), gray, pebbly clay.....................	9	11
Silt, yellow, shell fragments...................	29	40
Clay, gray, compact, fissile....................	16	56
Till, gray, sandy with shale pebbles............	14	70
Shale, gravel...................................	1	71
Till, gray clay with shale and limestone pebbles	19	90
Till, dark-gray, sandy, pebbly clay.............	20	110
Till, bouldery clay.............................	40	150
Till, gray clay with shale and limestone pebbles	30	180
Clay, gray, sandy, gravelly.....................	30	210
Shale and siltstone interbedded, gray...........	170	380
Clay, white to pink.............................	20	400
Clay, light-brown...............................	27	427

No. 9, 147-52-31ccc

Material	Thickness (feet)	Depth (feet)
Topsoil, black, silty	2	2
Clay, yellow	24	26
Clay, gray, hard, fissile	23	49
Till, sandy and pebbly gray clay	18	67
Shale gravel, clayey	2	69
Till, gravelly and bouldery clay	66	135

No. 10, 147-52-33ddd

Material	Thickness (feet)	Depth (feet)
Clay, yellow, silty	16	16
Clay, gray	37	53
Till, clay with shale and limestone pebbles	97	150
Gravel, clayey	6	156
Till, bouldery clay	21	177
Gravel, bouldery, chiefly shale pebbles	2	179
Till, gravelly, bouldery clay	6	185
Gravel, chiefly shale pebbles	9	194
Till, gravelly clay	19	213
Sand with shale pebbles	2	215
Clay, gray, fine, sandy	60	275
Clay, brown, fine, sandy	25	300
Clay, gray, interbedded silt and fine sand	17	317
Clay, white or light-gray	3	320
Clay, light-brown, interbedded fine sand	5	325
Clay, gray, interbedded silt and fine sand	20	345
Sand, coarse, well-rounded quartz grains	20	365
Clay, gray	5	370
Sand, coarse to fine, well rounded quartz grains	15	385
Clay or shale	10	395
Clay, dark-brown	5	400
Clay, gray, interbedded fine to medium sand	15	415
Clay or shale, brown	5	420
Clay or shale, gray	15	435
Clay or shale, black	5	440
Clay or shale, gray	7	447
Clay, white, talc-like, and angular quartz grains	5	452
Clay, interbedded white and red, talc-like, angular quartz	95	547
Clay, greenish-gray, talc-like	6	553
Core, hard compact mudstone, light greenish-gray with thin bands brick-red; chiefly clay with abundant angular quartz and some light-colored mica. Appears to have beer a fine-grained foliate before alteration (weathering) and possibly rhyolitic in composition	8	561

No. 11, 147-51-32ddd

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy	1	1
Sand, fine	8	9
Sand, fine, silty, clayey	21	30
Clay, blue-gray	40	70
Till, gray clay with shale and limestone pebbles	29	99
Gravel, chiefly shale pebbles	1	100
Till, bouldery clay	68	168
Sand and gravel	12	180
Till, gravelly clay	10	190

No. 12, 146-51-4aaa

Material	Thickness (feet)	Depth (feet)
Topsoil, black, silty	1	1
Till (?), yellow clay with gravel and cobbles	3	4
Clay, yellow, silty	23	27
Clay, blue-gray	56	83
Sand, coarse, gravelly	6	89
Till, gravelly and bouldery clay	19	108
Sand, coarse, gravelly	2	110
Till, gravelly clay	50	160

No. 13, 147-53-35aaa

Material	Thickness (feet)	Depth (feet)
Topsoil, black, silty	1	1
Clay, yellow, silty and sandy	25	26
Sand, fine to coarse, silty	9	35
Gravel and sand, silty	7	42
Till, sandy and gravelly clay	37	79
Shale gravel, clayey	1	80
Till, sandy and gravelly clay	30	110
Sand and gravel, mostly shale grains and pebbles	4	114
Till, gravelly clay	33	147

No. 14, 147-53-25ccc

Material	Thickness (feet)	Depth (feet)
Topsoil, black	1	1
Clay, yellow, silty, wood fragments at base	19	20
Clay, blue-gray	18	38
Till, light-gray, sandy, gravelly	12	50
Till, blue-gray, shale pebbles in clay	20	70
Till, light-gray, sandy, gravelly	56	126

No. 15, 147-53-35ada1

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy	1	1
Clay, brown, sandy	17	18
Sand, fine to medium, with many shell fragments	2	20
Sand, coarse	5	25
Till, sandy, gravelly	12	37
Shale gravel	2	39
Till, gravelly	37	76
Shale gravel	2	78
Till, sandy, gravelly	38	116

No. 16, 147-53-35dab

Material	Thickness (feet)	Depth (feet)
Topsoil, black	1	1
Clay, yellow, silty and gravelly	28	29
Sand and gravel, mostly shale pebbles, clayey	10	39
Till, sandy, gravelly	47	86
Shale gravel, clayey	2	88
Till, gravelly	42	130

No. 17, 147-53-36cad

Material	Thickness (feet)	Depth (feet)
Topsoil, black	3	3
Clay, mottled yellow and gray, conglomeratic	33	36
Till, pebbly gray clay	24	60
Till, dark-gray gravelly clay	39	99
Shale gravel, clayey	1	100
Till, gray gravelly clay	20	120

No. 21, 146-53-16bbc

Material	Thickness (feet)	Depth (feet)
Sand, fine to medium	2	2
Silt, clayey, sandy	5	7
Shale sand, coarse	15	22
Sand, brown, fine	5	27
Sand, very fine to fine, with lignite fragments	15	42
Shale sand, coarse	10	52
Clay, silty and sandy	30	82
Sand, gray, very fine	10	92
Silt or sand, very fine	10	102

No. 22, 146-53-16cbb

Material	Thickness (feet)	Depth (feet)
Clay, mottled yellow and gray, silty	12	12
Shale, gravel, fine, clayey; lignite flakes	15	27
Till, sandy, gravelly; lignite flakes	75	102

No. 23, 146-53-16ccc

Clay, yellow, sandy	2	2
Sand, light-brown, fine	5	7
Sand, light-gray, silty	25	32
Sand, light-tan, very fine	5	37
Sand, light-gray, very fine	35	72
Sand, light-brown, very fine, silty	30	102

No. 24, 146-53-21bcc

Topsoil, black, sandy	2	2
Sand, light-tan, fine, silty	5	7
Sand, light-gray, fine to very fine	10	17
Sand, light-gray, very fine, silty and clayey	65	82
Clay, light-gray, silty and sandy	20	102

No. 25, 146-53-28bbb

Topsoil, black, sandy	2	2
Sand, light-tan, fine to very fine	10	12
Sand, light-gray, clayey	10	22
Sand, light-gray, fine	30	52
Sand, light-gray, very fine, clayey	10	62
Sand, light-gray, fine	30	92
Till, sandy and gravelly clay	10	102

No. 26, 147-53-35ada2

Topsoil, black, sandy	2	2
Sand, brown, fine, silty and clayey	25	27
Sand and shale gravel, fine and clayey	10	37
Shale sand and gravel, clayey	30	67

No. 27, 147-53-35aad

Sand, light-brown, very fine, silty	12	12
Sand, light-brown, fine to coarse	15	27
Sand, light-gray, fine to coarse, and shale pebbles	10	37
Clay, gray, sandy	10	47
Shale sand, coarse, clayey	5	52

No. 27, 147-53-35aad (continued)

Material	Thickness (feet)	Depth (feet)
Shale gravel, fine, clayey	15	67
Clay, silty, sandy	10	77
Shale sand, coarse, clayey	15	92

No. 30, 146-53-8aaa

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy	2	2
Sand, light-tan, very fine, silty	30	32
Clay, light-gray	5	37

No. 31, 146-53-5dcc

Material	Thickness (feet)	Depth (feet)
Topsoil, black, gravelly	2	2
Sand, light-tan, fine to medium	5	7
Sand, tan to gray, very fine to fine	25	32
Clay, olive-gray	5	37

No. 32, 146-53-7aaa

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy	2	2
Sand, tan to gray, very fine to fine	20	22
Sand, light-tan, very fine, clayey	20	42
Clay, light-gray, silty	5	47

No. 33, 146-53-7baa

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy	2	2
Sand, tan, fine; contains some calcareous cement	5	7
Sand, light-brown, fine	5	12
Sand, grayish-tan, very fine to fine	5	17
Sand, gray, very fine, clayey	10	27
Silt and very fine sand, gray	20	47
Clay, light-gray, silty, compact	5	52

No. 36, 146-54-1ddd

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy	2	2
Sand, grayish-tan, very fine to fine	5	7
Sand, tan, very fine, clayey	5	12
Silt, gray to tan, fine sandy	10	22
Clay, gray, compact	5	27

No. 37, 146-54-1dcc

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy........................	2	2
Clay, yellow.................................	5	7
Sand, light-tan, fine to coarse, clayey.......	5	12
Sand and clay, interbedded...................	5	17
Clay, gray...................................	5	22

No. 38, 146-54-12bbb

Material	Thickness (feet)	Depth (feet)
Topsoil, black, sandy........................	2	2
Sand, grayish-tan, very fine to fine..........	25	27
Sand, very fine, silty.......................	20	47
Clay, light-gray, silty......................	15	62

No. 39, 147-53-27dad1

Material	Thickness (feet)	Depth (feet)
Topsoil, brown, sandy........................	2	2
Sand, grayish-brown, very fine................	10	12

No. 40, 147-53-26cad

Material	Thickness (feet)	Depth (feet)
Topsoil, brown, sandy........................	2	2
Silt, gray, clayey, sandy....................	5	7
Sand, fine to coarse, clayey, fresh-water shells..................................	5	12
Silt and clay, sandy, small snail shells......	5	17
Sand and gravel..............................	10	27
Sand, coarse, clayey.........................	5	32
Till, gray, clayey and gravelly silt..........	5	37

No. 41, 147-53-36cbb

Material	Thickness (feet)	Depth (feet)
Topsoil, grayish-brown, silty................	2	2
Clay, brown, silty...........................	15	17
Sand, coarse, silty with fresh-water shells...	5	22
Silt and clay, gray, gravelly................	15	37
Till, gray, clayey and gravelly silt..........	5	42

No. 42, 147-53-27dad2

Material	Thickness (feet)	Depth (feet)
Topsoil, brown...............................	2	2
Clay, brown, silty...........................	10	12
Clay, gray, sandy............................	5	17
Sand, coarse, clayey.........................	10	27
Till, gray, clayey and gravelly silt..........	10	37

No. 43, 147-53-27daa

Material	Thickness (feet)	Depth (feet)
Topsoil, brown, sandy	3	3
Sand, tan, very fine, clayey	4	7
Clay, buff, silty, sandy	10	17
Gravel and sand,	5	22
Till, gray, gravelly and silty clay	5	27

No. 44, 147-53-36caa

Material	Thickness (feet)	Depth (feet)
Topsoil, light-brown, sandy	2	2
Clay, buff, silty	15	17
Till, buff, gravelly clay	9	26
Sand and fine gravel	1	27
Till, gray, gravelly clay	10	37

No. 45, 147-53-36acc

Material	Thickness (feet)	Depth (feet)
Topsoil, brown, silty	2	2
Clay, grayish-tan, silty, compact	15	17
Clay, gray, silty, fresh-water shells	10	27
Till, gray, gravelly, silty clay	15	42

82833 Interior - Duplicating Section, Washington, D. C.