PROGRESS REPORT NUMBER TWENTY

STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GERALD E. EDDY, DIRECTOR

GEOLOGICAL SURVEY DIVISION
WILLIAM L. DAOUST, STATE GEOLOGIST

SUMMARY OF GROUND-WATER INVESTIGATIONS IN THE HOLLAND AREA, MICHIGAN

BY

MORRIS DEUTSCH, E. M. BURT, AND K. E. VANLIER

PREPARED COOPERATIVELY BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
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ABSTRACT

Ground water in the Holland area is contained in consolidated rocks of Paleozoic age and in unconsolidated glacial deposits which mantle the consolidated rocks in most of the area.

In the northeastern part of the area the Marshall formation yields small amounts of potable water. Ground water in other consolidated rocks is too highly mineralized for human consumption.

The glacial-drift aquifers, which are the chief sources of ground water in the area, consist of two major types of material: shallow outwash which is included in, and interbedded with, sandy and clayey lake deposits; and buried outwash which fills valleys cut into the Paleozoic formations in preglacial time. These deposits were the only sources of water used by the city of Holland during the period 1883 through 1956. Prior to 1921, only the shallow outwash was used as a source of municipal supply, and it is still the source of water for many domestic and industrial wells. In the period 1921 to 1956, most of the Holland municipal supply came from buried outwash aquifer of the East Channel which underlies the area east of Holland. Another buried channel filled with outwash deposits (aquifer of the South Channel) underlies the southeastern part of the area, but water from this aquifer is too highly mineralized for most uses. It has been difficult to obtain even small supplies of good quality water from parts of the area underlain by the South Channel.

Water from the shallow outwash aquifers is generally of good chemical quality, although these deposits are subject to contamination from sewers and surface sources. Prior to extensive development, the water produced from the aquifer of the East Channel was similar in chemical quality to the water in the shallow outwash. As water levels declined in response to pumping, the mineral content of the water increased. This increase probably represents migration of water from the Coldwater shale.

Because it was doubtful that the aquifers of the Holland area would yield water of good quality in sufficient quantity for anticipated demands, the city of Holland decided to utilize the water of nearby Lake Michigan.

INTRODUCTION

Purpose and Scope of Investigation

During the latter part of World War II the city of Holland was confronted with the problem of obtaining new sources of ground water. The need arose in part because the city questioned the adequacy of available ground-water sources to meet increasing demands, and in part because of potential health hazards arising from sewer systems constructed in areas of expanding domestic and commercial development.

As part of the statewide study of ground-water resources, the U. S. Geological Survey made an investigation of the ground-water resources of the Holland area in cooperation with the Michigan Department of Conservation, the Michigan Water Resources Commission, and the Holland Department of Public Works. The purpose of the study was to add to existing knowledge of ground-water conditions in the area through collection and compilation of readily available information on the source, occurrence, availability, and chemical quality of the ground water of the area. As part of this study, the city of Holland conducted a program of test drilling to determine the limits of a sand-and-gravel aquifer, the so-called aquifer of the East Channel, known to exist along the east side of the city.

The present report makes available the data collected and interprets them.

Cooperative ground-water investigations by the U. S. Geological Survey in Michigan are directed jointly by P. E. LaMoreaux, Chief of the Ground-Water Branch of the Survey, Washington, D. C., and W. L. Daoust, State Geologist, Michigan Department of Conservation, Lansing, Mich., and are under the direct supervision of Morris Deutsch, who succeeded J. G. Ferris as district supervisor for the Federal Survey.

Previous Investigations

Leverett, in 1899 (p. 388-392) and Leverett and Taylor in 1915 (p. 22, 224-228) described the surface geology of the Holland area. In 1906, Bowman (p. 263-265) reported briefly on the water resources in Ottawa County and summarized the history of the public water system of the city of Holland. Riggs (1938) summarized the geology of Allegan County during the course of his study on the gas and oil resources of that county. Ferris (1952) prepared an informal summary report on the geology and hydrology of the Holland area. The present report contains most of the data in Ferris' summary and supersedes that work.

Records of water-level measurements in selected wells have been maintained by the city of Holland since 1914. A water-level measurement program in cooperation with the city of Holland was started in 1945. Records of the measurements made during the years 1945-55 have been published by the U. S. Geological Survey (table 3).

Historical Sketch of Municipal Water Developments

From 1883 to 1957 the city of Holland utilized ground-water sources exclusively for municipal supply. The city's first well field was located near the former Fifth Street powerplant. Wells in that field were dug or driven into shallow aquifers to depths of about 30 feet (table 5). This well field, referred to herein as the Fifth Street station (fig. 14), was abandoned in 1921.

The 19th Street station in the south-central part of the city was put into operation before the turn of the century. Originally it included one dug well and several groups of shallow drive-point wells.

The 21st Street station was established in 1912, but it was abandoned in 1915 because of the high iron content of the water. In 1917 the city installed shallow wells and a pumping plant at a new station on 28th Street.

During the summer of 1921, the development of the Eighth Street station, east of the city limits, was started with the installation of a gang of driven wells. The first successful large-capacity tubular well was installed at this station in 1922. The city obtained additional water during subsequent years by reconditioning old wells or constructing new wells at the 19th, 28th, and Eighth Street stations. A new station on Waverly Road was put into operation in 1949. Late in 1950 the 28th Street station was taken out of service.

A new well, referred to herein as Station 6, was drilled near the Black River in May 1954, to relieve an anticipated summer water shortage. In 1955 and 1956 two gangs of 50 shallow drive-point wells each were installed at the site of the 28th Street station and on 25th Street (fig. 14) for emergency supplies of water.

On February 17, 1957, all pumping of ground water by the city of Holland ceased when the new Lake Michigan system was put into operation on a trial basis. Pumping of ground water was resumed temporarily on March 16, but in April, the lake system was put into permanent operation and the well-field system was abandoned.

Well-Numbering System

The well-numbering system used in the report indicates the location of the wells within the rectangular subdivisions of the public lands, with reference to the Michigan meridian and base line. The first two segments of a well number designate the township and range; the third segment designates both the section and the well within the section. Thus, well 5N 15W 18-2 is well number 2 in section 18, Township 5 North, Range 15 West. On the well-location maps (figs. 6 and 7) it is necessary to plot only the serial number, since the complete number of the well is evident by its location. Numbers formerly assigned to some of the wells included in this report are listed in table 5.

Acknowledgments

Special thanks are extended to the following well drillers who supplied helpful information: the Broekhuis Bros. of Overisel, Hamilton Manufacturing and Supply Co. of Holland, Layne-Northern Co. of Lansing, C. S. Raymer of Grand Rapids, and Leo Riegler of Muskegon. Thanks are extended also to the Detroit office of the Raymond Concrete Pile Co. which furnished records of borings, and to the engineering firm of Williams and Works of Grand Rapids, who assisted the study by providing valuable geochemical information.

Additional valuable information was obtained from reports of consultants and from several manufacturing firms in Holland, as well as from various State and local government agencies.

GEOGRAPHY

Location and Extent of the Holland Area

The area covered by the present report consists of about 51 square miles in southwestern Michigan including the city of Holland and neighboring parts of Holland and Park Townships in Ottawa County and Fillmore and Laketown Townships in Allegan County (fig. 1). Rectangular in shape, the area extends eastward about 8½ miles from the shore of Lake Michigan and includes all of Lake Macatawa. On some maps, Lake Macatawa, the name used herein, is referred to as Black Lake.

The city of Holland is near the center of the report area, on the southeast shore of Lake Macatawa, at the mouth of the Black River, and extends southward to the Allegan County line.

Population and Economic Development

The population of the city of Holland according to the 1950 census was 15,858, or 7.9 percent more than in 1940. According to the latest estimate, the population in 1955 was 18,500, or a 16.7 percent gain over 1950. The growth of population in the city of Holland and environs is shown in table 1.

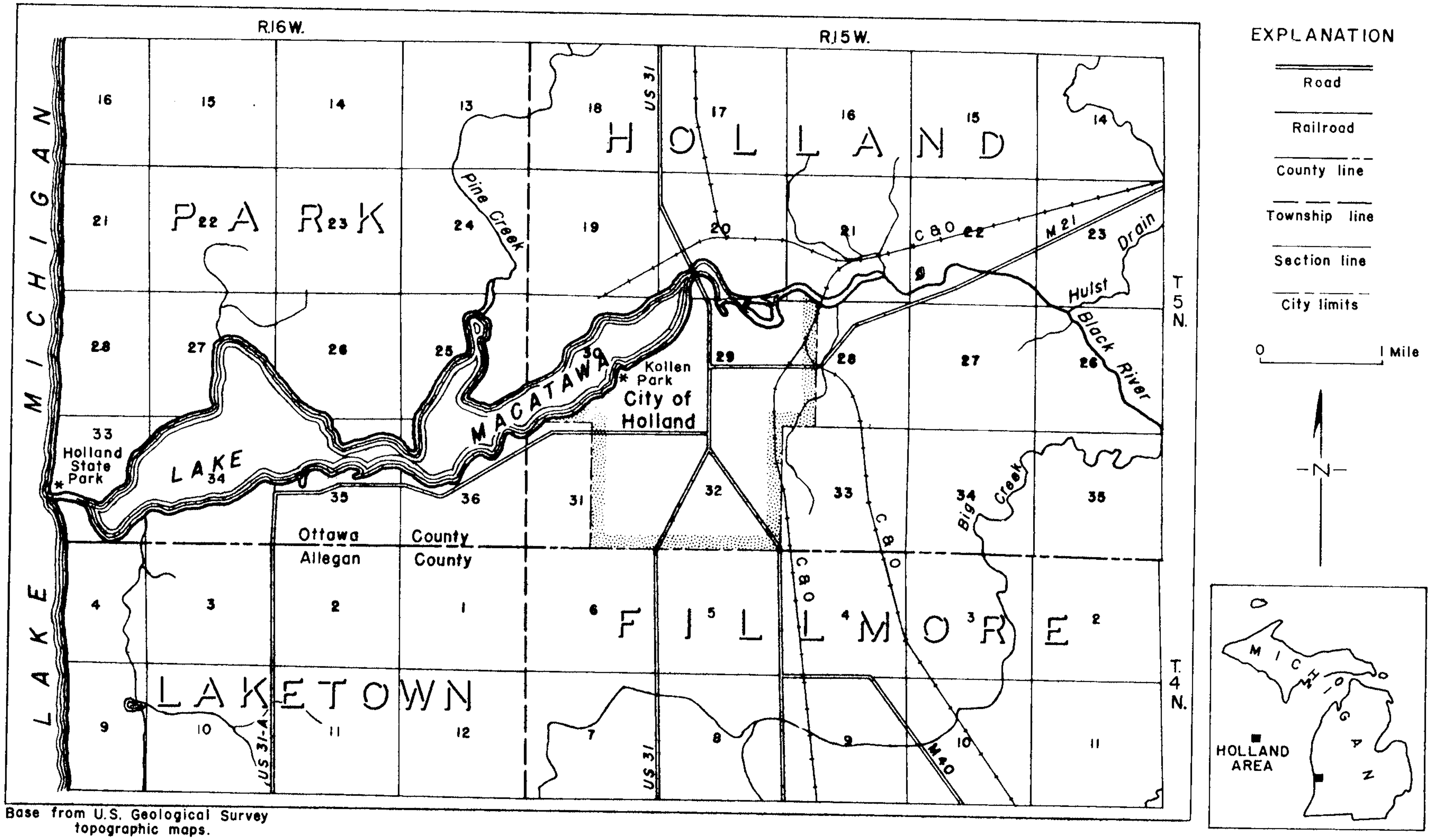


Figure 1. Index map showing location of the Holland area, Michigan.

Table 1.--Population of Holland and neighboring townships

Year	Ottawa County				Allegan County	
	City of Holland	Percent gain	Park Township	Holland Township	Laketown Township	Fillmore Township
1870	2,319	--	--	--	--	--
1880	2,620	13	--	--	--	--
1890	3,945	50.6	--	--	--	--
1900	7,790	97.5	--	--	--	--
1910	10,490	34.7	--	--	--	--
1920	12,183	16.1	--	--	--	--
1930	14,346	17.8	1,470	4,078	1,012	2,054
1940	14,616	1.9	1,974	4,913	1,075	2,309
1950	15,858	8.5	3,412	7,674	1,290	3,291
1955	18,500*	16.7	--	--	--	--

* Estimated by the Michigan Economic Development Department.

Holland is served by the Chesapeake and Ohio Railroad and is connected to other major cities by U. S. Highway 31 and State Highways M-40 and M-21. Port facilities for Great Lakes shipping as well as for small oceangoing vessels are provided through a 21-foot-deep channel into Lake Macatawa.

The industry of the area is diversified and in 1952 employed approximately 5,200 people. The agricultural land in the surrounding region produces a variety of specialized and general farm products. The area also enjoys a large tourist and resort business.

Physiography

The Holland area lies in a glaciated region formerly covered in part by the waters of the Glenwood, Calumet, and Toleston stages of ancient Lake Chicago (fig. 5). Beach deposits of these three major lake stages are at altitudes of about 80, 40, and 20 feet, respectively, above Lake Michigan level.

Figure I. Index map showing location of the Holland area, Michigan.

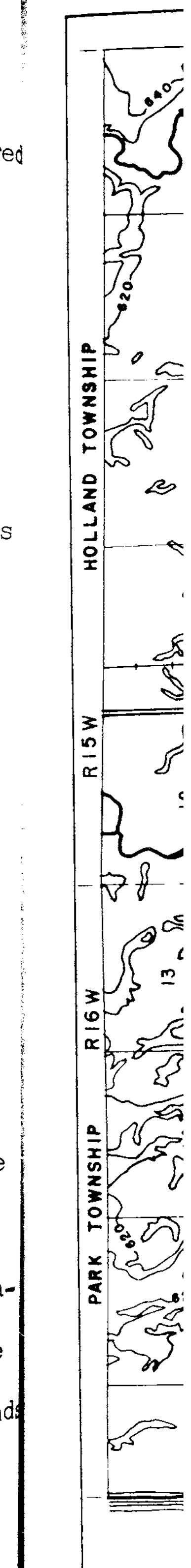
Lake Michigan is about 582 feet above mean sea level (fig. 2). Most of the Holland area is situated on the plains underlain by lake sediments deposited during the various stages of Lake Chicago. The lake plain north of the Black River and Lake Macatawa is of relatively low relief but is dotted with scattered low sand ridges which are remnants of dunes and beaches.

A complex of active sand dunes lies west of the lake plain along the Lake Michigan shore on both sides of the mouth of Lake Macatawa. The highest altitude in the Holland area, 805 feet above sea level, is that of one of the sand dunes.

Part of the Holland area is located on an upland composed of moraines of the Lake Border system (Leverett, 1915, p. 222). These moraines, which are the main physiographic features in the southeastern part of the area, were deposited by the Michigan lobe of the Wisconsin ice sheet. The moraines are separated by a narrow glacial till plain along the course of Big Creek. The moraines rise as much as 100 feet above the lake plain.

Part of the till plain and the lake plain along the Black River in the extreme eastern part of the report area are mantled by flat-lying outwash deposits and deltaic deposits of small relief.

Extensive marshes occupy the lowlands along the Black River from its mouth upstream to the Chesapeake and Ohio Railroad trestle, to which point Lake Macatawa extended several decades ago. This former part of the lake has been filled with fine alluvium deposited by the Black River and with decaying vegetation. From the edge of these riverside and lakeside lowlands, the land surface rises abruptly about 20 or 30 feet to an expanse of sandy lake plain that extends northward throughout Ottawa County and southward to the morainic hills at the south edge of the city of Holland.



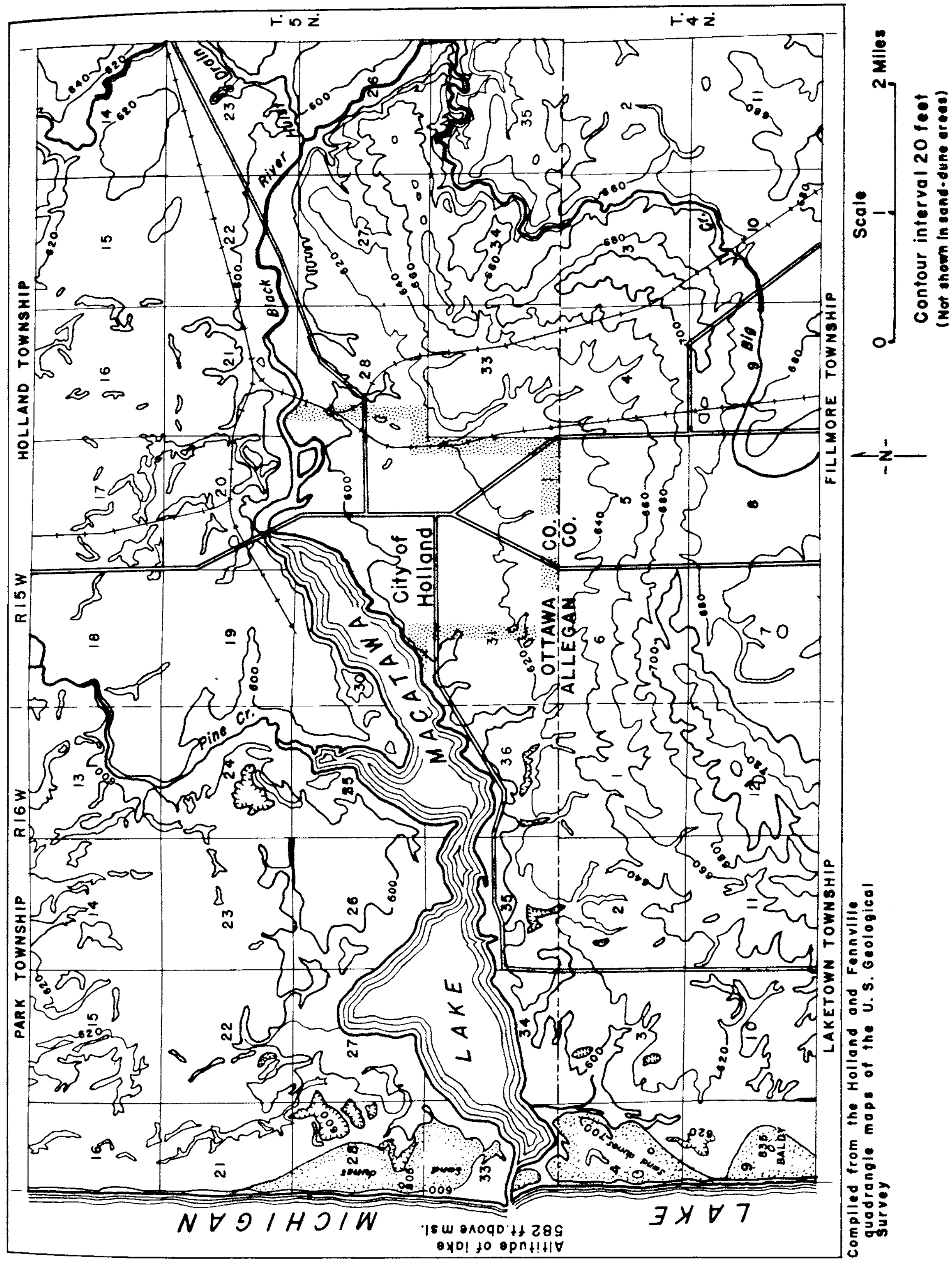


Figure 2. Topographic map of the Holland area.

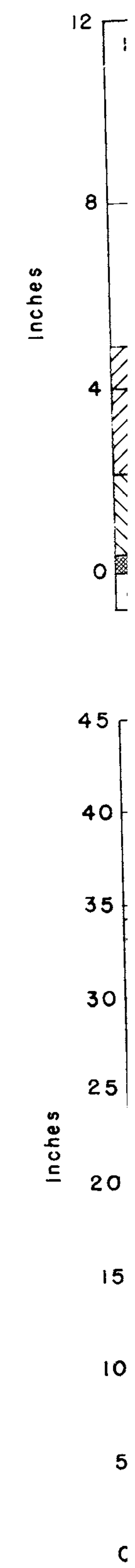
Drainage and Streamflow

The Holland area is drained by the Black River, Pine Creek, and a number of minor streams which empty into Lake Macatawa. The Hulst drain, Big Creek, and several small creeks are tributary to the Black River above Lake Macatawa within the report area. The drainage area of the Black River is estimated to be about 170 square miles.

On the basis of one discharge measurement of the Black River made during a period of low flow, flows during most of the year are fairly low as compared with other streams in the general area. When high flows occur, they are probably flashy. From correlations with other basins where records of streamflow are available, it is estimated that the minimum annual flow of the Black River does not exceed 10 cubic feet per second (cfs), and during the years of lowest flow it is probably less than 5 cfs. The mean flow is estimated to be about 60 cfs.

Climate

The average annual precipitation in the Holland area is about 33 inche and the mean annual air temperature is 48.6°F (fig. 3). The modifying influence of Lake Michigan tempers the climate of this area. The annual snowfall in the area probably compares to that of Grand Rapids, which averages 56.4 inches. The normal frost-free growing season lasts from May 10 to October 9. Prevailing winds are from the southwest.



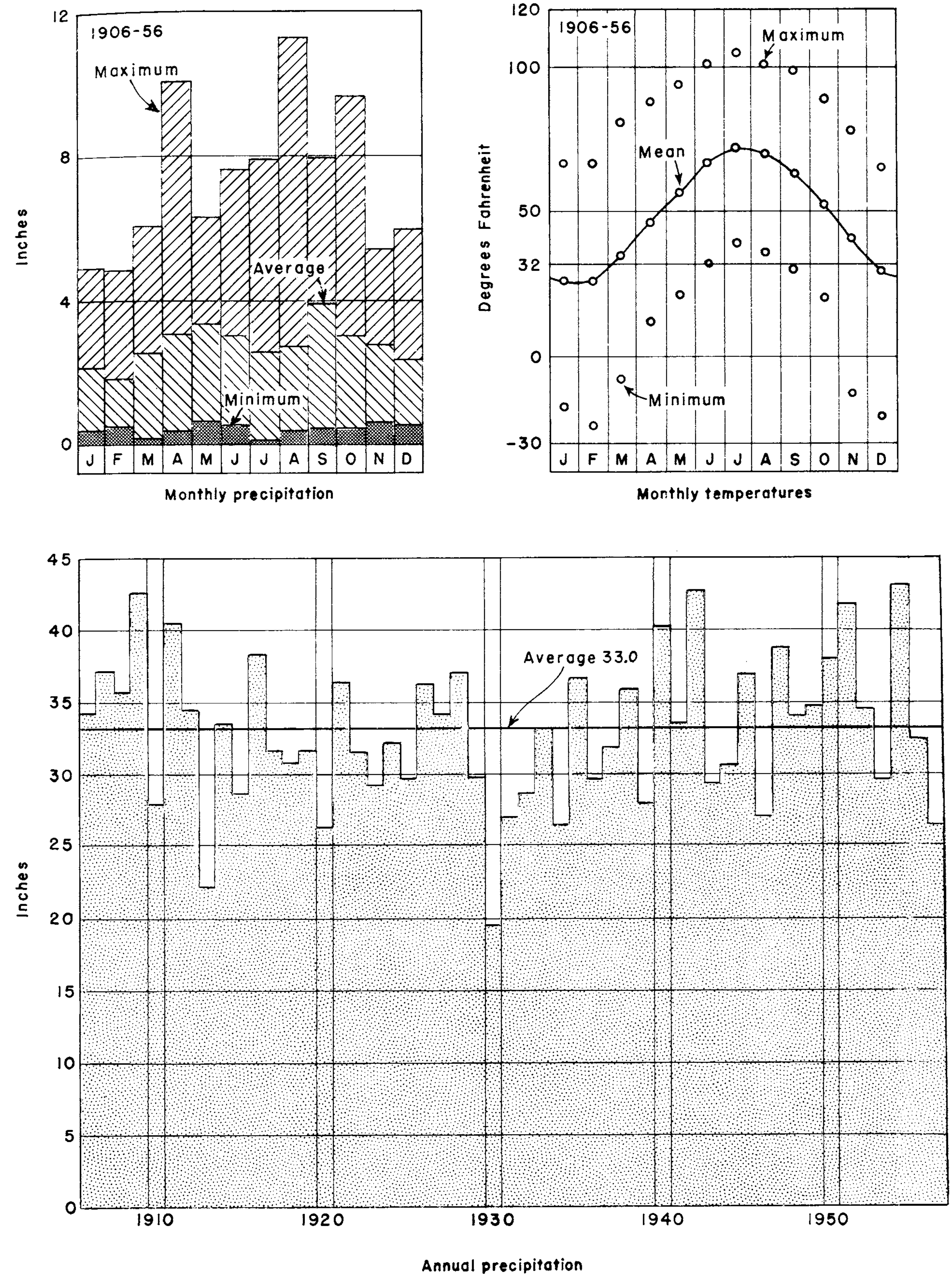


Figure 3. Precipitation and temperature records at Holland.

GEOLOGY

Summary of Geologic History

The consolidated rocks lying immediately below the glacial drift in the Holland area consist of strata of shale, sandstone, siltstone, and dolomite deposited in shallow seas which covered the Michigan Basin during the Mississippian period of the Paleozoic era. During the Mesozoic and most of the Cenozoic eras, Paleozoic sedimentary rocks in the Michigan Basin were subjected to erosion, which formed the preglacial bedrock topography. Several deep valleys cut into the bedrock surface in the Holland area during the long erosional interval were subsequently filled with Pleistocene glacial sediments.

In the Pleistocene epoch ice migrated into the Great Lakes region from the north during at least four major glacial stages. Many of the present surface features of the area are the result of deposition and erosion during the latest (Wisconsin) of the great continental ice sheets. The glacier scoured and abraded the surface, and transported and reworked vast amounts of rock material picked up during its advance. This glacial drift was redeposited over the bedrock surface, either as the ice moved or when it melted. Much of the drift in the Holland area consists of clay derived from shale of the underlying bedrock.

A large part of the Holland area was submerged beneath the waters of glacial Lake Chicago. This lake was formed during the period of recession of the Lake Michigan glacial lobe and is ancestral to the present Lake Michigan. The Glenwood, Calumet, and Toleston beaches mark successive stages of Lake Chicago. Fine sand and clay, as well as coarser outwash materials, were deposited in Lake Chicago. Outwash deposits along the Black River represent deltas formed where the river emptied into the lake.

Southwesterly winds during and after the glacial epoch formed the large sand dunes which now border the Lake Michigan shore.

Bedrock Structure

The Paleozoic sediments of the Michigan basin were deposited in nearly horizontal layers, but gradual subsidence and compaction of the beds, which was contemporaneous with deposition and was greatest in the center of the basin, produced a bowl-shaped structure or basin. The youngest rocks are exposed at the surface in the central part of this structure and the successively older formations crop out in roughly concentric bands around them. The Holland area is on the southwest flank of the basin, where Mississippian rock formations compose the bedrock surface. Older rocks of the southwest flank of the basin crop out under Lake Michigan and in eastern Wisconsin.

Anticlinal and related structures in the Holland area are the result of folding due to compressional forces from two directions (Riggs, 1938). Entrapment of petroleum within the area is controlled by these local alterations in the basin structure.

GROUND WATER

Principles and Occurrence

A water-bearing formation that yields water in usable quantities is termed an "aquifer". In areas underlain primarily by shale, clayey till, or fine-grained lake sediments, as in parts of the Holland area, ground water is difficult to obtain, and formations yielding several gallons a minute to wells may constitute important aquifers. Aquifers that yield only a few gallons a minute can be considered nonproductive in other parts of the Holland area where wells tapping deposits of permeable sand and gravel yield hundreds of gallons per minute.

The amount of water available to a well depends upon the regional and local geologic and hydrologic characteristics of the aquifer (table 2), the climatic conditions in the area, and the hydraulic properties of the soils and subsurface rocks in the recharge areas.

On the basis of water occurrence, aquifers may be classified as water table or artesian. In a water-table aquifer - for example, surficial sand and gravel deposits - ground water is unconfined and the water surface within the aquifer is termed the "water table". Water-table conditions prevail in the shallow drift deposits which cover much of the Holland area. The city of Holland derived its first public water supply from wells finished in these deposits. Many industrial and domestic wells tap this source of supply at the present time.

In an artesian aquifer, ground water in permeable strata is confined under pressure between relatively impermeable strata (strata through which water does not reaily move). The chief fresh-water artesian aquifer in the Holland

SYSTEM SERIES	FORMATION Thickness (feet)	LITHOLOGY	HYDROLOGY
PLEISTOCENE	GLACIAL DRIFT 0 to 400	MORAINAL DEPOSITS: Composed of glacial till, a heterogeneous mass of boulders, gravel, and sand embedded in a matrix of clay and silt. Lenses of permeable outwash are interbedded within the till.	Generally a poor source of water, but local outwash deposits within moraines will yield small to moderate quantities of water.
		TILL: Deposits similar in lithology to morainal till.	Same hydrologic characteristics as morainal deposits.
		OUTWASH DEPOSITS: Channel and deltaic deposits of well-sorted sand and gravel and some finer sediments.	Permeability moderate to high. Major source of ground water in the Holland area.
		LAKE DEPOSITS: Deposits of fine to medium sand and interbedded clay.	Generally of low permeability. Locally a source of small supplies of water. May yield moderate supplies where water can infiltrate from surface streams.
		DUNE SAND: Well-sorted windblown sand.	Permeable, but a poor source of ground water as most dunes are above the regional water table.
MISSISSIPPIAN	MARSHALL FORMATION 0 to 58	Greenish-gray to gray or buff dolomitic and fossiliferous sandstone, and dolomite.	Not important as a source of ground water because of limited thickness and extent within Holland area.
	COLDWATER SHALE 300 to 770	Blue-gray to green shale and thin interbeds of sandstone, siltstone, and dolomite.	Not a source of water supply in the Holland area. Water in the formation too highly mineralized for most uses.

area is composed of deposits of permeable sand and gravel that lies on a shale or clay base and is buried beneath clayey deposits of low permeability. Deep wells at the Eighth Street and Waverly Road stations tap these coarse sediments.

Under natural conditions, the water in a well that is finished in an artesian aquifer and is tightly cased through the overlying confining bed will rise above the bottom of that bed. An artesian aquifer is at all times full of water, even during the time that water is being removed from it. Enough water had been pumped from the artesian aquifer at the Eighth Street and Waverly Road stations to draw the water level below the bottom of the overlying confining bed, thus temporarily creating water-table conditions. With abandonment of these stations, the water level will rise to and above the top of the aquifer and artesian conditions will recur.

The imaginary surface including all points to which water would rise in wells tapping an artesian aquifer is called the "piezometric surface". In topographically low areas, the piezometric surface may be higher than the land surface. Wells tapping artesian aquifers in these areas will flow at or above the land surface.

Ground Water in Consolidated Rocks

The Marshall formation of Mississippian age (fig. 4) is the only bedrock formation in the Holland area that is known to produce fresh water. Deeper rock formations are not potential sources of fresh water. All the water encountered by oil wells or tests drilled into the Coldwater shale and underlying rocks has been highly mineralized.

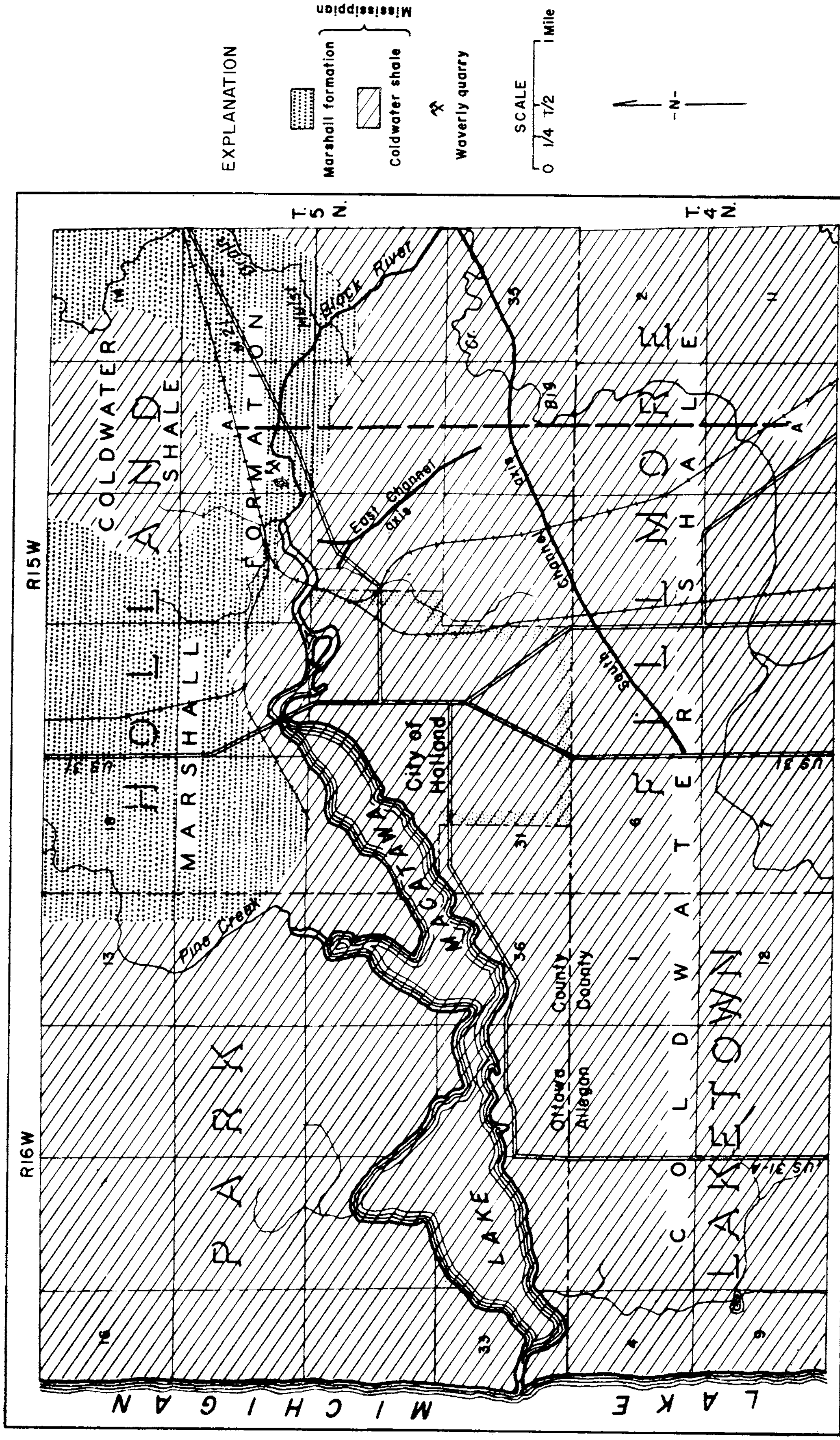


Figure 4. Bedrock geology of the Holland area.

Coldwater shale

The Coldwater shale directly underlies the glacial drift except in the northeastern part of the area, where it is overlain conformably by the Marshall formation. The Coldwater strata are reported (Newcombe, 1933, p. 54) to consist of blue to greenish-gray shale and subordinate thin, lenslike beds of dolomite, siltstone, and sandstone.

The Coldwater shale is widely distributed throughout the Southern Peninsula. In the Holland area it ranges in thickness from about 300 feet at places where valleys were eroded into the bedrock surface to about 700 feet where the entire section is present (areas where it is overlain by the Marshall formation).

Over much of the Holland area the glacial-lake clay or clayey till resembles the weathered Coldwater shale from which it was derived, and it is difficult to determine accurately the contact between the shale and the overlying glacial drift. Hence, the configuration of the buried surface of the Coldwater shale in the Holland area has not been accurately defined.

The stronger and more brittle dolomite and dolomitic sandstone of the Coldwater formation are broken by joint cracks through which ground water moves. Insofar as is known, all the ground water contained in the Coldwater in this area is too highly mineralized for most uses. Heavy pumping of water from overlying aquifers has induced upward migration of mineralized water from the Coldwater shale (see section on quality of water).

Figure 4. Bedrock geology of the Holland area.

Marshall formation

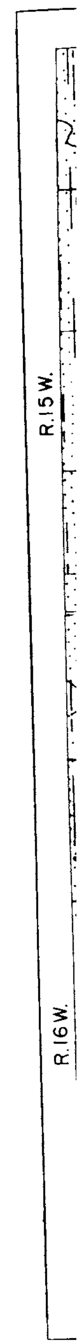
The Marshall formation is composed of two members; the lower referred to as the Marshall sandstone (Winchell, 1861, p. 80) and the upper as the Napoleon sandstone (Houghton, 1928, p. 100). The upper member was later designated the upper Marshall sandstone by Lane (1900, p. 18). The U. S. Geolo Survey recognizes an unnamed lower member and an upper Napoleon member. Roming (1876, p. 84) reported that beds of the Marshall formation exposed in the Waver quarry near the Black River (fig. 4) ranged from thin laminations to relatively thick regular ledges of "greenish...fine-grained, micaceous sand rock".

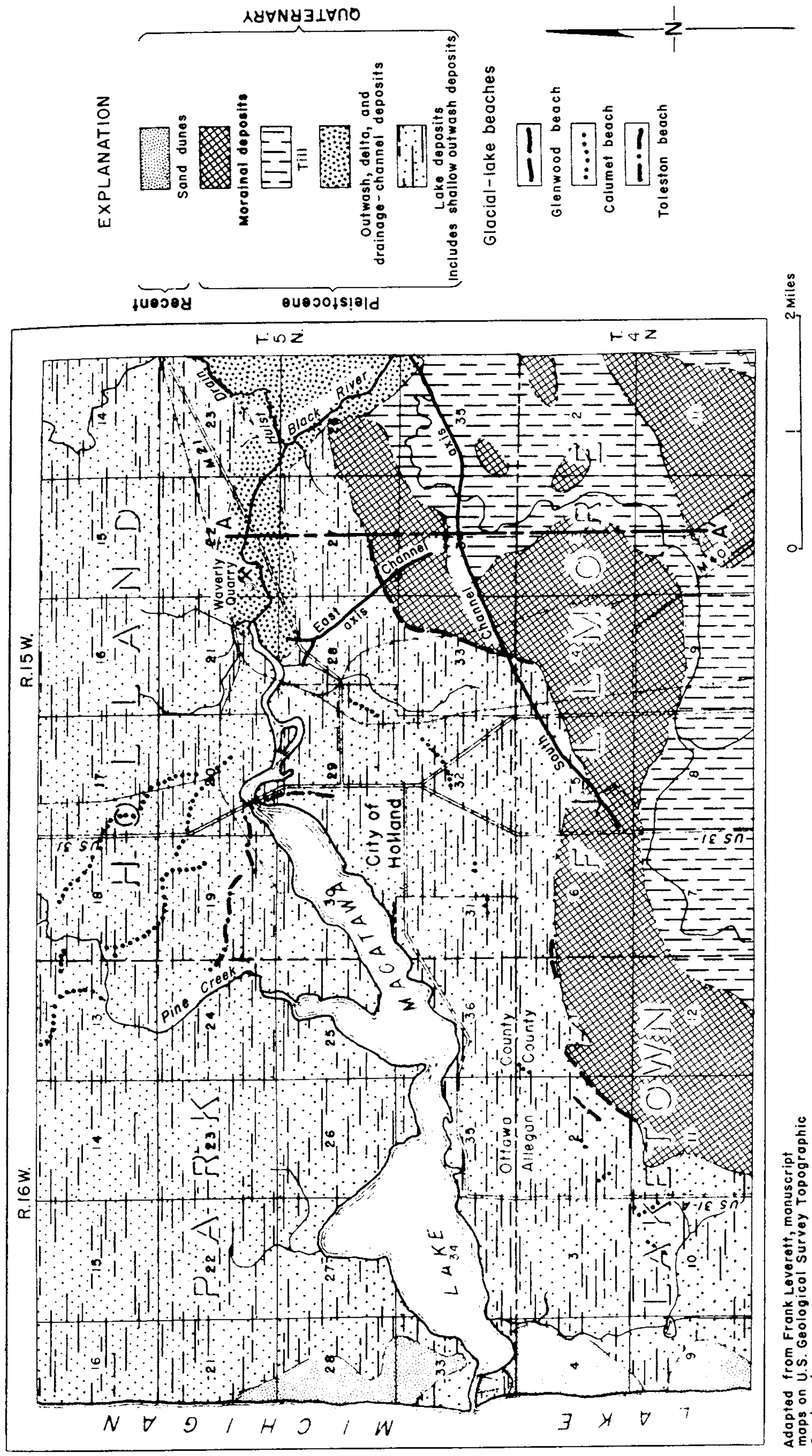
Only a small remnant of the lower strata of the Marshall formation is present within the Holland area, as most of the formation was removed by erosion in pre-Pleistocene time. The maximum reported thickness of this remnant is 58 feet, in oil-test well 5N 15W 19-30 (table 7). In adjacent areas, where the entire thickness is present, the formation is reported to be 260 feet thick.

Where the Marshall formation is present in the Holland area, it is a source of small supplies of potable water. However, the formation is thin, small in areal extent, and of low permeability. Thus, it has little potential as a source of industrial or municipal water supply.

Ground Water in Unconsolidated Sediments

Most of the potable ground water in the Holland area is in the unconsolidated sediments which mantle practically all the bedrock surface (fig. 5). These sediments are thin or discontinuous in the immediate vicinity of the Waverly quarry, where the Marshall formation crops out or is near the surface, but where the sediments occupy valleys cut into the bedrock they are more than





Adapted from Frank Leverett, manuscript maps on U.S. Geological Survey Topographic Quadrangles.

Figure 5. Map of the surficial deposits of the Holland area.

400 feet thick. These unconsolidated sediments, which collectively may be called "glacial drift", were deposited primarily by ice, melt-water streams, lakes, and wind action during the glacial epoch. A small portion of the sediments in the bottoms of valleys that were formed before the Pleistocene epoch may represent preglacial stream-deposited alluvium.

The permeability of the drift is determined primarily by the size of individual grains and the degree of sorting. The most permeable are the stream-laid outwash deposits of sand and gravel, which are composed of the larger particles of rock debris and are relatively well sorted. Dune sand, which is composed predominantly of relatively small but well-sorted particles, is moderat permeable. Clayey till deposited directly from the glacial ice and the silt and clay deposited in the waters of Lake Chicago are generally of low permeabili

Figure 5 shows the surface distribution of the glacial deposits, but as one type of glacial deposit may mantle other types, it does not necessarily indicate the presence of the same type of material throughout the drift section. Therefore, the map can be used only as a general aid in locating ground-water supplies.

Morainal deposits

Moraines are ridges composed of glacial till deposited along the edge or, as in this area, the relatively static front of a glacier. The till of the Holland area is a heterogeneous, unstratified, poorly sorted mass of boulder, cobble, gravel, and sand particles imbedded in a matrix of clay and silt. Altho the till may have appreciable water-storage capacity, it has relatively low permeability.

Locally, the morainal deposits include lenses of sorted materials which will furnish ground water in sufficient quantity for domestic supply. State Highway Department borings 4N 15W 4-3 to 12 (fig. 6, table 6) indicate the presence of a layer of medium sand 3 to 5 feet thick near the surface, and layers of sand 1 to 3 feet thick interbedded with clayey till at greater depths. Where these sand layers are below the water table they are possible sources of domestic water supply. In general, however, thick or extensive deposits of permeable drift have not been penetrated in wells drilled into the morainal deposits in the highlands that border Holland to the south and east. Locally, where deposits of permeable drift have been penetrated, they have yielded mineralized waters. Thus, there is little opportunity for the development of industrial or municipal wells in this area.

Till

Till plains (ground moraines) are areas of low relief underlain by glacial till deposited directly under moving or melting ice. The till deposits present in the southeastern part of the Holland area are similar in lithology to the morainal tills described above, and hence have similar hydrologic characteristics.

The log of well 5N 15W 34-12 (table 8) shows a layer of 7 feet of clean water-bearing sand and gravel beneath 65 feet of till. Clayey materials are present beneath the permeable zone to a depth of 287 feet, where another bed of permeable water-bearing sand was penetrated. The log of this well illustrates the fact that permeable materials may be present at depth even where clayey deposits of low permeability are present at the surface. It is probable, however, that the deeper permeable zones will yield water high in mineral content.

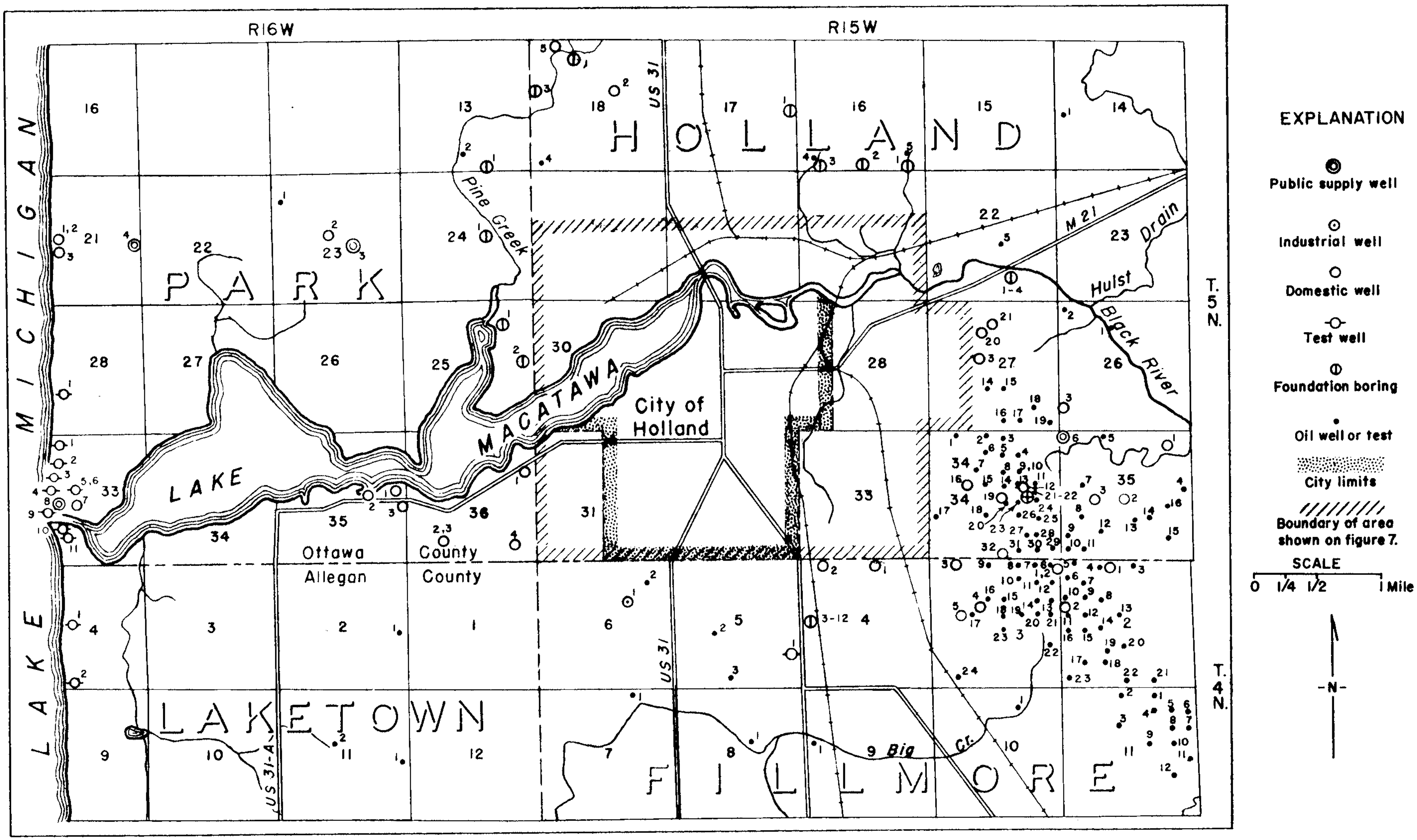


Figure 6. Location of wells, test holes, and borings in the Holland area. (Except those in the immediate area of the City of Holland. See fig. 7.)

Outwash deposits

The most important source of ground-water supplies in the Holland area is deposits of stratified, well-sorted sand and gravel-glacial outwash. The outwash was deposited by melt-water streams discharging from the glacial ice. Some of these outwash deposits filled deep valleys cut into the underlying Coldwater shale. Subsequent glaciation buried the channel fills beneath additional outwash, till, and lake deposits.

Shallow outwash.--Deposits of permeable glacial outwash are present at shallow depth in much of the report area. Some of this outwash was deposited as deltas in glacial Lake Chicago. It consists of permeable fine to coarse sand and some gravel. Figure 5 shows one area along the Black River where outwash deposited in glacial Lake Chicago is exposed at the surface. Elsewhere the shallow outwash is mantled by, and interbedded with, lake-deposited clay, silt, sand, and peat.

The shallow outwash deposits are included with the deposits underlying the lake plains shown on figure 5. Along the shore of Lake Macatawa and the Black River the outwash ranges in thickness from about 10 to 70 feet and probably averages less than 30 feet. The thickness of the section decreases to the south toward the morainal uplands.

The original water supply for the city of Holland was from wells finished in the shallow outwash at the Fifth Street station, at depths of less than 30 feet. Wells at the 19th Street station tapped an average thickness of 32 feet of shallow sand and gravel. Shallow outwash deposits were tapped also by wells at the 21st, 25th, and 28th Street stations. Numerous domestic and industrial wells in the area obtain water from the shallow outwash deposits (fig. 7, table 5).

Figure 6. Location of wells, test holes, and borings in the Holland area. (Except those in the immediate area of the City of Holland. See fig. 7.)

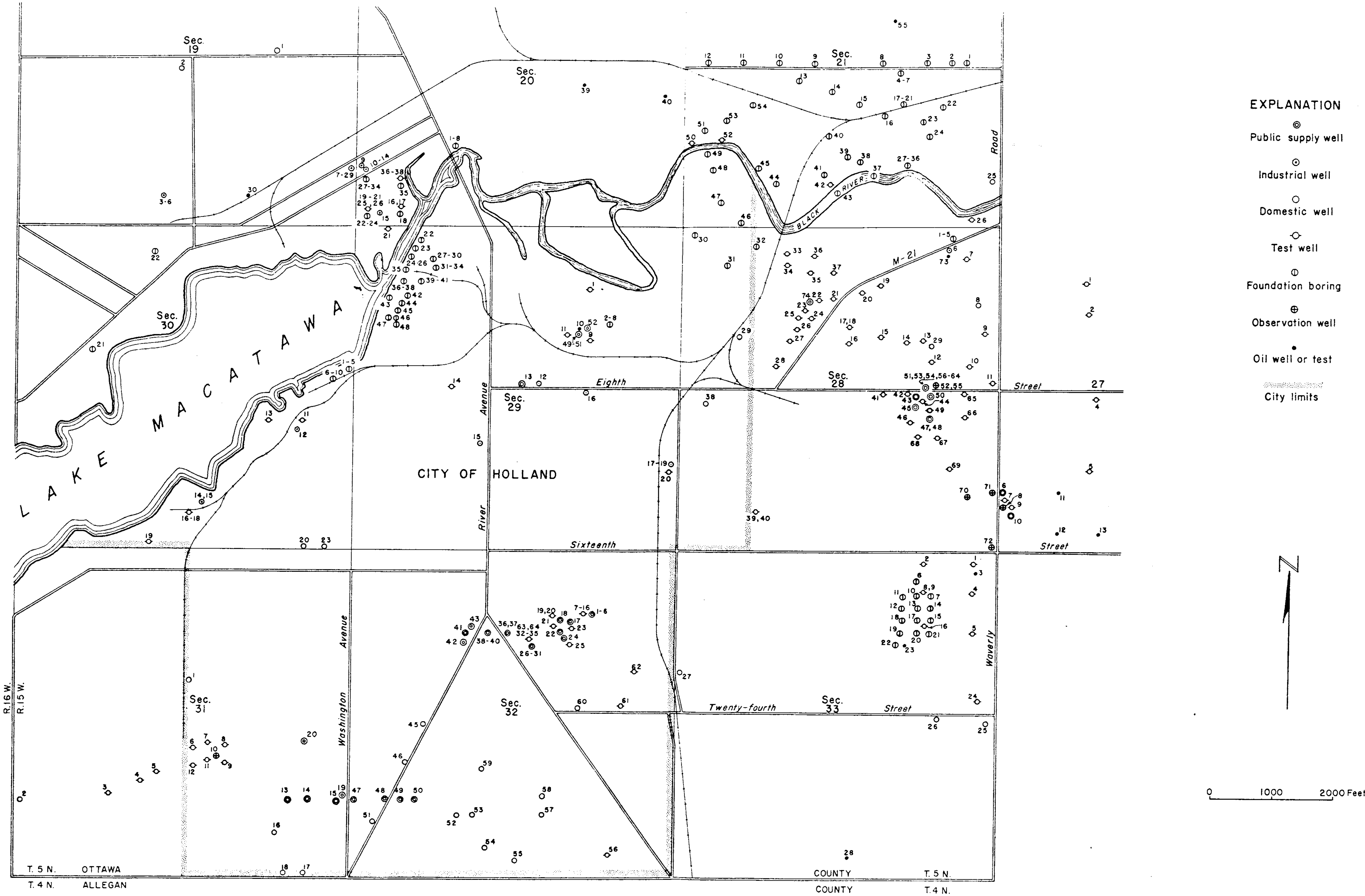


Figure 7. Location of wells, test holes, and borings in and adjacent to the city of Holland.

Studies were made by the city of Holland to determine the feasibility of utilizing infiltration galleries or collectors in the shallow outwash aquifers adjacent to the major bodies of surface water in the area. Construction of such facilities was never undertaken, as the city deemed it more advantageous to take water directly from Lake Michigan. However, the possibilities would be worth investigating if development of other large ground-water supplies were contemplated.

Buried outwash.--Two outwash deposits of appreciable thickness and high permeability occur at depth within the Holland area. These deposits of permeable glacial drift fill former drainage channels developed in the underlying Coldwater shale prior to the Pleistocene epoch. The deposits may include some preglacial alluvium.

One of these channels extended from a headwaters region east or northeast of Holland in a westerly direction into the city along the Ottawa-Allegan County line. For convenience, this channel is herein referred to as the "South Channel" (fig. 4). A generalized section through the South Channel, along A-A' of figure 4, is shown by figure 8.

Records of oil tests (table 7) indicate that 400 feet or more of glacial sediments were deposited in the South Channel, which bottoms at an altitude of about 200 feet above sea level. According to these records, the sediments that fill the South Channel range widely in lithology and, hence, in hydrologic characteristics. The more permeable zones within the channel fill probably can yield moderate to large supplies of water, but the water is reported to be too highly mineralized for most uses.

A second buried channel, referred to herein as the "East Channel", crosses the eastern limit of the city of Holland in a direction trending

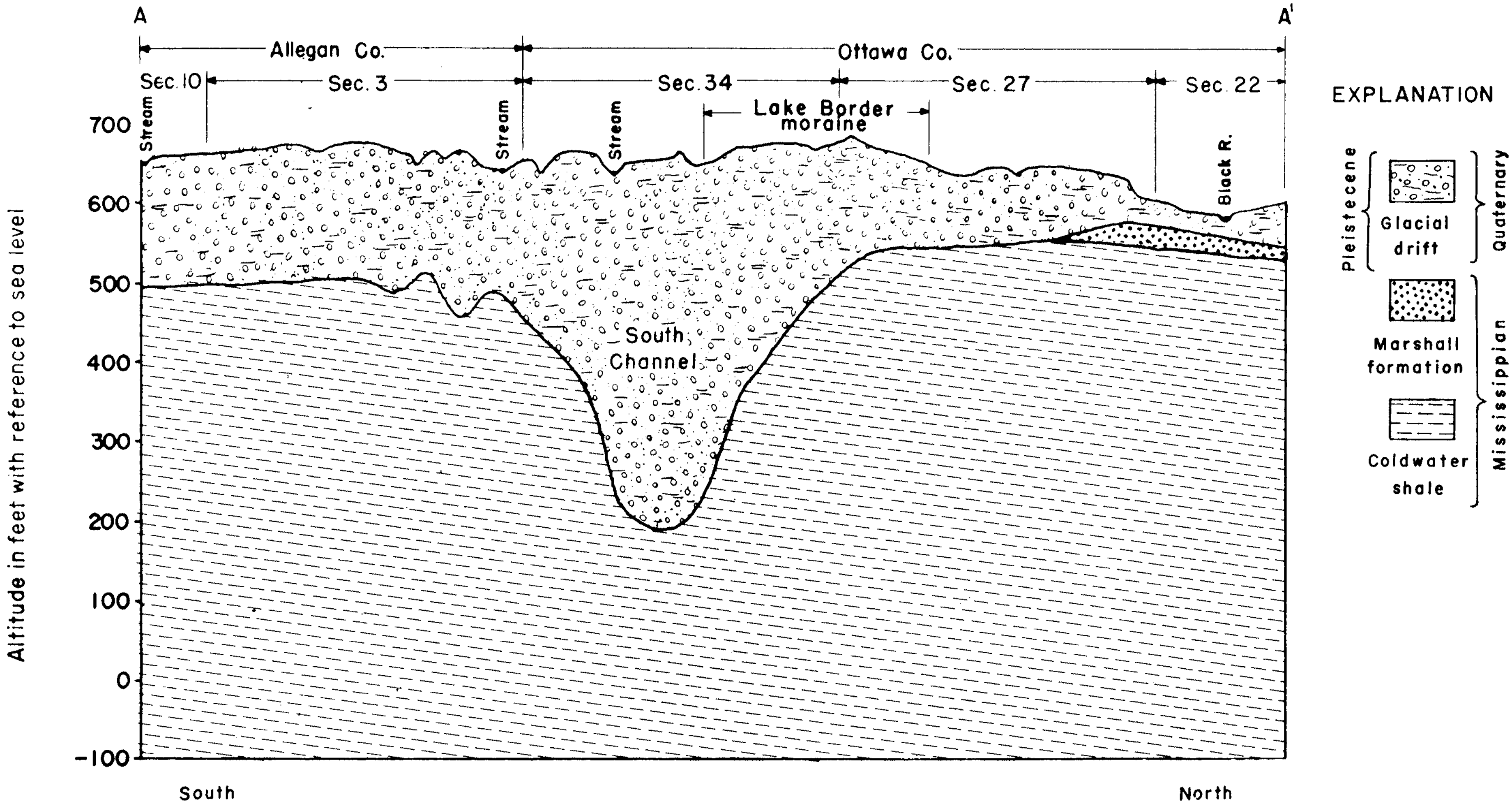


Figure 8. Geologic cross section through the aquifer of the South Channel along line A-A' shown on figures 4 and 5.

approximately southeast to northwest. The nature, extent, and thickness of deposits in this channel are fairly well defined as a result of test drilling in the vicinity of the Eighth Street and Waverly Road well stations, where water is pumped from the permeable sediments deposited in the channel. Drilling records indicate that the East Channel pinches out a short distance north of highway M-21, but they are too few to define accurately its southward extent. Geologic data, however, indicate that the East Channel crosses the fill of the deeper South Channel.

The reported depths to bedrock place the base of this channel about 460 feet above sea level, or about 260 feet higher than the base of the South Channel.

The permeable outwash in the East Channel consists of sand, gravel, and cobbles which attain an aggregate thickness of more than 100 feet (fig. 9). This aquifer is confined beneath layers of clay, silt, or clay till of low permeability. The confining layer ranges in thickness from about 20 feet at the Eighth Street station to about 70 feet at the Waverly Road station (fig. 10).

The sands and gravels of the East Channel were tapped for water supply for the first time in 1921 by wells at the Eighth Street station. In the years that followed, most of the additional development by the city of Holland for a municipal supply was made by adding wells at that station. Further development of the deposits of the East Channel was made when the Waverly Road station was put into operation in 1949.

<u>Glacial-lake sediments and beach deposits</u>

Stratified clay, silt, and fine sand were deposited in the waters of Lake Chicago which covered much of the Holland area during the glacial epoch. Sediments were deposited also along definable beaches (fig. 5) during the various

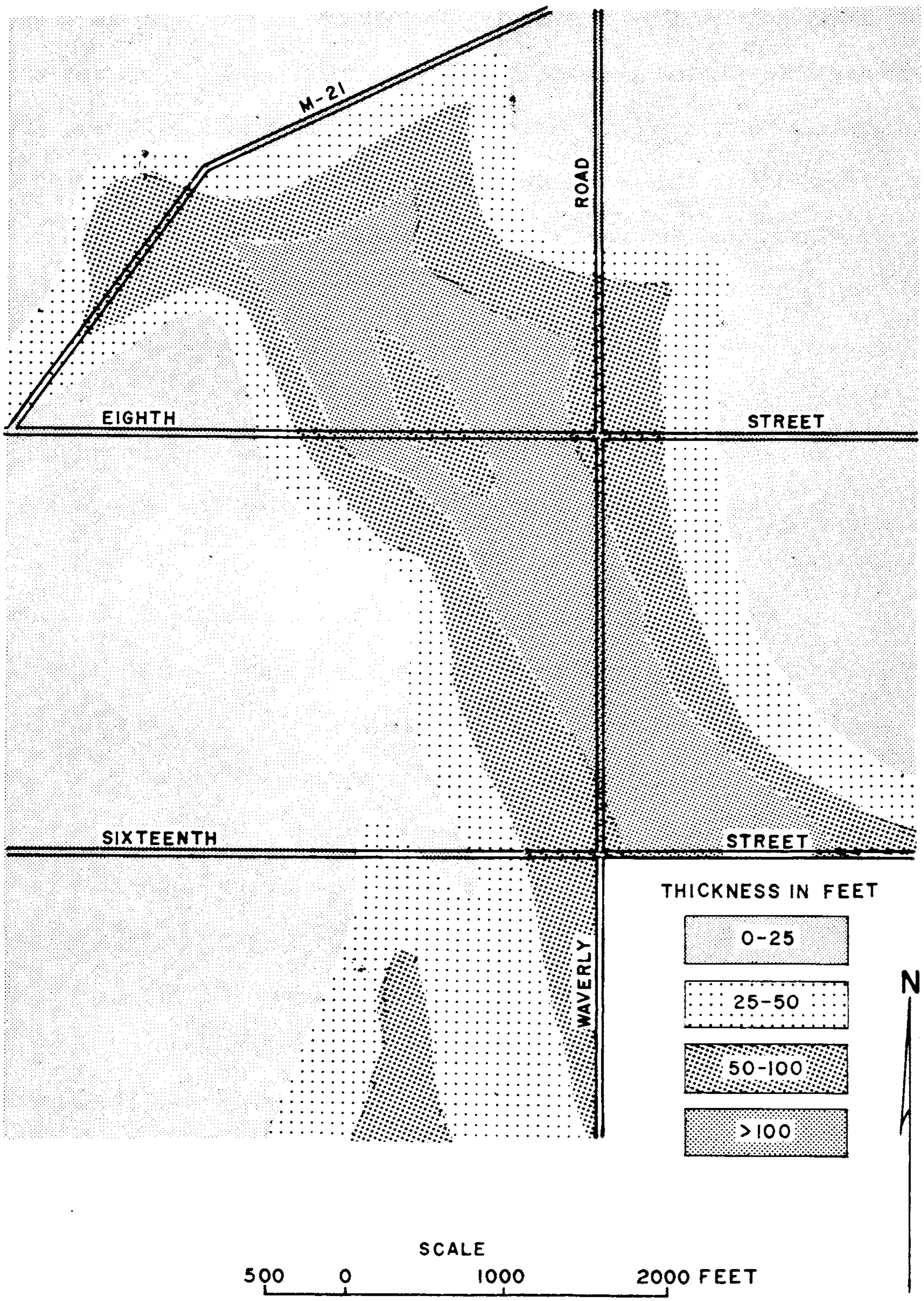


Figure 9. Isopachous map showing thickness of the permeable drift within the East Channel.

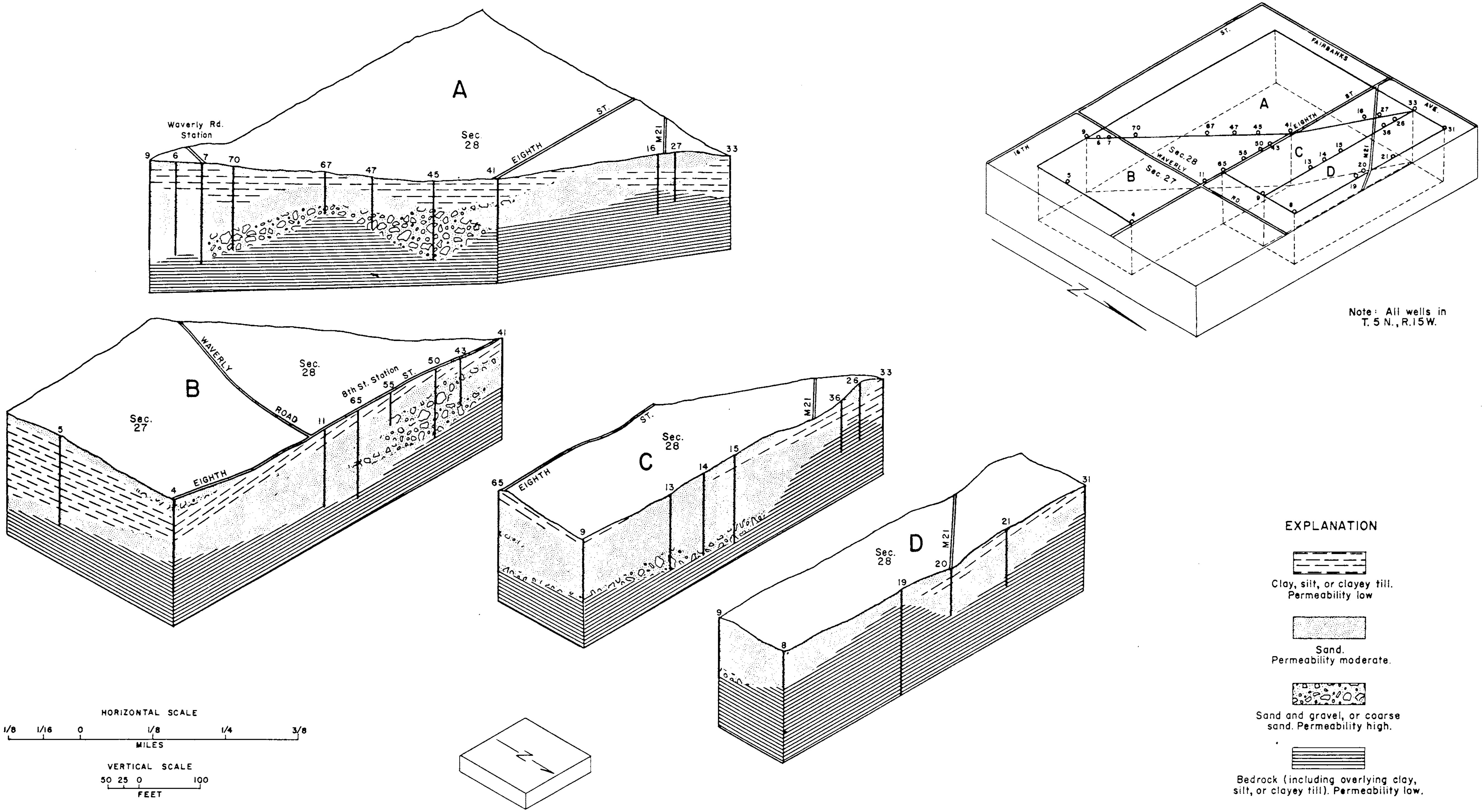


Figure 10. Schematic block diagrams showing geologic cross sections through the aquifer of the East Channel in the vicinity of the Eighth Street and Waverly Road pumping stations.

major stages of the lake. These sediments are of two major types: varved or finely laminated clayey lake deposits, and sandy deposits composed of medium to fine sand and silt.

The clayey lake deposits are of low permeability and are not a source of well water. Along with deposits of till, however, they act as the upper confining layer in the East Channel and South Channel artesian systems.

The sandy lake deposits, which mantle about three-quarters of the Holland area, are permeable and important as a source of ground water. It is difficult to distinguish between the sandy lake-deposited sediments and the shallow sandy outwash deposits. These two types of sediments are similar in physical character, are intimately interbedded or interfingered, and hence, for the purposes of this report, are treated as a single aquifer, which is described above in the section entitled "Shallow outwash".

Dune sand

Large sand dunes are prominent features along the Lake Michigan shore (fig. 5). The dunes are composed of windblown, and hence very well sorted, sand. Locally, the sand is still being moved by the prevailing southwesterly winds from Lake Michigan. Loose drifted sand, blown from these large dunes or reworked from beaches associated with Lake Chicago or from other glacial sediments, forms a thin, discontinuous mantle over the western part of the report area. These deposits are not delineated on figure 5. Locally, saturated zones in these deposits may yield small supplies of water to properly constructed shallow wells, but in general the dunes are a poor potential source of water because they lie above the water table. The permeable dune deposits have moderate infiltration capacity and, where a hydraulic connection exists between surface water and ground water, may yield moderate to large supplies of water to infiltration galleries or collectors.

Ground-Water Phase of the Hydrologic Cycle

Recharge

Precipitation, which averages about 33 inches per year, is the initial source of fresh ground water in the aquifers of the Holland area. Precipitation may recharge the ground-water reservoir by direct infiltration or, under certain conditions, by influent seepage from a running stream or other surface body of water.

Not all the precipitation falling on the Holland area enters the ground. Much is lost by evapotranspiration or by surface runoff. The amount of precipitation that does enter the aquifers is influenced by a number of factors, including the duration, intensity, and type of precipitation, the density and type of vegetation, the topography, and the porosity and permeability of the soil and underlying rocks, including those forming the aquifers.

Areas favorable for ground-water recharge are those underlain by appreciable thicknesses of permeable outwash, sandy lake deposits, or dune sand. Figure 5 may be used only as a general guide for the determination of such areas, for layers of lake-deposited clay of low permeability which materially impede infiltration are present at shallow depth in some places. The permeable but thin surficial deposits in such places are quickly saturated during a rainfall or period of thaw, and then water is lost by surface runoff. Soils in areas underlain by clayey till (areas mapped as morainal deposits and till on fig. 5) are rather impermeable and promote surface runoff, thus hindering recharge to the underlying aquifers.

The aquifers in the Holland area are fed in part also by ground-water underflow from adjacent areas, mainly on the north and east. Underflow from the south is blocked by the morainal till roughly along the Ottawa-Allegan County line

Movement and Discharge

The movement of water underground is similar to that in surface streams in that the water moves by gravity from high levels to lower levels. Ground water moves very slowly, however, because of the resistance to flow offered by the small openings through which it moves. Rates of ground-water movement range from a few feet per year to as much as several feet per day. Water may travel great distances underground from areas where recharge is received at the surface to areas downgradient where it may be pumped from wells, or, under natural conditions where it may once more reach the surface and join the flow of streams, appear as a seep or spring, enter a lake, or escape directly to the atmosphere by evaporation or transpiration.

Prior to intensive development of ground water in the Holland area, the ground water moved approximately in accordance with the topography. The principal directions of ground-water movement under natural conditions were northward from the morainal highlands and southward from the sandy lake plains. Most of the natural discharge of ground water is to the Black River and Lake Macatawa.

Under the original conditions, ground water in the East Channel moved along the axis of the channel (fig. 4) from southeast to northwest. Ground water confined in the basal gravel deposits escaped by slow upward percolation through the confining layer over an extensive area along the lowlands bordering Lake Macatawa, or by more rapid flow in places where the confining layer is absent and the shallow and deep aquifers are connected (fig. 10).

Pumping at the Eighth Street and Waverly Road stations has increased the northwestward gradient in the southeastern extension of the East Channel and has reversed the gradient in the northwestern extension of the channel. Abandonment of those well fields will result eventually in the restoration of the natural gradient and will increase the discharge to the Black River and Lake Macatawa to a rate comparable to that which existed prior to pumping in this area.

Water Levels

Ground-water levels in the parts of the shallow outwash that are not affected by pumping range from about the mean stage of Lake Macatawa and the Black River to more than 20 feet above. Water levels are highest at the north flank of the moraines in the southeastern part and along the northern boundary of the report area.

The hydrograph of well 5N 15W 31-10 (fig. 11), which is southwest of Holland, shows that water levels in the shallow outwash have remained fairly steady from the beginning of record in 1949 through 1955. The principal fluctuations have been those due to climatic influences. Although this aquifer is still being tapped by a number of domestic and industrial wells, declines in response to pumping from such wells are slight.

Ground water in buried outwash deposits of the East Channel generally occurs under artesian conditions. Reports of static water levels before pumping began at the Eighth Street station in 1921 indicate that at one time water from wells tapping the sand and gravel in this channel flowed at altitudes of as much as 20 feet above the normal stage of Lake Macatawa, which is at about the level of Lake Michigan.

During the period 1949-54 water levels in wells near the Waverly Road station declined at rates ranging from a few feet to more than 10 feet per year

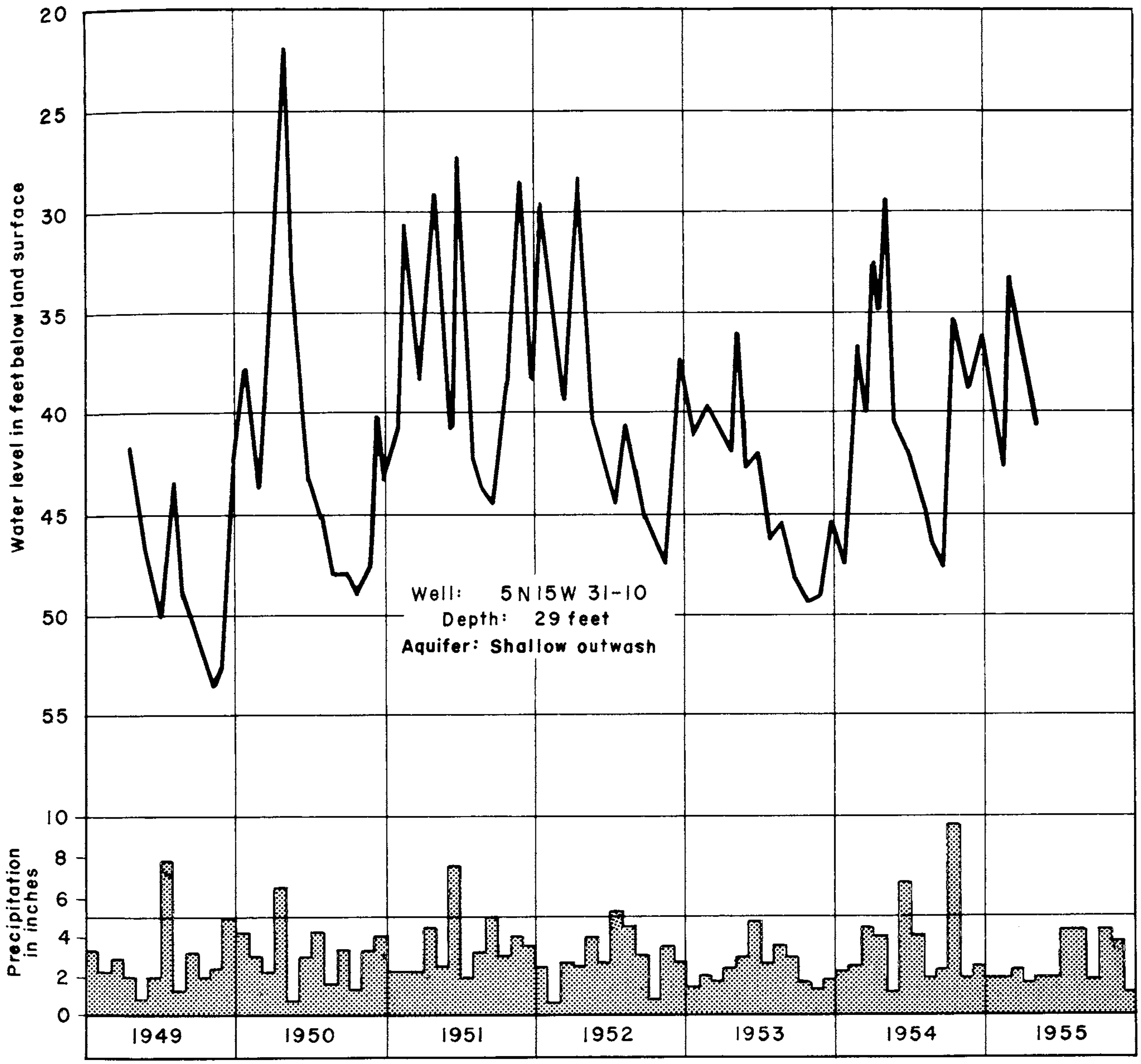


Figure 11. Hydrograph of well 5N 15W 31-10 and graph of total monthly precipitation at Holland, 1949-55.

(figs. 12 and 13). At the beginning of 1955, water levels in this vicinity were 100 feet or more below the land surface and were still declining. Figure 12 shows that the declines in water level occurred during a period of generally above-average precipitation. Water-level measurements were not made during most of the period 1955 through 1957, and the maximum decline prior to the discontinuance of ground-water pumping by the city of Holland, in April 1957, is not known. The decline of water levels in wells 5N 15W 27-8 (fig. 12) and 5N 15W 28-71 (fig. 13) correlated closely with the trend of cumulative pumpage at the Waverly Road station. Extrapolation of the hydrographic record indicates that water levels at the station may have declined as low as 114 feet below the land surface by February 1957, when the station was shut down for a month. By October 1957 the water levels had recovered to depths of about 95 to 100 feet below the land surface.

Water levels in the same aquifer in the vicinity of the Eighth Street station also declined, as indicated by the hydrograph of well 5N 15W 28-55 (fig. 12). However, the well was not sufficiently deep to record the lowest levels reached during the period of record.

The piezometric surface was not everywhere lowered, however. Water levels in well 5N 15W 34-22, about 1½ miles from the Eighth Street station and 1 mile from the Waverly Road station, were near or slightly above the land surface throughout the period of record.

Records of measurements made during the years 1945-55 have been published by the U. S. Geological Survey in the annual series of water-supply papers entitled "Water Levels and Artesian Pressures in Observation Wells in the United States". Table 3 gives the numbers of those papers containing water-level data for the Holland area.

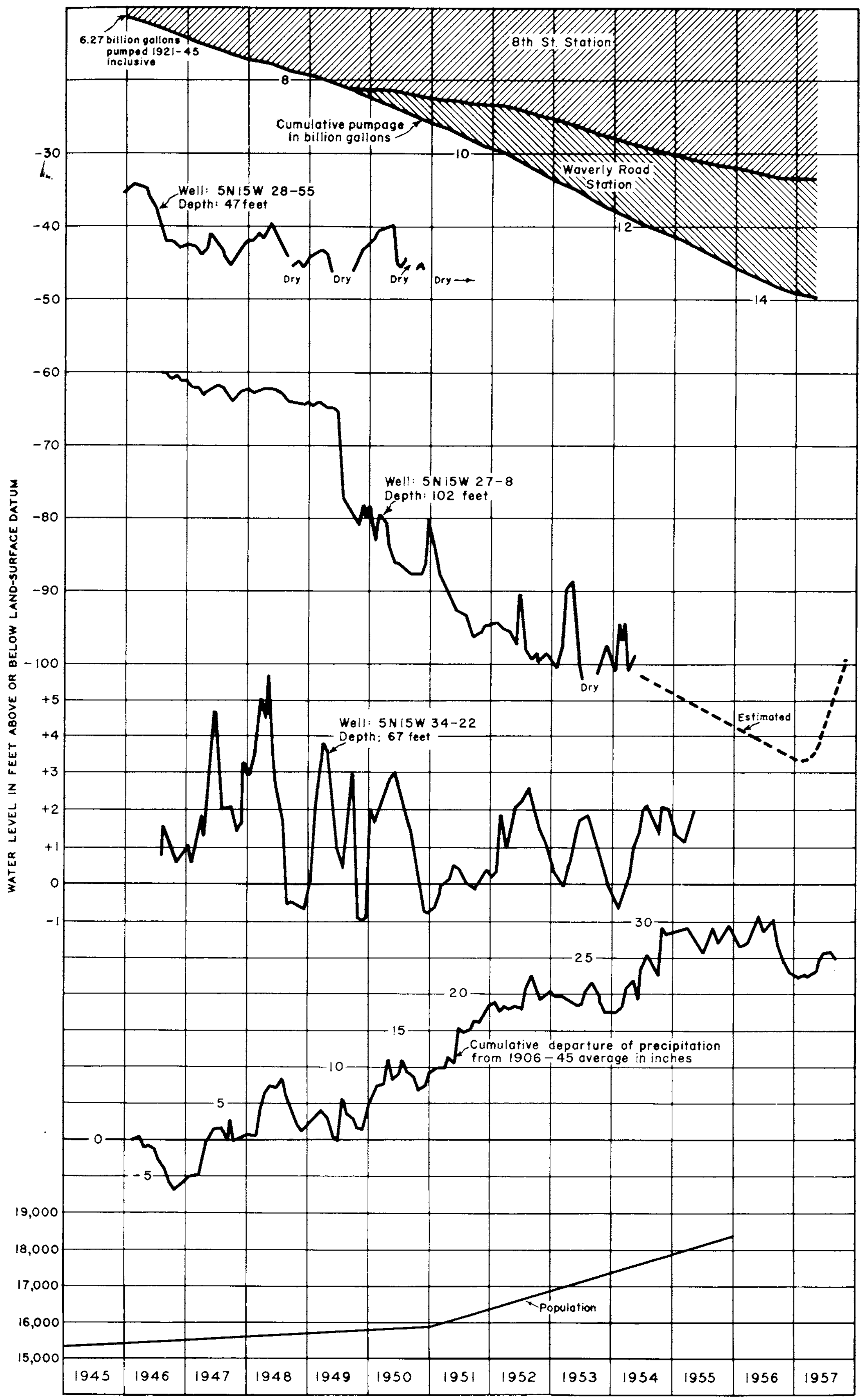


Figure 12. Hydrographs of wells tapping the aquifer of the East Channel, and graphs of cumulative pumpage at the Eighth Street and Waverly Road stations, cumulative precipitation departure, and population growth at Holland.

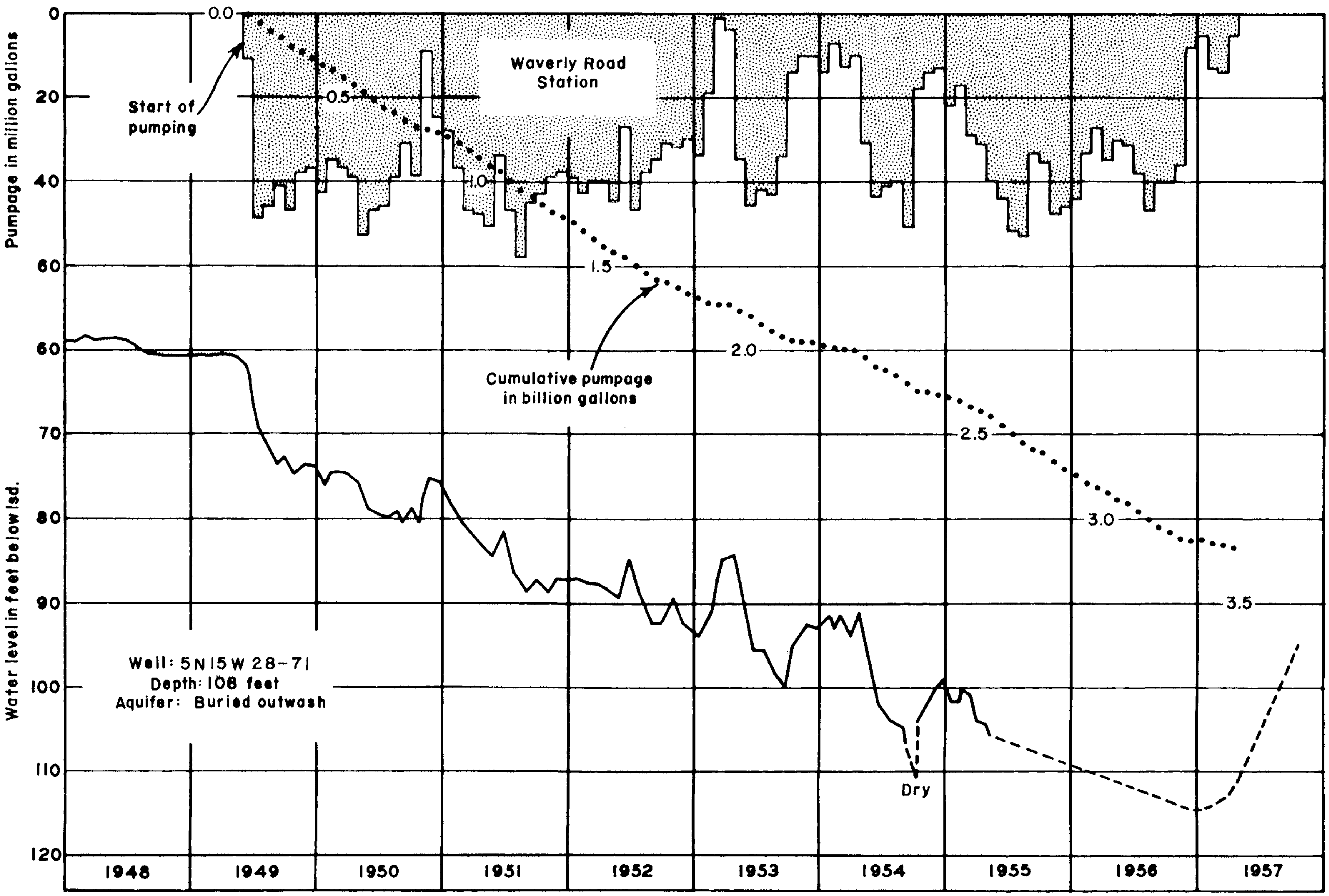


Figure 13. Hydrograph of well 5N 15W 28-71 and graphs of monthly and cumulative pumpage at the Waverly Road station

Table 3.--Water-supply papers containing water-level data for the Holland area.

Year	No.	Year	No.	Year	No.
1945	1023	1949	1156	1953	1265
1946	1071	1950	1165	1954	1321
1947	1096	1951	1191	1955	1404
1948	1226	1952	1221		

Pumpage

Shallow outwash was the source of all water pumped by the city of Holland from 1883 to 1921 (fig. 14). Pumpage for those years was from the Fifth, 19th, 21st, and 28th Street stations. It ranged from 66 million gallons in 1883 to 554 million gallons in 1911 (fig. 15) and averaged 170 million gallons annually. Beginning in 1912, all the water delivered to consumers was metered. As a result, pumpage declined to 310 million gallons in 1912. Average annual pumpage from 1912 through 1920 was about 305 million gallons.

In 1921, the aquifer of the East Channel was tapped for the first time at the station on Eighth Street. Pumpage at this station ranged from 25 million gallons in 1921 to a maximum of about 580 million gallons in 1947. In 1949, a second station whose wells tapped the same aquifer was put into operation on Waverly Road. By 1953, total pumpage at all stations reached 1 billion gallons annually. About 85 percent of this total was pumped from the aquifer of the East Channel. During that year the average withdrawal of water by municipal wells tapping the aquifer of the East Channel ranged from 1.3 million gallons per day (mgd) in January to 3.4 mgd in July and averaged 1.9 mgd. In the same period, an average of 0.42 mgd was pumped at the 19th Street station.

Figure 13. Hydrograph of well 5N 15W 28-71 and graphs of monthly and cumulative pumpage at the Waverly Road station

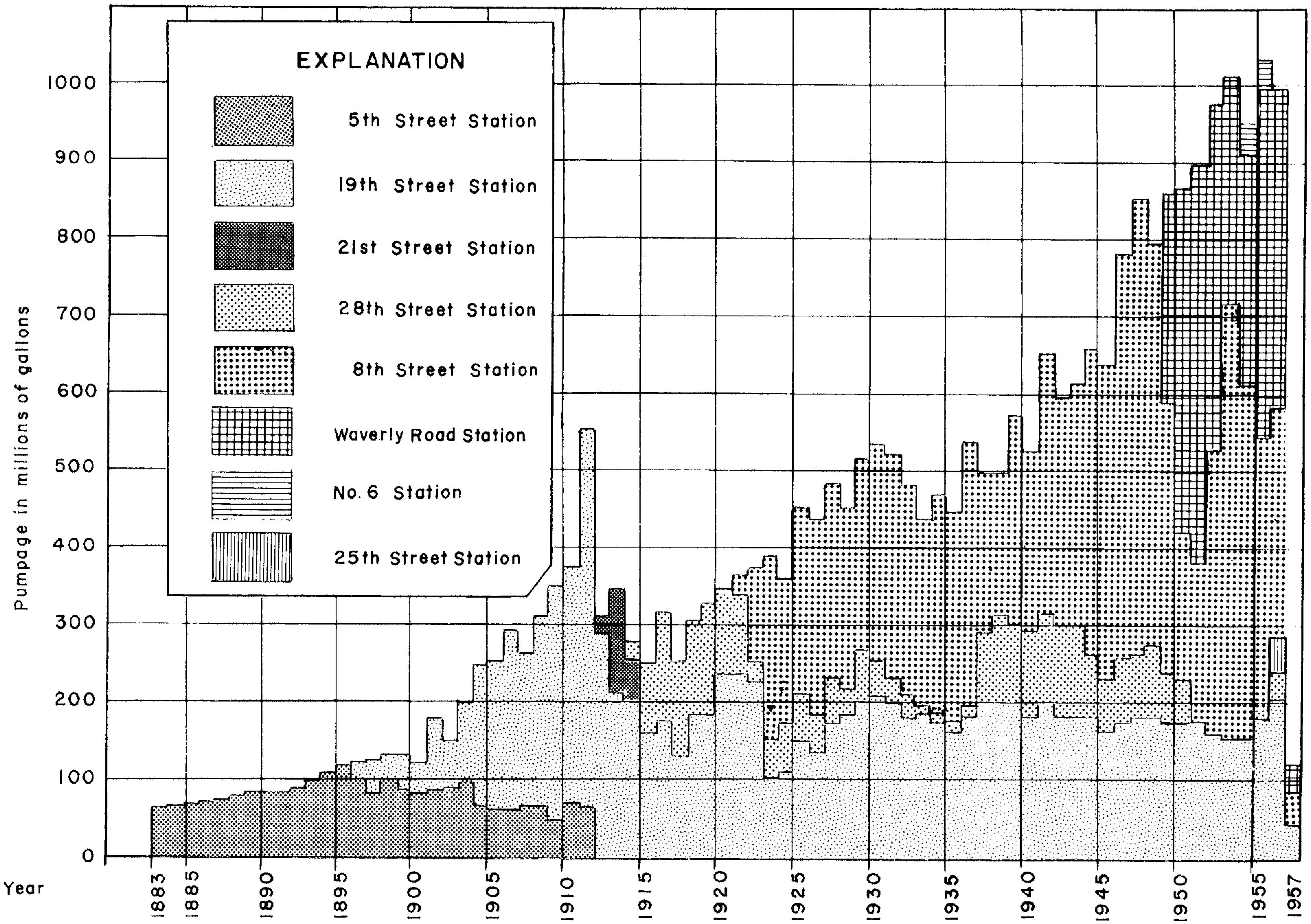


Figure 14. Annual pumpage by the city of Holland, 1883-1957.

Figure 14. Annual pumpage by the city of Holland, 1883-1957.

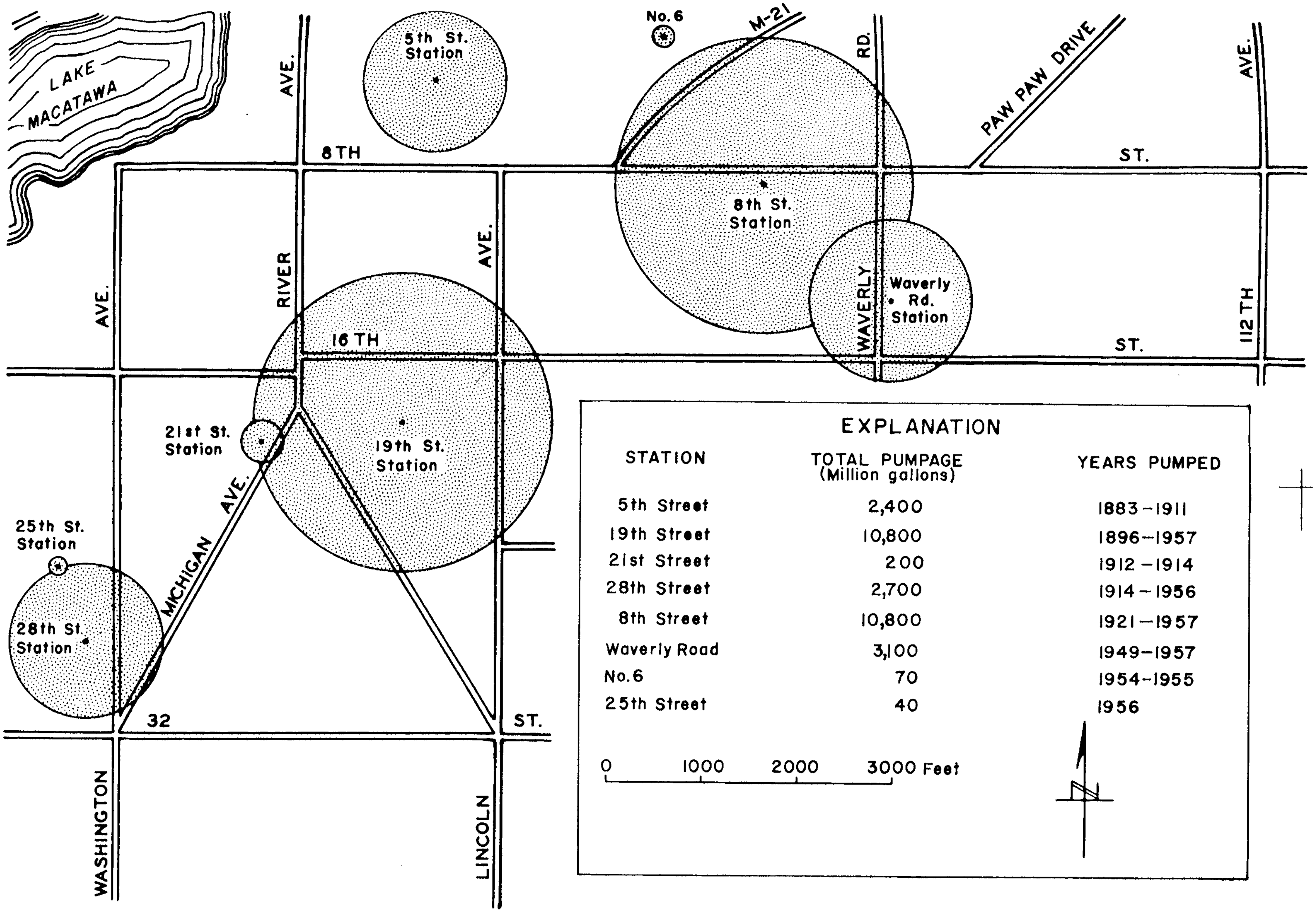


Figure 15. Distribution and magnitude of ground-water pumpage by stations in Holland, 1883-1957.

In 1954, an emergency supply well (station 6) installed north of the Eighth Street station pumped 37 million gallons from the East Channel aquifer. The following year a gang of 50 shallow drive-point wells installed on an emergency basis at the site of the 28th Street station yielded 9 million gallons from shallow outwash deposits. This station yielded 34 million gallons in 1956. A third emergency-supply system of 50 shallow drive-point wells tapping the same aquifer was installed on 25th Street in 1956, and yielded 42 million gallons that year. In 1957, about 125 million gallons of ground water had been pumped by all stations before the well system was finally abandoned following completion of the Lake Michigan intake facilities.

During the last 4 years of ground-water pumping by the city, about one billion gallons was pumped annually, compared to about 500 million gallons annually from 1935 to 1940, 250 million gallons in 1915, and 125 at the turn of the century. Although some of this increase in pumping may be attributed to growth in population, most of the increase is due to greater per capita consumption. Although the city's pumpage by the mid-1950's had increased eightfold over that at the turn of the century, the population had increased only from about 8,000 to 18,500 (table 1). These figures indicate that the per capita consumption of water for all purposes increased from about 45 gallons per day (gpd) in 1900 to about 150 gpd in 1955. It should be noted, however, that per capita consumption before metering increased to about 140 gpd by 1911, more than triple the rate in 1900.

Information concerning the amount of nonmunicipal pumpage from the many industrial and domestic wells in the area is not available. Most of these wells tap the various glacial-drift aquifers, although a few produce a small amount of water from the Marshall formation.

Pumping Tests

The most effective method of determining the amount of water available from an aquifer is analysis of records of pumping and of water levels. This type of data, which is presented above, is supplemented by results of a number of aquifer (pumping) tests made in the Holland area during the period 1945-57 to determine the hydraulic characteristics of the buried outwash aquifer.

Using methods devised by Theis (1935) and others, one can determine the hydraulic characteristics of an aquifer, which are commonly expressed as the coefficient of transmissibility (T) and the coefficient of storage (S). The tests consist of pumping one well at a constant rate for a short period of time and measuring in nearby observation wells the change in water levels caused by the pumping.

The coefficient of transmissibility is expressed as the number of gallons of water per day, at the prevailing water temperature, that will move through a vertical strip of the aquifer 1 foot wide and of a height equal to the full thickness of the aquifer, under a hydraulic gradient of 100 percent, or 1 foot per foot. The field coefficient of permeability (P_f) is equal to the transmissibility divided by the thickness (m) of the aquifer, in feet. 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 Theis nonequilibrium equation, which may be used to predict water-level changes from anticipated pumping rates, is as follows:

$$T = \frac{114.6\ Q\ W(u)}{s}$$

Where

T = coefficient of transmissibility, in gallons per day per foot

Q = rate of pumping, in gallons per minute

s = drawdown or recovery of water level, in feet

$W(u)$ = well function of u

or

$$W(u) = \int_{u}^{\infty} \frac{e^{-u}}{u} du$$

and $$u = \frac{1.87 r^2 S}{T t}$$

r = distance from pumping well, in feet

t = time since pumping started or stopped, in days

S = coefficient of storage

The formula is based on the assumption that the aquifer is infinite in extent, that it is homogeneous and isotropic (transmits water in all directions with equal facility), that its coefficients of transmissibility and storage are constant, that the water is under artesian conditions, and that the water is released from storage instantaneously with the decline in head. None of these assumptions are satisfied fully in nature, and often appropriate adjustments must be made in the formula. The presence of boundaries of the aquifer, leakage through the confining beds, and lowering of the water level below the upper confining bed are among the conditions that nullify the basic assumptions of the formula and therefore require adjustment.

The coefficients of transmissibility and storage obtained from the pumping tests in the aquifer of the East Channel are given in table 4. The computations were based on the assumption that the Theis formula could be applied without modification.

Table 4.--Hydraulic characteristics determined from pumping tests in the aquifer of the East Channel.

Date of test	Well pumped	Transmissibility T (gpd/ft)	Storage S	Saturated thickness m (ft)	Field permeability P_f (gpd/ft^2)
Dec. 11-15, 1945	5N 15W 28-45 28-47	94,000	0.21	90±	1,000
Jan. 28-Feb. 6, 1946	28-11	40,000	.10	90	440
April 1946	27-7	78,000	.16	100	800
Mar. 18, 1947	28-50	104,000	--	62±	1,700
June 6, 1947	27-6	82,000	.25	100±	800

The differences in transmissibility and permeability result from the differences in lithology and thickness of the aquifer at the various test sites. The relationship of transmissibility and permeability to lithology and thickness of the aquifer can be seen by comparing the values shown in table 4 with the lithology and thickness of the aquifers shown in figure 10.

The performance of a well or a well field is a function of the transmissibility and storage coefficients of the aquifer. If T and S are known, the short-term yield from a well or well field can be predicted, and the efficiency of individual wells and the proper well spacing can be computed. The long-term yield of a well or a well field can be determined if the location and character of the aquifer's boundaries, as well as T and S, are known. Seldom, however, is knowledge of these factors complete enough to permit an accurate long-term prediction. Generally, a prediction is made and then refined as data on actual withdrawals and water levels become available.

Reported capacities of the municipal wells in the aquifer of the East Channel range from 700 to as much as 2,400 gpm. Specific capacities range from 75 to as much as 140 gpm per foot of drawdown. The pumping-test results indicate that the average field permeability of the sand and gravel in the East Channel is of the order of 1,100 gpd per square foot.

Records of the performance of wells tapping the shallow outwash deposits indicate that the field permeability of these sands and gravels averages about 1,000 gpd per square foot. Wells of moderate to large diameter finished in the shallow outwash deposits yield 50 to as much as 400 gpm, their specific capacities ranging from 5 to 20 gpm per foot. Well 5N 16W 33-8 at the Holland State Park yielded 218 gpm at a drawdown of 32 feet, indicating a specific capacity of 7 gpm per foot.

QUALITY OF WATER

Ground Water

Comprehensive and partial analyses and records of various physical properties of the ground water in the Holland area are listed in table 9. These analyses reveal the differences in mineral content of water from the various sources sampled, and changes in chemical quality of water sampled from the same sources at different times.

Analyses of water from the Coldwater shale are not available, but records of oil-test drilling reveal that water in this formation is highly mineralized and undoubtedly unfit for most uses. The analysis of a water sample taken from well 5N 15W 21-25 indicates that water from the Marshall formation within the area is of the calcium bicarbonate type and is of moderate mineral content (fig. 16).

Water from the drift aquifers also if of the calcium bicarbonate type. Water samples from the shallow outwash tapped at the 19th and 28th Street stations ranged in hardness from 121 to 268 parts per million (ppm) and generally contained only small amounts of iron. It was reported, however, that the 21st Street station was abandoned in 1915 because of the high iron content of the water. In general, water from the shallow outwash deposits is clear and odor free. Locally, it is reported to contain hydrogen sulfide. The quality of water in these deposits is nearly uniform throughout the year. The mineral content of water samples taken at the 19th Street station is about twice that of samples at the 28th Street station (fig. 16). The difference in degree of mineralization, in view of the fact that larger quantities of water have been pumped for a longer period of time at the 19th Street station, may indicate that the pumping has induced a flow of water, from deep and distant sources, that is higher in mineral content than the water pumped at the 28th Street station.

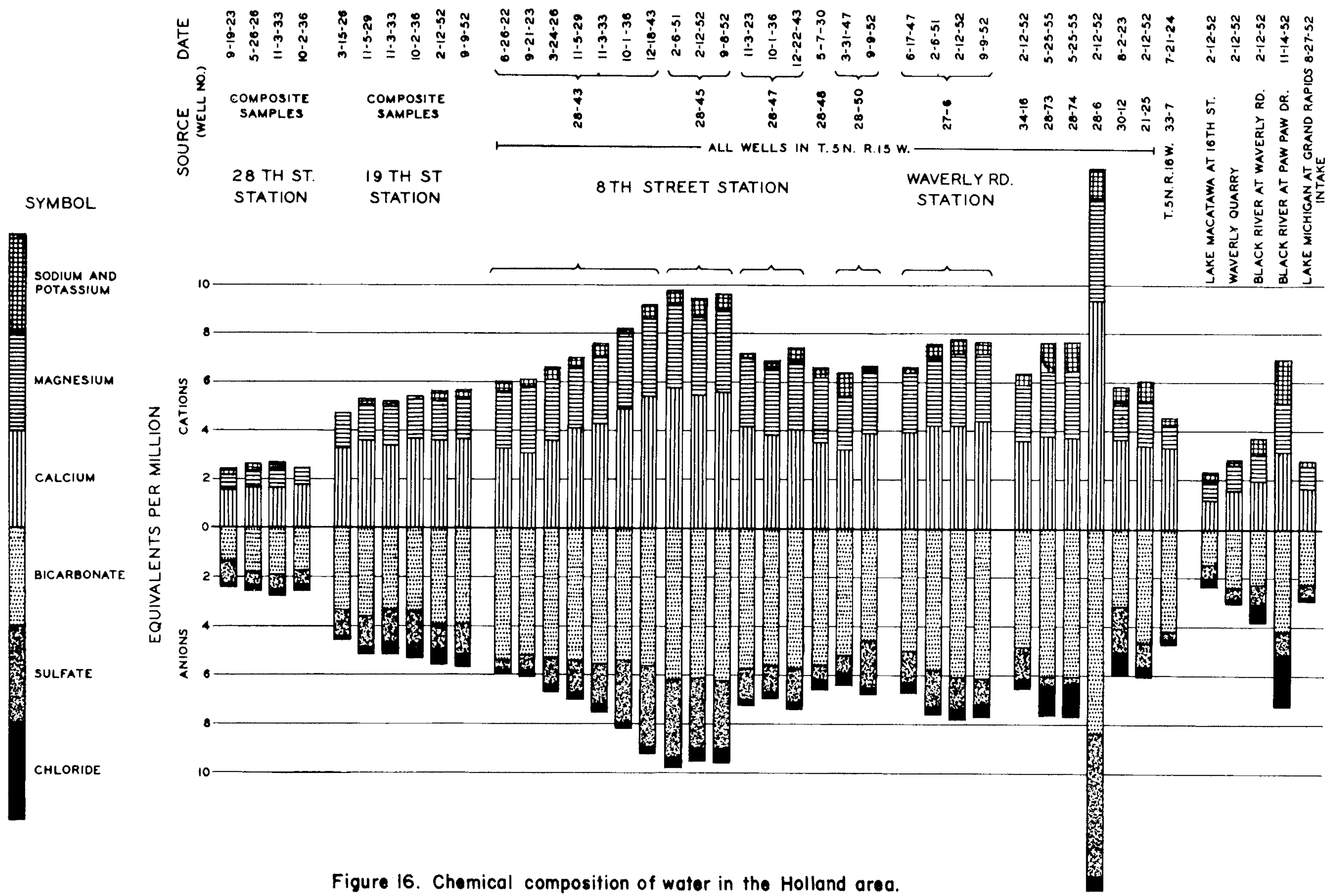


Figure 16. Chemical composition of water in the Holland area.

Initially the ground water pumped from the aquifer of the East Channel was similar in quality to that pumped from the shallow outwash deposits. The total mineral content of the water from the aquifer of the East Channel has increased since the Eighth Street station was put into operation in 1921. During that period of pumping at this station the hardness of the water has increased from about 300 to 460 ppm. There has been a persistent uptrend also in the calcium and sulfate content of the water, although the magnesium and bicarbonate content has remained relatively constant. It appears that the increase in calcium and sulfate is proportional to the decline of water level in the aquifer. The increase in mineral content of water pumped from wells 5N 15W 28-43 and 45 at the Eighth Street station is illustrated graphically by figure 16. The increase in the calcium and sulfate probably is due to migration of water from the underlying Coldwater shale. Further lowering of the water level probably would result in continued increases in concentration of these constituents.

Analyses of water from the buried outwash in the South Channel are not available, but the water is reported to be too highly mineralized for domestic or public supplies, and probably for most industrial uses. Because of the absence of fresh-water aquifers overlying the South Channel, it has been difficult, and in some places impossible, to obtain supplies of potable water in the vicinity of the South Channel.

The measured temperatures of the water in the aquifer of the East Channel average 50.8°F. Temperatures of water in the shallow outwash aquifers range from about 52° to about 55°F. Ground-water temperatures in the very shallow aquifers may be affected substantially by seasonal fluctuations of the air temperature, and thus the range probably is greater than indicated by existing data.

Surface Water

Surface streams and lakes, especially the smaller ones, are often subject to large fluctuations in water temperature, chemical quality, and organic content. Some fluctuations are of short duration, as, for example, those produced by flood flows or changes of wind direction. Other fluctuations may be of much longer duration, such as the seasonal trends of water temperature and quality.

The chemical quality of water in the Black River varies considerably. Greater mineral concentrations than are shown in figure 16 or table 10 may be expected during periods of very low flow, but the mineral content may be very slight during periods of flood flow. During such periods, however, the turbidity is high. At normal stages the water in the Black River is of objectionable color, as it drains large areas of peat and marshlands.

The water of Lake Macatawa is moderately hard to hard, the range of hardness being from about 100 to 150 ppm, as compared with 150 to 250 ppm for samples taken from the Black River. Treated effluents and high-temperature condensing waters from several industries, however, are discharged into the upper part of the lake. In addition, widespread growths of algae are frequently present in the lake.

Lake Michigan water is generally of good chemical quality (table 10), but in the vicinity of the Lake Macatawa outlet it is affected by the chemical and bacteriological quality of the water discharged. The hardness is about 140 ppm or less. The temperature of the shallow water offshore from the Holland area ranges from freezing to about 70°F.

The water from wells or collectors that induce infiltration from adjacent surface sources ultimately will be similar in chemical quality to that of the surface source. But where infiltration systems are located at great distances from the surface source the time of travel from the source to the point of withdrawal is appreciable and the effect on quality of the ground water is less pronounced.

The Lake Michigan shore is the most favorable location for infiltration systems because the water of Lake Michigan is superior in chemical quality and lower in organic materials than Lake Macatawa or Black River water. The advantages of an infiltration system using Lake Michigan water may be outweighed, however, by those of a direct lake-intake system, inasmuch as the lake water is of good quality and is available in large quantities.

SUMMARY AND CONCLUSIONS

The principal source of water supply for the city of Holland during the period 1921 through 1956 was the aquifer of the East Channel. The water level of this aquifer declined continuously during this period, and within a few years further declines would have seriously diminished the yields of the Waverly Road and Eighth Street stations. Moreover, the mineral content of the water from some wells in this aquifer had been increasing as the water levels declined. Additional development of the aquifer of the East Channel south of the Waverly Road station might have induced flow of highly mineralized water from the aquifer of the South Channel. Test drilling north of the Eighth Street station demonstrated that permeable deposits in that area are too thin to yield sufficient water to meet the growing needs of the city.

The shallow outwash aquifers which had supplied the city for many years might possibly yield enough water to satisfy foreseeable needs, but extensive test drilling and aquifer tests throughout the area would be needed to determine the potential yield. A well system tapping these deposits would of necessity be widespread and would require elaborate collection and pumping systems. Serious problems of well-field location in respect to sewer lines and other sources of contamination also would have to be overcome.

The possibility that the aquifers in the Holland area would not yield, at feasible cost, sufficient water of good quality to meet anticipated demands for the next several decades resulted in the decision by the city of Holland to utilize Lake Michigan as a source of supply.

The existing well fields in the city provide an excellent standby source of as much as 1 billion gallons of water per year in the event of an emergency. In addition, the aquifers in much, though not all, of the Holland area are adequate for those industrial and domestic water needs that are not supplied from the city system.

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Table 5.--Records of wells in the Holland area

Diameter: Minimum diameter listed.

Altitude: Feet above mean sea level. Those reported to tenths of a foot were determined by the City of Holland or industrial firms by instrumental leveling; those reported to feet were taken from U. S. Geological Survey topographic maps.

Use: D - domestic; I - industrial; O - observation; P - public supply (City of Holland wells no longer in use); S - stock; T - test.

Remarks: L - log, see table 8; C - chemical analysis, see table 9.

Well designation T.R.sec-no.	Location ¼ ¼ ¼	Owner	Driller	Year Drilled	Depth (ft.)	Diameter (in.)	Altitude	Use	Remarks
			Ottawa County, Park Township (T. 5 N., R. 16 W.)						
5N 16W									
21-1	SW SE NW	Getz Farm	-	1930	50	36	600	D,S	L
21-2	do.	do.	-	-	27	-	600	D,S	L
21-3	NW NE SW	G. Combs	Hamilton Mfg. and Supply Co.	1951	40	4	605	D	L
21-4	NE NE SE	Lakewood School	-	-	35	-	605	P	
23-2	SE SE NW	R. Anys	-	-	12	-	610	D	Sand aquifer
23-3	NE NW SE	Waukazoo School	-	1948	20	3	610	P	do.
28-1	SW NE SW	City of Holland	Ranney Water Methods Co.	1953	54	-	585.4	T	L
33-1	NW NE NW	do.	do.	1953	100	-	585.7	T	L
33-2	SW NE NW	do.	do.	1953	70	-	585.8	T	L
33-3	NW SE NW	do.	do.	1954	34	-	585.5	T	L
33-4	SW SE NW	do.	do.	1953	45	-	585.6	T	L
33-5	SE SE NW	Holland State Park	-	-	257	-	595	T	L
33-6	do.	do.	-	1940	70	4	595	T	
33-7	NE NE SW	W. Murphy	-	-	80	-	595	D	L, C
33-8	NW NE SW	Holland State Park	L. Riegler	1941	71	8	595	P	
33-9	NE NW SW	City of Holland	Ranney Water Methods Co.	1953	99	6	585.9	T	L
33-10	SW NE SW	do.	do.	1953	38	-	585.2	T	L, C
33-11	NE SE SW	do.	do.	1953	95	-	593.0	T	L
35-1	- SE NE	J. Keift	Hamilton Mfg. and Supply Co.	1954	40	2	590	D	Sand aquifer
35-2	SE SW NE	D. VanderYacht	D. VanderYacht	-	17	-	615	D	Coarse gravel
35-3	SE SE NE	J. Bowman	J. Bowman	1936	24	1¼	605	D	Gravel
36-1	- SE NE	D. Muller	Hamilton Mfg. and Supply Co.	-	111	4	600	D	L
36-2	- SE SW	R. VanVoorst	do.	1951	28	2	630	D	L
36-3	- SE SW	J. Harsten	Hamilton Mfg. and Supply Co.	1951	35	2½	610	D	L
36-4	- SE SE	A. VanDyke	do.	1952	119	2	620	D	L
			Ottawa County, Holland Township and the City of Holland (T. 5 N., R. 15 W.)						
5N 15W									
18-2	NW SW NE	H. J. Rowan	-	-	14	1¼	610	D	Gravel aquifer
18-5	NE NW NW	R. Anys	R. Anys	1954	27	1¼	610	D	Sand and gravel from 13 to 27 ft.
19-1	SE SW NE	P. Knoll	W. Kool	1946	25	1¼	600	D	Sand, fine, and gravel aquifer
19-2	NE NE SW	DeVecht	-	-	24	1½	600	D	Sand aquifer

Table 5.--Records of wells in the Holland area.--Continued

Well designation T.R.sec-no.	Location ¼ ¼ ¼	Owner	Driller	Year Drilled	Depth (ft.)	Dia-meter (in.)	Alti-tude	Use	Remarks
5N 15W									
19-3	SE SE SW	Chris Craft Corp.	IXL Machine Shop	1939	26	4	610	P,I	
19-4	do.	do.	do.	1939	26	4	610	P,I	
19-5	do.	do.	Hamilton Mfg. and Supply Co.	1941	26	4	610	P,I	
19-6	do.	do.	do.	1943	26	4	610	P,I	
19-7	NE SE SE	Parke, Davis and Co.	-	-	34	-	606.5	P,I	
19-8	do.	do.	-	-	31	-	605.2	P,I	
19-9	do.	do.	-	-	33	-	603.5	P,I	
19-10	do.	do.	-	-	32	-	603.1	P,I	
19-11	do.	do.	-	-	-	-	604.1	P,I	
19-12	do.	do.	-	-	31	-	603.8	P,I	
19-13	do.	do.	-	-	-	-	607.7	P,I	
19-14	do.	do.	-	-	29	-	601.3	P,I	
19-15	do.	do.	-	-	-	-	604.0	P,I	
19-16	do.	do.	-	-	35	-	603.9	P,I	
19-17	do.	do.	-	-	34	-	602.9	P,I	
19-18	do.	do.	-	-	30	-	604.0	P,I	
19-19	do.	do.	-	-	31	-	608.5	P,I	
19-20	do.	do.	-	-	33	-	606.2	P,I	
19-21	do.	do.	-	-	33	-	606.2	P,I	
19-22	do.	do.	-	-	-	-	605.6	P,I	
19-23	do.	do.	-	-	33	-	604.1	P,I	
19-24	do.	do.	-	-	35	-	605.0	P,I	
19-25	do.	do.	-	-	31	-	607.9	P,I	
19-26	do.	do.	-	-	31	-	607.6	P,I	
19-27	do.	do.	-	-	-	-	606.0	P,I	
19-28	do.	do.	-	-	32	-	605.9	P,I	
19-29	do.	do.	-	-	31	-	605.3	P,I	
20-9	NW SW SW	do.	-	-	32	-	605.1	P,I	
20-10	do.	do.	-	-	39	-	613.2	P,I	
20-11	do.	do.	-	-	31	-	605.9	P,I	
20-12	do.	do.	-	-	29	-	603.9	P,I	
20-13	do.	do.	-	-	26	-	603.1	P,I	
20-14	do.	do.	-	-	30	-	605.6	P,I	
20-15	SW SW SW	do.	Busk and Ormiston	1951	1634	6	587.7	I	Mich. Dept. Conserv. Brine Disposal Permit No. 52. Log published by Mich. Geol. Survey
20-16	SE SW SW	do.	C. S. Raymer	1950	64	-	583.8	T	L
20-17	do.	do.	do.	1950	62	-	583.2	T	L
20-19	SW SW SW	do.	do.	1950	63	-	582.7	T	L
20-20	do.	do.	do.	1950	45	-	584.3	T	L
20-21	do.	do.	do.	1950	37	-	584.5	T	L
20-25	do.	do.	do.	1950	52	6	604.5	T	L
20-26	do.	do.	do.	1950	35	-	591.0	T	L
20-36	NE SW SW	do.	do.	1950	79	-	587.5	T	L
20-37	do.	do.	do.	1950	81	-	589.6	T	L
20-38	do.	do.	do.	1950	56	-	585.7	T	L
21-25	NE SE SE	H. Tubergen	-	-	22	4	590	D	C, in Marshall formation.
21-26	SE SE SE	City of Holland	L. Riegler	1945	45	-	591.6	T	L

Table 5.--Records of wells in the Holland area.--Continued

Well designation T.R.sec-no.	Location ¼ ¼ ¼	Owner	Driller	Year Drilled	Depth (ft.)	Diameter (in.)	Altitude	Use	Remarks
5N 15W									
21-42	NE SE SW	City of Holland	Ranney Water Methods Co.	1953	34	-	586.0	T	L
21-50	NW SW SW	do.	do.	1953	45	-	583.0	T	L
21-52	SE NW SW	do.	do.	1954	65	-	592.0	T	L
26-3	NW SW SW	P. Wabeke	Hamilton Mfg. and Supply Co.	1954	61	3	675	D	
27-1	SE NW NW	City of Holland	L. Riegler	1945	60	-	607.2	T	L
27-2	NE SW NW	do.	do.	1945	122	-	609.9	T	L
27-3	SE SE NW	F. Todd	Hamilton Mfg. and Supply Co.	1951	72	-	640	D	L
27-4	NW NE SW	City of Holland	L. Riegler	1945	160	-	639.1	T	L
27-5	SW NE SW	do.	do.	1946	146	-	642.6	T	L
27-6	NW SW SW	do.	Layne-Northern Co.	1947	158	26	641.6	P	L, C, formerly OtHo 4, Waverly Rd. Station
27-7	do.	do.	L. Riegler	1946	166	-	641.6	T	L
27-8	do.	do.	do.	1946	102	1¼	640	O	Formerly OtHo 10
27-9	do.	do.	do.	1946	175	-	647.4	T	L
27-10	SW SW SW	do.	Layne-Northern	1947	178	26	655	P	L, formerly OtHo 11
27-20	SE NE NW	A. Timmer	Hamilton Mfg. and Supply Co.	1954	76	4	630	D	
27-21	SW NW NE	M. DeRidder	do.	1954	80	4	630	D	
28-6	NE NW NE	Holland Rendering Works	A. Webber	-	87	6	600	I	L, C
28-7	NE NE NE	City of Holland	L. Riegler	1945	80	-	597.5	T	L
28-8	SE NE NE	F. Cherven	Hamilton Mfg. and Supply Co.	1951	58	2	610	D	L
28-9	NE SE NE	City of Holland	H. Menken	1921	96	-	605	T	L
28-10	SE SE NE	do.	L. Riegler	1945	132	-	605.6	T	L
28-11	do.	do.	do.	1946	129	-	610.3	T	L
28-12	SW SE NE	do.	H. Menken	1921	104	-	600	T	L
28-13	NW SE NE	do.	do.	1921	128	-	600	T	L
28-14	NE SW NE	do.	do.	1921	134	-	600	T	L
28-15	NW SW NE	do.	do.	1921	145	-	600	T	L
28-16	do.	do.	American Water Corp.	1927	100	-	600	T	L
28-17	do.	do.	do.	1927	28	-	600	T	L
28-18	do.	do.	do.	1947	87	-	600	T	L
28-19	SE NW NE	Holland Pattern Co.	Hamilton Mfg. and Supply Co.	1951	180	-	600	T	L, Dry hole
28-20	SW NW NE	City of Holland	American Water Corp.	1927	78	-	590	T	L
28-21	SE NE NW	do.	H. Menken	1929	93	-	600	T	L
28-22	do.	do.	do.	1929	88	-	600	T	L
28-23	do.	do.	American Water Corp.	1927	107	-	600	T	L
28-24	NE SE NW	do.	Ranney Water Methods Co.	1953	112	-	584.1	T	L
28-25	NW SE NW	do.	American Water Corp.	1927	102	-	600	T	L
28-26	do.	do.	do.	1927	100	-	600	T	L
28-27	do.	do.	do.	1927	83	-	600	T	L
28-28	SW SE NW	do.	do.	1927	74	-	600	T	L
28-29	NW SE NW	A. Teitsma	-	1927	16	-	600	D	Gravel aquifer.

Table 5.--Records of wells in the Holland area.--Continued

Well designation T.R.sec-no.	Location ¼ ¼ ¼	Owner	Driller	Year Drilled	Depth (ft.)	Diameter (in.)	Altitude	Use	Remarks
5N 15W									
28-33	NW NE NW	City of Holland	Ranney Water Methods Co.	1953	80	-	582.6	T	L
28-34	SW NE NW	do.	do.	1953	42	-	582.3	T	L
28-35	do.	do.	do.	1953	65	-	582.0	T	L
28-36	NE NE NW	do.	do.	1953	77	-	582.3	T	L
28-37	SE NE NW	do.	H. Menken	1929	60	-	590	T	L
28-38	NW NW SW	H. Arnoldink	Knoll	-	15	-	600	D	Sand aquifer, sand from 13 to 15 ft.
28-39	NW SE SW	City of Holland	American Water Corp.	1927	37	-	608	T	L
28-40	do.	do.	do.	1927	64	-	607.7	T	L
28-41	NE NW SE	do.	H. Menken	1921	112	-	600	T	L
28-42	do.	do.	do.	1921	130	-	600	T	L
28-43	do.	do.	Kelly Well Co.	1922	73	25	600	P	L, C 8th St. Station
28-44	do.	do.	L. Riegler	1949	140	6	600	T	L
28-45	do.	do.	R. F. Dunbar and Sons	1950	131	16	600	P	L, C
28-46	do.	do.	Layne Ohio Co.	1932	83	-	600	T	L
28-47	NW NE SE	City of Holland	Kelly Well Co.	1932	83	25	605	P	L, C
28-48	do.	do.	Fairbanks-Morse Water Supply Co.	1929	90	24	605	P	L, C
28-49	do.	do.	H. Menken	1921	91	-	605	T	L
28-50	do.	do.	Layne-Northern Co.	1947	110	26	605	P	L, C, formerly OtHo 3
28-51	- NE SE	do.	H. Menken	1921	41	6	610.0	P	
28-52	do.	do.	do.	1921	43	1¼	609.8	O	Formerly OtHo 2
28-53	do.	do.	do.	1921	42	6	609.6	P	
28-54	do.	do.	do.	1921	47	5	609.3	P	
28-55	do.	do.	do.	1921	49	6	609.1	O	Formerly OtHo 5
28-56	do.	do.	do.	1921	43	5	609.1	P	
28-57	do.	do.	do.	1921	50	6	608.6	P	
28-58	do.	do.	do.	1921	38	5	608.6	P	
28-59	do.	do.	Meyers	1921	54	6	608.1	P	
28-60	do.	do.	H. Menken	1921	35	5	607.9	P	
28-61	do.	do.	Meyers	1921	49	6	607.9	P	
28-62	do.	do.	H. Menken	1921	33	5	607.7	P	
28-63	- NW SE	do.	Meyers	1921	45	6	607.3	P	
28-64	do.	do.	do.	1921	41	6	606.5	P	
28-65	NE NE SE	do.	L. Riegler	1945	142	-	610.1	T	L
28-66	do.	do.	do.	1945	140	-	616.5	T	L
28-67	SW NE SE	do.	H. Menken	1921	72	-	620	T	L
28-68	SE NW SE	do.	do.	1921	93	-	620	T	L
28-69	SW NE SE	do.	Ranney Water Methods Co.	1953	160	-	634.1	T	
28-70	NE SE SE	do.	L. Riegler	1945	140	-	634.9	T	L, formerly OtHo 6
28-71	do.	do.	do.	1946	108	1¼	640	T	Formerly OtHo 9
28-72	SE SE SE	do.	do.	1946	84	1¼	661.6	T	L, formerly OtHo 7, NaCl 3.4 gr.
28-74	SE NE NW	do.	do.	1954	70	12	-	P	No. 6 Station. Buried outwash aquifer
29-1	SE NW NE	do.	American Water Corp.	1927	78	-	585	T	L

Table 5.--Records of wells in the Holland area.--Continued

Well designation T.R.sec-no.	Location ¼ ¼ ¼	Owner	Driller	Year Drilled	Depth (ft.)	Diameter (in.)	Altitude	Use	Remarks
5N 15W									
29-9	NE SW NE	City of Holland	Ranney Water Methods Co.	1953	125	-	600	T	L
29-11	NE SW NE	City of Holland	R. F. Dunbar and Sons	1940	103	6	600	T	L
29-12	SW SW NE	Center Theatre	do.	1939	20	8	605	I	
29-13	do.	Warm Friends Hotel	-	-	13	6	605	P	
29-14	SW SE NW	City of Holland	American Water Corp.	1927	75	-	600	T	L
29-15	SW NE SW	Park Theatre	Hamilton Mfg. and Supply Co.	1954	31	8	605	I	L
29-16	NE NW SE	Holland Theatre	-	-	30	8	605	I	
29-17	SE NE SE	Mich. Gas and Elec. Co.	Layne-Northern Co.	-	35	8	610	I	
29-18	do.	do.	do.	1935	58	-	610	I	L
29-19	do.	do.	do.	1943	34	-	610	I	L
29-20	do.	do.	do.	1946	31	-	610	T	L
29-21	NE NW NW	Parke, Davis and Co.	C. S. Raymer	1950	63	-	582.7	T	L
29-49	- SE NE	City of Holland	-	1883	20	144	600	P	5th St. Station Dug well
29-50	- SE NE	City of Holland	-	1883	-	-	600	P	5th St. Station. Dug well
29-51	do.	do.	-	1883	65	192	600	P	do.
29-52	do.	do.	-	1883	24	2	600	P	44 drive-point wells at 5th St. Station
30-11	NW NE SE	Superior Pure Ice and Mach. Co.	Layne Northern Co.	1938	35	-	595	T	L
30-12	NW NE SE	Superior Pure Ice and Mach. Co.	Layne-Northern Co.	1923	22	6	595	I	L, C
30-13	NE NW SE	City of Holland	American Water Corp.	1927	65	-	585	T	L
30-14	NW SW SE	H. J. Heinz Co.	R. F. Dunbar and Sons	1942	26	-	595	I	L
30-15	do.	do.	do.	1942	30	-	595	I	L
30-16	do.	do.	do.	-	110	6	590	T	L
30-17	do.	do.	do.	-	30	-	590	T	L
30-18	do.	do.	do.	-	22	-	590	T	L
30-19	SW SE SW	City of Holland	American Water Corp.	1927	71	-	590	T	L
30-20	SW SE SE	G. VanDerBie	G. VanDerBie	-	20	1¼	605	D	Gravel aquifer
30-23	SE SE SE	D. Lam	D. Lam	1922	25	2	605	D	Fine gravel aquifer
31-1	SE SE NW	A. VanMaurick	-	1917	30	1	600	D	
31-2	NW SW SW	P. Brandsen	Hamilton Mfg. and Supply Co.	1951	46	3	610	D	L
31-3	SW NE SW	City of Holland	L. Riegler	1945	85	-	610	T	L
31-4	do.	do.	do.	1945	24	-	610	T	L
31-5	SE NE SW	do.	do.	1945	115	-	605	T	L
31-6	NW NW SE	do.	R. F. Dunbar and Sons	-	38	6	610	T	L
31-7	do.	do.	do.	-	45	6	610	T	L
31-8	do.	do.	do.	-	135	6	610	T	L
31-9	SW NW SE	do.	do.	-	35	6	610	T	L
31-10	do.	do.	-	1939	29	18	610	O	Formerly OtHo 12, gravel aquifer

Table 5.--Records of wells in the Holland area.--Continued

Well designation T.R.sec-no.	Location ¼ ¼ ¼	Owner	Driller	Year Drilled	Depth (ft.)	Diameter (in.)	Altitude	Use	Remarks
5N 15W									
31-11	do.	do.	R. F. Dunbar	-	35	6	610	T	L
31-12	do.	do.	do.	-	38	6	610	T	L
31-13	SW NE SE	do.	Kelly Well Co.	1923	29	24	633	P	L
31-14	do.	do.	do.	1923	28	24	633.2	P	L
31-15	NE SE SE	do.	do.	1922	28	24	633.2	P	L
31-16	NW SW SE	H. Bontekoe	J. Knoll	1946	15	1½	635	D	Sand aquifer
31-17	SE SW SE	A. Bushee	A. Bushee	1946	20	1¼	635	D	Sand and gravel aquifer
31-18	SW SW SE	G. Groenewoud	-	-	12	1½	635	D	
31-19	NE SE SE	City of Holland	-	1955	26	1½	-	P	28th St. Station. 50 drive-point wells for emergency supply
31-20	NW NE SE	do.	-	1956	26	1½	-	P	25th St. Station. 50 drive-point wells for emergency supply
32-1	- NW NE	do.	-	1896-7	39	5	620	P	Sand aquifer
32-2	do.	do.	-	1896-7	43	5	620	P	do.
32-3	do.	do.	-	-	42	5	620	P	do.
32-4	do.	do.	-	-	39	5	620	P	
32-5	do.	do.	-	-	26	5	620	P	
32-6	do.	do.	-	-	37	5	620	P	Sand aquifer
32-7	do.	do.	-	1896-7	-	-	620	T	
32-8	do.	do.	-	1896-7	-	-	620	T	
32-9	do.	do.	-	-	-	-	620	T	
32-10	do.	do.	-	-	-	-	620	T	
32-11	do.	do.	-	-	-	-	620	T	
32-12	do.	do.	-	-	-	-	620	T	
32-13	do.	do.	-	-	-	-	620	T	
32-14	do.	do.	-	-	-	-	620	T	
32-15	do.	do.	-	-	-	-	620	T	
32-16	do.	do.	-	-	-	-	620	T	
32-17	do.	do.	-	1896	30	280	620	P	Dug well, 19th St. Station
32-18	do.	do.	-	-	35	5	620	P	Sand aquifer
32-19	do.	do.	-	-	-	-	620	T	
32-20	do.	do.	-	-	-	-	620	T	
32-21	do.	do.	-	-	-	-	620	T	
32-22	do.	do.	-	-	33	5	620	P	Sand aquifer
32-23	do.	do.	-	1903	111	7	615	T	L, saline water
32-24	- SW NE	do.	-	-	35	5	620	P	Sand aquifer
32-25	do.	do.	-	-	-	-	620	T	
32-26	do.	do.	-	-	34	-	620	P	Sand aquifer
32-27	do.	do.	-	-	33	5	620	P	do.
32-28	do.	do.	-	1896-7	33	5	620	P	do.
32-29	do.	do.	-	-	33	5	620	P	do.
32-30	do.	do.	-	-	32	5	620	P	do.
32-31	do.	do.	-	-	31	5	620	P	do.
32-32	do.	do.	-	-	-	-	620	T	
32-33	do.	do.	-	-	-	-	620	T	
32-34	do.	do.	-	-	-	-	620	T	
32-35	do.	do.	-	-	-	-	620	T	
32-36	- NE NW	do.	-	1920	-	5	620	P	

Table 5.--Records of wells in the Holland area.--Continued

Well designation T.R.sec-no.	Location ¼ ¼ ¼	Owner	Driller	Year Drilled	Depth (ft.)	Diameter (in.)	Altitude	Use	Remarks
5N 15W									
32-37	- NE NW	City of Holland	-	1920	-	5	620	P	
32-38	do.	do.	-	1920	-	5	620	P	
32-39	do.	do.	-	1920	-	5	620	P	
32-40	do.	do.	-	1920	-	5	620	P	
32-41	do.	do.	-	1912	32	360	620	P	21st St. Station. Dug well
32-42	do.	do.	-	1912	33 to 47	5	620	P	11 wells of 21st St. Station.
32-43	do.	do.	-	1912	33 to 47	5	620	P	4 wells of 21st St. Station hooked in with 19th St. Station in 1920.
32-45	SE SW NW	A. Speet	Hamilton Mfg. and Supply Co.	1944	24	2	620	D	Sand aquifer
32-46	SE NW SW	G. Mannes	-	1925	22	2	625	D	Fine gravel
32-47	- NW SW	City of Holland	Kelly Well Co.	1922	27	24	630.4	P	L
32-48	do.	do.	do.	1922	28	24	632.1	P	L
32-49	do.	do.	do.	1923	27	24	631.9	P	L
32-50	do.	do.	do.	1923	28	24	632.5	P	L
32-51	NW SW SW	A. Pommerening	-	1929	20	-	630	D	
32-52	NW SE SW	C. DePree	C. DePree	1948	23	1¼	630	D	Sand aquifer
32-53	do.	F. Bouman	F. Bouman	-	14	2	630	D	do.
32-54	SW SE SW	D. Piersma	-	1938	12	-	635	D	do.
32-55	SE SE SW	Mrs. J. Franks	-	-	21	-	635	D	do.
32-56	SW SE SE	City of Holland	American Water Corp.	1927	62	-	630	T	L
32-57	NW SW SE	M. Elterbeek	M. Elterbeek	1940	15	1½	630	D	Sand aquifer
32-58	SW NW SE	W. Miller	-	1940	15	-	630	D	do.
32-59	SW NE SW	K. Beeden	K. Beeden	1946	20	-	620	D	do.
32-60	SE SW NE	R. Brink	R. Brink	1942	20	3	620	D	do.
32-61	SW SE NE	City of Holland	R. F. Dunbar and Sons	1940	100	6	630	T	L
32-62	NE SE NE	do.	American Water Corp.	1927	62	-	620	T	L
32-63	- SW NE	do.	-	-	-	-	615	T	
32-64	do.	do.	-	1896-7	-	-	615	T	
33-1	NE NE NE	do.	R. F. Dunbar and Sons	1940	105	6	660	T	L
33-2	NW NE NE	do.	do.	1940	90	6	645	T	L
33-4	SE NE NE	do.	do.	1940	120	6	680	T	L
33-5	do.	do.	do.	1940	100	6	680	T	L
33-8	SW NE NE	do.	do.	1940	85	-	650	T	L
33-9	do.	do.	do.	1940	85	10	650	T	
33-16	do.	do.	do.	1940	90	-	660	T	L
33-24	SE SE NE	do.	L. Riegler	1946	210	-	669.3	T	L
33-25	NE NE SE	J. Boreman	-	-	124	-	670	D	
33-26	NW NE SE	D. Por	-	-	45	-	675	D	
33-27	NW SW NW	A. Reinink	-	-	-	-	635	D	
34-12	NW NE SE	City of Holland	L. Riegler	1946	290	6	640.6	T	L
34-16	SW SE NW	L. Schaap	H. Mulder	-	133	2	660	D	C
34-19	NW NW SE	J. Vandervaarden	-	-	55	-	660	D	
34-21	NW NE SE	City of Holland	L. Riegler	1949	289	1	640.6	O	L, formerly OtHo 21
34-22	do.	do.	do.	1949	67	1	640.6	O	L, formerly OtHo 22
34-32	SE SE SW	A. Elferdink	-	-	92	-	660	D	
35-1	SW NE NE	H. Atman	Hamilton Mfg. and Supply Co.	1951	42	2	600	D	L

Table 5.--Records of wells in the Holland area.--Continued

Well designation T.R.sec-no.	Location ¼ ¼ ¼	Owner	Driller	Year Drilled	Depth (ft.)	Diameter (in.)	Altitude	Use	Remarks
5N 15W									
35-2	NE NE SW	W. Naber	-	-	134	-	660	D	
35-3	NE NW SW	J. Helder	-	-	103	-	660	D	
35-6	NW NW NW	DeHaan	-	-	65	2	650	P	
Allegan County, Laketown Township (T. 4 N., R. 16 W.)									
4N 16W									
4-1	SE SE NW	City of Holland	Ranney Water Methods Co.	-	90	-	598.0	T	L
4-2	SE SW SE	do.	do.	1953	84	-	605.0	T	L
Allegan County, Fillmore Township (T. 4 N., R. 15 W.)									
4N 15W									
2-1	NE NE NW	E. Helder	-	-	18	-	665	D	
2-2	SW SW NW	N. Dykheries	-	-	95	-	675	D	
3-1	NE NE NE	-	S. Cook	-	200	10	660	-	
3-2	do.	J. Pelon	-	-	72	-	660	D	
3-3	NE NW NW	J. Schaap	-	-	112	-	700	D	
3-4	SE SE NW	J. Wescott	-	-	128	-	685	D	
3-5	NE NW SW	C. Pelon	-	-	100	-	700	D	
4-1	NW NW NE	T. Westing	-	-	58	-	650	D	
4-2	NE NW NW	F. Kooyers	-	-	16	-	645	D	
5-1	NE SE NE	City of Holland	L. Riegler	1945	174	2	670	T	
6-1	NE SW NE	L. W. Lamb Construction Co.	Hamilton Mfg. and Supply Co.	1951	168	3	660	I	L

Table 6.--Records of borings in the Holland area

Logs published for all borings except 5N 15W 21-15 and 29-2 to 29-7. See Table 8.

Borings 5N 15W 33-6, 33-7, and 33-10 to 33-22 were 2½ inches in diameter; other diameter records not available.

Altitude: Feet above mean sea level.

Number	Location ¼ ¼ ¼	Owner	Year Drilled	Depth	Altitude
Ottawa County (T. 5 N., R. 16 W.)					
5N 16W					
13-1	- SE SW	City of Holland	1910	30	595
24-1	NW NE SE	do.	1910	27	588
25-1	SW NE NE	do.	1910	27	590
25-2	SE SE NE	do.	1910	33	600
Ottawa County (T. 5 N., R. 15 W.)					
5N 15W					
16-1	SW SE SE	City of Holland	1910	3	610
16-2	SW SW SE	do.	1910	12	610
16-3	SE SW SW	do.	1910	10	610
17-1	NE NE SE	do.	1910	24	620
18-1	NW NW NW	do.	1910	31	610
18-3	NW SW NW	do.	1910	26	600
20-1	- - SW	State Highway Dept.	1930	50	589.3
20-2	do.	do.	1930	63	589.6
20-3	do.	do.	1930	48	581.8
20-4	do.	do.	1930	48	582
20-5	do.	do.	1930	50	581.4
20-6	do.	do.	1930	49	580.7
20-7	do.	do.	1930	60	588.6
20-8	do.	do.	1930	53	581.7
20-18	SE SW SW	Parke, Davis and Co.	1950	70	584.2
20-22					
20-22	SW SW SW	do.	1950	62	586.4
20-23	do.	do.	1950	40	587.6
20-24	do.	do.	1950	67	591.0
20-27	NW SW SW	do.	1950	40	591.9
20-28	do.	do.	1950	66	592.2
20-29	do.	do.	1950	64	590.6
20-30	do.	do.	1950	71	586.7
20-31	do.	do.	1950	78	590
20-32	do.	do.	1950	83	599
20-33	do.	do.	1950	67	605.1
20-34	do.	do.	1950	68	605.3
20-35	NE SW SW	do.	1950	75	588.4
21-1	NE NE SE	City of Holland	1910	7	596.3
21-2	NW NE SE	do.	1910	7	590.2
21-3	do.	do.	1910	5	601.7
21-4	SE SW NE	State Highway Dept.	1945	23	600.6
21-5	do.	do.	1945	21	601.1

Number	Location ¼ ¼ ¼	Owner	Year Drilled	Depth	Altitude
Ottawa County (T. 5 N., R. 15 W.) Continued					
5N 15W					
21-6	SE SW NE	State Highway Dept.	1945	23	602.2
21-7	do.	do.	1945	19	601.3
21-8	NE NW SE	City of Holland	1910	6	601.5
21-9	NE NE SW	do.	1910	15	600.8
21-10	NW NE SW	do.	1910	24	602.6
21-11	NE NW SW	do.	1910	16	597.9
21-12	NW NW SW	do.	1910	23	603.9
21-13	NW NE SW	do.	1910	18	595.2
21-14	NE NE SW	do.	1910	14	594.2
21-15	NW NW SE	do.	1910	14	591.4
21-16	SE NW SE	do.	1910	55	589.7
21-17	SW NE SE	State Highway Dept.	1945	12	585.7
21-18	do.	do.	1945	16	585.7
21-19	do.	do.	1945	22	592.8
21-20	do.	do.	1945	22	593.3
21-21	do.	do.	1945	25	595.7
21-22	do.	City of Holland	1910	4	583.4
21-23	SE NW SE	do.	1910	7	584.1
21-24	SW NE SE	do.	1910	10	583.8
21-27	- NW SE	State Highway Dept.	1946	24	585.2
21-28	do.	do.	1946	25	585.2
21-29	do.	do.	1946	7	590.6
21-30	do.	do.	1946	23	591.1
21-31	do.	do.	1946	21	580.5
21-32	do.	do.	1946	19	580.5
21-33	do.	do.	1946	3	580.5
21-34	do.	do.	1946	20	581.4
21-35	do.	do.	1946	9	580.5
21-36	do.	do.	1946	14	580.8
21-37	- SW SE	City of Holland	1910	14	584.1
21-38	do.	do.	1910	16	584.8
21-39	- NW SE	do.	1910	19	584.0
21-40	- NE SW	do.	1910	14	596.6
21-41	- SE SW	do.	1910	19	584.1
21-43	- SW SE	do.	1910	23	583.8
21-44	- SE SW	do.	1910	12	583.8
21-45	- SW SW	do.	1910	16	583.4
21-46	do.	do.	1910	16	600
21-47	do.	do.	1910	24	600
21-48	do.	do.	1910	8	582.7

Table 6.--Records of borings in the Holland area.--Continued

Number	Location ¼ ¼ ¼	Owner	Year Drilled	Depth	Alti- tude
Ottawa County (T. 5 N., R. 15 W.) Continued					
5N 15W					
21-49	- SW SW	City of Holland	1910	15	605.7
21-51	- NW SW	do.	1910	25	602.8
21-53	do.	do.	1910	16	603.7
21-54	do.	do.	1910	16	603.4
22-1	SE SW NW	State Highway Dept.	1929	24	585.2
22-2	do.	do.	1929	21	584
22-3	do.	do.	1929	21	585.9
22-4	do.	do.	1929	17	584.3
28-1	- NE NE	do.	1952	44	593.6
28-2	do.	do.	1952	35	591.5
28-3	do.	do.	1952	32	599.4
28-4	do.	do.	1952	32	598.7
28-5	do.	do.	1952	33	597.4
28-30	- NW NW	City of Holland	1910	34	600
28-31	SE NW NW	do.	1910	36	600
28-32	- NW NW	do.	1910	36	600
29-2	- SW NE	do.	-	-	582.3
29-3	do.	do.	-	-	584.3
29-4	- SE NE	do.	-	-	595.7
29-5	do.	do.	-	-	598.2
29-6	do.	do.	-	-	597.7
29-7	do.	do.	-	-	600.2
29-8	do.	do.	-	15	601.2
29-22	NW NE NW	do.	1938	58	588.9
29-23	do.	do.	1938	60	584.3
29-24	do.	do.	1938	61	581.3
29-25	do.	do.	1938	55	580.2
29-26	do.	do.	1938	60	583.0
29-27	- - NW	do.	1938	71	582.8
29-28	do.	do.	1938	81	583.0
29-29	do.	do.	1938	84	582.2
29-30	do.	do.	1938	84	580
29-31	NW NE NW	do.	1938	57	580.5
29-32	do.	do.	1938	59	580.5
29-33	do.	do.	1938	68	580.2
29-34	do.	do.	1938	57	581
29-35	do.	do.	1938	60	582.9
29-36	do.	do.	1938	63	585.3
29-37	do.	do.	1938	60	586.1
29-38	do.	do.	1938	63	583.5
29-39	do.	do.	1938	74	585.2
29-40	do.	do.	1938	64	583
29-41	do.	do.	1938	67	582.9
29-42	do.	do.	1938	67	585.7
29-43	do.	do.	1938	61	580.4
29-44	do.	do.	1938	66	584.8
29-45	do.	do.	1938	66	586.6
29-46	do.	do.	1938	61	580.7
29-47	do.	do.	1938	56	589
29-48	do.	do.	1938	62	581
30-1	SE SE NE	Medusa Portland Cement Co.	1938	92	583.6
30-2	do.	do.	1938	82	582.6
30-3	SE SE NE	Medusa Portland Cement Co.	1938	90	584.5
30-4	do.	do.	1938	90	585.6
30-5	do.	City of Holland	1938	68	582.9
30-6	do.	do.	1938	87	583.2
30-7	do.	do.	1938	62	584.2
30-8	do.	do.	1938	80	583.8
30-9	NE NE SE	do.	1938	85	590.7
30-10	do.	do.	1938	77	584.7
30-21	- SW NW	do.	1910	35	600
30-22	- NE NW	do.	1910	31	605
33-6	- SW NE	General Electric Co.	1953	19	653
33-7	do.	do.	1953	22	646
33-10	do.	do.	1953	20	650
33-11	do.	do.	1953	25	645
33-12	do.	do.	1953	18	649
33-13	do.	do.	1953	17	653
33-14	do.	do.	1953	19	656
33-15	do.	do.	1953	20	661
33-17	do.	do.	1953	15	655
33-18	do.	do.	1953	16	650
33-19	do.	do.	1953	19	647
33-20	do.	do.	1953	17	655
33-21	do.	do.	1953	19	662
33-22	do.	do.	1953	21	640
Allegan County (T. 4 N., R. 15 W.)					
4N 15W					
4-3	NW NW SW	State Highway Dept.	-	42	656.0
4-4	do.	do.	-	62	657.3
4-5	SW SW NW	do.	-	52	657.2
4-6	do.	do.	-	44	656.3
4-7	do.	do.	-	38	655.5
4-8	do.	do.	-	63	655.9
4-9	do.	do.	-	52	654.6
4-10	do.	do.	-	40	655.0
4-11	do.	do.	-	49	653.9
4-12	do.	do.	-	50	655.1

Table 7.--Selected information from oil-drilling records in the Holland area.

MDC permit: Michigan Department of Conservation permit number. (Refer requests for logs and related information to the Michigan Geological Survey.)

Altitude in feet above mean sea level; LS - land surface, BR - bedrock surface.

Number	Location ¼ ¼ ¼	MDC Permit	Year Drilled	Altitude LS	Altitude BR
Ottawa County (T. 5 N., R. 16 W.)					
5N 16W					
13-2	NE SE SW	109	1929	604.7	505
23-1	SW NW NW	8092	1940	609.1	279
Ottawa County (T. 5 N., R. 15 W.)					
5N 15W					
14-1	NW NW SW	11035	1944	623.4	488
16-4	- SW SW	6970	1939	612.9	523
16-5	- SE SE	120	1928	618	453
18-4	SW SW SW	15529	1949	614.8	485
19-30	NE SW SE	5593	1938	603.8	476
20-39	NE NW SE	11814	1945	627.6	505
20-40	NE NE SE	5012	1938	602.4	512
21-55	NE SW NE	76	1928	602	565
22-5	NW NW SE	8113	1940	604	542
26-1	SE NE NW	10454	1943	591.4	503
26-2	NW NW NW	7495	1940	633.4	577
27-11	NE SW SW	11662	1945	646.3	522
27-12	SE SW SW	12021	1946	663.6	529
27-13	SW SE SW	11567	1945	668.7	529
27-14	SE NE SW	7490	1940	646	536
27-15	SW NW SE	7454	1940	648.1	545
27-16	SW SW SE	11975	1945	677.0	521
27-17	SE SW SE	11863	1945	680.7	538
27-18	NW SE SE	12057	1946	673.1	515
27-19	SE SE SE	7509	1940	677.1	542
28-73	NW NE NE	4777	1938	600	510
29-10	NE SW NE	7738	1940	583.3	459
33-3	NE NE NE	11314	1945	666.8	555
33-23	NE SW NE	7582	1940	647.1	447
33-28	SW SW SE	12765	1946	651.2	389
34-1	NE NW NW	7440	1940	686.3	526
34-2	NE NE NW	11707	1945	677.6	510
34-3	NW NW NE	8248	1941	675.1	459
34-4	SE NW NE	11789	1945	665.9	419
34-5	SW NW NE	7337	1940	664	439
34-6	SE NE NW	7441	1940	663.4	463
34-7	NW SE NW	11465	1945	663.2	303
34-8	NW SW NE	7585	1940	656.6	362
34-9	NE SW NE	7442	1940	681.2	350
34-10	do.	12246	1946	677.9	366
34-11	SW SE NE	11209	1944	635.4	241
34-13	SE SW NE	11420	1945	657.0	230
34-14	SW SW NE	11507	1945	663.9	186
34-15	SE SE NW	11386	1945	667.0	191
34-17	SW NW SW	7840	1940	666.9	214
34-18	SE NE SW	10908	1944	653.4	300
34-20	NW NW SE	11486	1945	667.6	205
34-23	NE NW SE	11298	1945	650.6	191
Ottawa County (T. 5 N., R. 15 W.) Cont'd)					
5N 15W					
34-24	NW NE SE	11300	1945	658.0	201
34-25	SW NE SE	11014	1944	658.9	247
34-26	SE NW SE	11133	1944	641.8	223
34-27	NE SW SE	11458	1945	671.2	371
34-28	NW SE SE	11011	1944	667.4	367
34-29	SE SE SE	10692	1944	660.8	466
34-30	SW SE SE	11101	1944	657.4	466
34-31	SE SW SE	11214	1944	652.9	433
35-4	SE SE NE	10363	1943	670.8	351
35-5	NW NE NW	7497	1940	629.9	382
35-7	SE SW NW	10953	1944	665.1	171
35-8	SE NW SW	10700	1944	672	276
35-9	NW SW SW	10749	1944	675	332
35-10	SW SW SW	10776	1944	666.5	410
35-11	SE SW SW	10689	1944	664.2	436
35-12	NW SE SW	10954	1944	668.0	346
35-13	SW NW SE	11797	1945	660.2	392
35-14	SE NW SE	11359	1945	665.4	401
35-15	NW SE SE	11925	1945	668.7	399
35-16	NW NE SE	12026	1946	661.9	392
Allegan County (T. 4 N., R. 16 W.)					
4N 16W					
2-1	NE NE SE	5859	1939	640.4	505
11-1	SE SE NE	15142	1949	692.6	497
11-2	- SE NW	647	1929	661	469
Allegan County (T. 4 N., R. 15 W.)					
4N 15W					
2-3	NW NW NE	7483	1940	670.9	471
2-4	NW NE NW	10690	1944	660.3	185
2-5	NW NW NW	10781	1944	660.7	480
2-6	SW NW NW	11056	1944	662.2	519
2-7	SE NW NW	10627	1944	660.5	529
2-8	NW SE NW	10948	1944	660.3	513
2-9	NE SW NW	11104	1944	665.0	531
2-10	NW SW NW	10491	1944	666	556
2-11	SW SW NW	11586	1945	670.2	567
2-12	SE SW NW	10742	1944	670.4	566
2-13	SE SE NW	10323	1943	622.8	528
2-14	NW NE SW	10955	1944	681.8	572
2-15	NE NW SW	11658	1945	672.6	573
2-16	NW NW SW	10229	1943	670.1	580
2-17	NE SW SW	10946	1944	659.3	574
2-18	NW SE SW	10693	1944	663.3	493
2-19	SE NE SW	12750	1946	661.3	551
2-20	SE NE SW	10809	1944	661.4	599

Table 7.--Selected information from oil drilling records in the Holland area.--Continued

Number	Location ¼ ¼ ¼	MDC Permit	Year Drilled	Altitude LS	Altitude BR
Allegan County (T. 4 N., R. 15 W.) Cont'd)					
4N 15W					
2-21	SE SW SE	10092	1943	665.6	586
2-22	SE SE SW	10729	1944	663.2	595
2-23	SW SW SW	5316	1938	661.6	481
3-6	NE NE NE	11134	1944	658.0	484
3-7	NW NE NE	10843	1944	666.8	517
3-8	NE NW NE	11089	1944	642.6	492
3-9	NE NE NW	11255	1945	665.2	515
3-10	SE NW NE	11208	1944	663.0	453
3-11	SW NE NE	11229	1944	671.9	511
3-12	SE NE NE	10614	1944	664.1	518
3-13	NE SE NE	11309	1945	669.0	554
3-14	NW SE NE	11362	1945	662.2	534
3-15	NW SW NE	11823	1945	665.0	512
3-16	NE SE NW	11246	1945	683.8	466
3-17	SW SE NW	11401	1945	713.1	488
3-18	SW SW NE	11699	1945	668.0	458
3-19	SE SW NE	11494	1945	663.8	489
3-20	SW SE NE	11596	1945	652.5	422
3-21	SE SE NE	10438	1943	667.4	572
3-22	SE NE SE	10309	1943	655.5	411
3-23	NW NW SE	11933	1945	673.7	506

Number	Location ¼ ¼ ¼	MDC Permit	Year Drilled	Altitude LS	Altitude BR
Allegan County (T. 4 N., R. 15 W.) Cont'd)					
4N 15W					
3-24	SE SW SW	7491	1940	695.4	525
5-2	NW NE SW	12896	1947	650.5	405
5-3	SE SE SW	12265	1946	687.0	437
6-2	SW NE NE	13694	1947	679.5	444
7-1	NE NW NE	11020	1944	677.2	419
8-1	SW SW NE	13330	1947	670.3	485
9-1	SW SW NW	12467	1946	671.0	461
10-1	SE NW NE	8750	1941	656.2	496
11-1	NE NW NE	10753	1944	681.8	572
11-2	NE NE NW	10900	1944	666.7	571
11-3	NE SE NW	10571	1944	669.2	556
11-4	SE NW NE	10341	1943	675.4	575
11-5	SW NE NE	10711	1944	674.3	560
11-6	SE NE NE	11037	1944	670.1	572
11-7	NE SE NE	10601	1944	665.3	560
11-8	NW SE NE	11437	1945	681.6	580
11-9	SE SW NE	10238	1943	684.2	511
11-10	SW SE NE	10093	1943	674.8	551
11-11	NE NE SE	10405	1943	667.2	452
11-12	SW NE SE	10508	1943	670.4	460

Table 8.--**Logs of wells and test borings in the Holland area.**

Alt.: Altitude approximate or estimated in feet above mean sea level.

Thickness in feet. Depth in feet below land surface.

	Thickness	Depth
5N 16W 13-1 Alt. 595		
Muck	4	4
Sand, fine	26	30
5N 16W 21-1 Alt. 600		
Sand and gravel, sandy	32	32
Sand, very fine	18	50
5N 16W 21-2 Alt. 600		
Sand	21	21
Sand, water-bearing	7	28
5N 16W 21-3 Alt. 605		
Sand	30	30
Sand, clayey	4	34
Sand	6	40
5N 16W 24-1 Alt. 588		
Muck	5	5
Sand, fine	22	27
5N 16W 25-1 Alt. 590		
Sand, fine	27	27
5N 16W 25-2 Alt. 600		
Sand, fine	33	33
5N 16W 28-1 Alt. 585		
Sand, fine to medium, silty	10	10
Sand, medium to coarse, gravelly	8	18
Sand, buff, fine, silty	21	39
Sand, gray, fine, silty	15	54
5N 16W 33-1 Alt. 586		
Sand, beach	7	7
Sand, medium to coarse, gravelly	13	20
Sand, fine to medium	6	26
Sand, fine, hard, clayey, silty	74	100
5N 16W 33-2 Alt. 586		
Sand, beach	8	8
Sand, medium to coarse, gravelly	16	24
Sand, fine to medium	25	49
Sand, coarse, gravelly	3	52
Clay, gray, hard, sandy	18	70
5N 16W 33-3 Alt. 585		
Sand, beach	5	5
Sand, medium to coarse, and medium gravel	18	23
Sand, medium	7	30
Sand, medium, gravelly	4	34
5N 16W 33-4 Alt. 586		
Sand, beach	3	3
Sand, medium to coarse, and medium gravel	34	37
Sand, fine, silty	7	44
Clay balls	1	45
5N 16W 33-5 Alt. 595		
Sand, tan, coarse	25	25
Sand, fine to coarse, and gravel	5	30
Sand, coarse	5	35
Sand, tan, coarse, and gravel	5	40
5N 16W 33-5 Cont'd.		
Sand, tan, coarse	27	67
Sand and gravel	3	70
Clay and sand	15	85
Sand, gray, fine to medium, clayey	33	118
Sand, tan, fine to medium	13	131
Clay, sandy	5	136
Clay, gray, and shale	40	176
Shale, blue	81	257
5N 16W 33-7 Alt. 595		
Sand	30	30
Clay, red	3	33
Sand	10	43
Clay, red	5	48
Sand	15	63
Clay, red	7	70
Gravel	10	80
5N 16W 33-9 Alt. 586		
Sand, fine to medium	19	19
Sand, fine to medium, and gravel	5	24
Sand, fine to medium	36	60
Sand, fine to medium, and medium gravel	9	69
Sand, fine to medium, silty, clay balls	13	82
Sand, silty, hard, and clay balls	9	91
Clay, gray, sandy	8	99
5N 16W 33-10 Alt. 585		
Sand, beach	5	5
Sand, medium to coarse, and medium gravel	30	35
Sand, silty, fine	3	38
5N 16W 33-11 Alt. 593		
Sand, fine to medium, and silt	19	19
Sand, medium to coarse	41	60
Clay, gray	1	61
Sand, medium to coarse	9	70
Sand, coarse, and clay balls	3	73
Sand, medium to coarse	3	76
Clay, black, and sand, interbedded	6	82
Clay, blue to gray, soft	13	95
5N 16W 36-1 Alt. 600		
Soil	1	1
Sand, brown	12	13
Sand, water-bearing	5	18
Clay, sandy	38	56
Sand, fine	4	60
Gravel, water-bearing	1	61
Sand, fine	5	66
Clay, sandy	36	102
Sand, coarse	9	111
5N 16W 36-2 Alt. 630		
Sand	24	24
Sand, water-bearing	4	28
5N 16W 36-3 Alt. 610		
Sand	15	15
Clay	15	30
Gravel, clayey	5	35
5N 16W 36-4 Alt. 620		
Sand	14	14
Clay	1	15
Sand, clay, and gravel	98	113
Sand	6	119
Clay	-	-
5N 15W 16-1 Alt. 610		
Soil and sand	2	2
Sand	1	3
Clay	-	-
5N 15W 16-2 Alt. 610		
Soil and sand	2	2
Sand	10	12
Clay	-	-
5N 15W 16-3 Alt. 610		
Sand	10	10
Clay	-	-
5N 15W 17-1 Alt. 620		
Sand, fine, and clay	24	24
Clay	-	-
5N 15W 18-1 Alt. 610		
Sand, fine	31	31
5N 15W 18-3 Alt. 600		
Sand, fine	26	26
5N 15W 20-1 Alt. 589		
Sand, fill	10	10
Muck, wood fragments	4	14
Sand, wood fragments	17	31
Clay, marl	14	45
Sand	5	50
Gravel	-	-
5N 15W 20-2 Alt. 590		
Sand, fill	13	13
Muck	2	15
Sand, wood fragments	18	33
Clay, marl	12	45
Sand	18	63
Gravel	-	-
5N 15W 20-3 Alt. 582		
Water	15	15
Sand	5	20
Clay, marl	21	41
Sand, water-bearing	7	48
Gravel	-	-
(Boring in river bottom)		
5N 15W 20-4 Alt. 582		
Water	2	2
Mud	4	6
Sand, wood fragments	14	20
Clay, marl	23	43
Sand, water-bearing	5	48
(Boring in river bottom)		
5N 15W 20-5 Alt. 581		
Ashes, river silt	3	3
Sand, gray, coarse	10	13
Gravel, compact	4	17
Sand, gray, fine	8	25
Clay, lake	21	46
Sand, gray	4	50
Rock	-	-

Table 8.-- Logs of wells and test borings in the Holland area.--Continued

	Thick-ness	Depth
5N 15W 20-6 Alt. 581		
Silt, river	3	3
Sand, gray, water-bearing	3	6
Sand, gray, coarse	25	31
No record	15	46
Sand, gray	3	49
Rock	-	-
5N 15W 20-7 Alt. 589		
Sand and gravel	10	10
Sand, gray, coarse	10	20
Gravel, fine	11	31
No record	18	49
Sand, gray	11	60
Rock	-	-
5N 15W 20-8 Alt. 582		
Sand, gray, coarse	21	21
No record	17	38
Sand, gray, coarse	15	53
Rock	-	-
5N 15W 20-16 Alt. 584		
Muck and fill	7	7
Sand	18	25
Silt	30	55
Sand	4	59
Sand and gravel	5	64
5N 15W 20-17 Alt. 583		
Muck and fill	7	7
Sand	15	22
Silt	29	51
Sand, gas reported	6	57
Sand and gravel	5	62
Clay and stones	-	-
5N 15W 20-18 Alt. 584		
Fill	7	7
Sand, coarse	16	23
Silt, brown, soft	20	43
Sand, coarse, gas reported	19	62
Clay, gravel, and sand, hard	8	70
Stones and hardpan	-	-
5N 15W 20-19 Alt. 583		
Fill and muck	6	6
Sand	11	17
Sand and silt	5	22
Silt	24	46
Sand, gas reported	11	57
Sand and gravel	6	63
Clay	-	-
5N 15W 20-20 Alt. 584		
Fill	2	2
Muck	5	7
Sand	17	24
Gravel, fine	4	28
Clay, sandy	10	38
Clay	7	45
5N 15W 20-21 Alt. 584		
Fill	6	6
Sand and gravel	9	15
Sand	22	37
Clay	-	-
5N 15W 20-22 Alt. 586		
Fill	11	11
Sand, medium	19	30
Sand, seams of clay	14	44
Clay	18	62
Hardpan	-	-
5N 15W 20-23 Alt. 588		
Fill	8	8
Sand	15	23
5N 15W 20-23 Cont'd.		
Sand and gravel	4	27
Clay, sandy	13	40
5N 15W 20-24 Alt. 591		
Fill	9	9
Sand, medium	20	29
Sand, seams of clay	24	53
Clay	14	67
Hardpan	-	-
5N 15W 20-25 Alt. 604		
Sand	37	37
Silt and clay	15	52
5N 15W 20-26 Alt. 591		
Fill	2	2
Sand	14	16
Sand, fine, and silt	19	35
Clay	-	-
5N 15W 20-27 Alt. 592		
Fill	6	6
Sand	16	22
Sand, coarse	3	25
Sand, very fine	9	34
Sand, very fine, and clay	2	36
Clay	4	40
5N 15W 20-28 Alt. 592		
Fill	8	8
Sand, medium	5	13
Sand, fine	16	29
Sand, seams of clay	19	48
Clay	18	66
Hardpan	-	-
5N 15W 20-29 Alt. 591		
Fill	7	7
Sand	18	25
Sand and gravel	3	28
Clay, sandy	4	32
Clay, soft	32	64
Hardpan	-	-
5N 15W 20-30 Alt. 587		
Sand	17	17
Sand and gravel	4	21
Sand, fine, and clay	11	32
Clay, soft	29	61
Clay and stones	10	71
Hardpan	-	-
5N 15W 20-31 Alt.		
Fill	5	5
Sand	10	15
Sand and gravel	11	26
Clay, soft	39	65
Clay and small stones	13	78
Hardpan	-	-
5N 15W 20-32		
Fill	7	7
Sand	26	33
Sand, very fine, and clay	7	40
Clay, soft	30	70
Clay and stones	13	83
Hardpan	-	-
5N 15W 20-33 Alt. 605		
Fill	5	5
Sand, medium	19	24
Sand, seams of clay	38	62
Clay	5	67
5N 15W 20-34 Alt. 605		
Fill	5	5
Sand, coarse	9	14
5N 15W 20-34 Cont'd.		
Sand, fine	15	29
Sand, seams of clay	33	62
Clay	6	68
5N 15W 20-35 Alt. 588		
Fill	3	3
Sand and gravel	20	23
Clay, soft	40	63
Clay with stones	12	75
5N 15W 20-36 Alt. 587		
Fill	7	7
Clay, sandy, soft	11	18
Clay, soft	44	62
Clay and stones	17	79
Hardpan	-	-
5N 15W 20-37 Alt. 590		
Cinders	1	1
Sand	15	16
Sand and gravel	5	21
Clay, soft	44	65
Clay and stones	16	81
5N 15W 20-38 Alt. 586		
Fill	6	6
Muck	12	18
Sand, coarse	5	23
Silt	20	43
Silt and sand	5	48
Sand and clay	5	53
Sand	3	56
Clay	-	-
5N 15W 21-1 Alt. 596		
Sand	7	7
Clay	1	8
5N 15W 21-2 Alt. 590		
Sand, fine	7	7
Rock (?)	1	8
5N 15W 21-3 Alt. 602		
Sand	5	5
Clay	1	6
5N 15W 21-4 Alt. 601		
Sand, medium, gravelly	8	8
Clay, blue, soft	1	9
Sand, gray, medium, and blue clay	1	10
Clay, blue, plastic, sandy, gravelly	1	11
Sandstone, hard	1	12
Sandstone and shale interbedded	2	14
Sandstone, hard	1	15
Shale, blue, hard	1	16
Sandstone, gray	3	19
Shale, sandy, hard	3	22
Sandstone and shale interbedded, hard	1	23
5N 15W 21-5 Alt. 601		
Sand, yellow-brown, medium, gravelly	8	8
Clay, blue, plastic, and gravel	2	10
Clay, blue, sand, and gravel	2	12
Sand, gray, fine	1	13
Sand, fine, gravelly, and clay	1	14
Gravel, coarse, and blue clay, sandy	1	15
Clay, blue, stiff, gravelly	1	16
Sand, gray, fine	1	17
Clay, blue, stiff	1	18
Gravel and coarse sand	2	20
Sandstone, hard	1	21

Table 8.--Logs of wells and test borings in the Holland area.--Continued

	Thickness	Depth
5N 15W 21-6 Alt. 602		
Sand and gravel	8	8
Clay, blue, plastic, gravelly	6	14
Sand, gray, blue clay, and gravel	2	16
Clay, blue, gravelly	2	18
Sand, gray, fine	2	20
Clay, blue, hard	1	21
Sand, gray, fine	1	22
Sandstone, hard	1	23
5N 15W 21-7 Alt. 601		
Sand, yellow, medium, and gravel	7	7
Clay, blue, plastic, and gravel	5	12
Sand, gray, fine	1	13
Clay, blue, gravelly	3	16
Clay, blue	1	17
Gravel, sandy	1	18
Gravel, hard, and sand, cemented	1	19
5N 15W 21-8 Alt. 602		
Sand	6	6
Clay	-	-
5N 15W 21-9 Alt. 601		
Sand, fine to coarse	14	14
Clay	1	15
5N 15W 21-10 Alt. 603		
Sand	8	8
Sand, coarse	16	24
5N 15W 21-11 Alt. 598		
Sand	12	12
Sand, hardpacked	2	14
Clay	2	16
5N 15W 21-12 Alt. 604		
Sand	3	3
Sand, coarse	6	9
Clay, sandy	1	10
Sand	13	23
Clay	-	-
5N 15W 21-13 Alt. 595		
Sand, fine	5	5
Sand, coarse	13	18
Clay	-	-
5N 15W 21-14 Alt. 594		
Sand, fine	6	6
Clay	8	14
5N 15W 21-16 Alt. 590		
Sand and gravel	6	6
Clay	-	-
5N 15W 21-17 Alt. 586		
Water	1	1
Soil, peaty	1	2
Sand, yellow	2	4
Clay, yellow to blue, silty	2	6
Clay, blue, and sandstone	1	7
Sandstone, gray and shale	2	9
Shale, blue, and sandstone	3	12
Sandstone	-	-
(Boring in river bottom)		
5N 15W 21-18 Alt. 586		
Water	1	1
Soil, peaty	1	2
Sand, yellow, and gravel	2	4
5N 15W 21-18 Cont'd.		
Clay, yellow to blue	4	8
Clay, blue, and sandstone	2	10
Shale, blue	2	12
Sandstone	1	13
Shale, blue, and sandstone	3	16
Sandstone	-	-
(Boring in river bottom)		
5N 15W 21-19 Alt. 593		
Sand and gravel, fill	5	5
Cinders, fill	4	9
Sand, yellow, clay, and gravel	2	11
Clay, yellow, sandy	1	12
Sand, yellow to gray, and clay	2	14
Clay, blue, silty and sandstone	3	17
Sandstone	5	22
5N 15W 21-20 Alt. 593		
Cinders, fill	3	3
Clay, blue, and thin sand lenses	4	7
Clay, blue	2	9
Sand, gravelly, and clay	1	10
Sand, gray, fine	10	20
Clay, sand, and gravel	1	21
Sand and sandstone	1	22
5N 15W 21-21 Alt. 596		
Sand, brown	2	2
Sand, yellow	2	4
Clay, yellow to blue, sandy	2	6
Clay, yellow to blue, sandy, gravelly	3	9
Clay, blue, sandy	2	11
Sand, yellow to gray, fine	2	13
Sand, gray, fine	10	23
Clay, blue, and sand, fine	2	25
Sandstone	1	26
5N 15W 21-22 Alt. 583		
Clay, sand, and gravel	4	4
Sandstone	-	-
5N 15W 21-23 Alt. 584		
Soil, sandy, black	3	3
Sand	3	6
Clay	1	7
5N 15W 21-24 Alt. 584		
Clay and sand	6	6
Clay	4	10
Sandstone	-	-
5N 15W 21-26 Alt. 592		
Sand, clean	5	5
Sand and gravel	10	15
Clay and gravel	5	20
Sandstone and fine gravel	20	40
Clay, blue	5	45
5N 15W 21-27 Alt. 582		
Topsoil, sandy	2	2
Sand, yellow, fine	4	6
Sand, yellow, fine, peaty	2	8
Sand, peaty	4	12
Peat, sandy	4	16
Sand, gray, medium to coarse	5	21
Sand, fine, gravel, and sandstone	4	25
5N 15W 21-28 Alt. 585		
Sand	2	2
Sand, yellow, fine	4	6
Sand, yellow, fine, and clay blue	2	8
Sand, medium, peaty	5	13
Peat and sand	4	17
Sand, fine, peaty	2	19
Sand, medium to coarse, and fine gravel	3	22
Sand, fine, and fine gravel	2	24
Sandstone, soft to hard	1	25
5N 15W 21-29 Alt. 591		
Sand, brown to yellow	1	1
Soil, yellow, sandy	1	2
Clay, blue to yellow, sandy, plastic	1	3
Clay, blue to yellow, firm	3	6
Clay, blue to yellow, and gravel	1	7
Sand, yellow, and fine gravel	1	8
Sandstone, hard	-	-
5N 15W 21-30 Alt. 591		
Sand, brown to yellow	1	1
Clay, blue to yellow, plastic	1	2
Clay, blue to yellow, silty	4	6
Clay, blue to yellow, sandy	1	7
Sand, yellow, gravelly	1	8
Clay, blue, sandy, gravelly	2	10
Sand, yellow, fine, and sandstone	9	19
Shale, blue, and very fine gray sand	1	20
Shale, blue, silty, with sandstone	3	23
Sandstone, hard	-	-
5N 15W 21-31 Alt. 580		
Water	4	4
Sand, peaty, and silt	4	8
Peat, soft	2	10
Sand, gray, medium	4	14
Gravel and shells	2	16
Sand, gravel, and clay	2	18
Clay, blue, plastic, silty	4	22
Sandstone, hard	-	-
(Boring in river bottom)		
5N 15W 21-32 Alt. 580		
Water	4	4
Silt and clay	1	5
Sand, wood fragments	4	9
Peat, soft	4	13
Sand, gray, and gravel	3	16
Sand, gravel, and sandstone	2	18
Shale, blue, soft, and sandstone	2	20
(Boring in river bottom)		
5N 15W 21-33 Alt. 580		
Water	3	3
Sandstone, yellow, hard	1	4
(Boring in river bottom)		
5N 15W 21-34 Alt. 581		
Water	1	1
Clay, soft, and silt	1	2
Sand, yellow, and sandstone	6	8
Shale, blue, and sandstone	2	10
Shale, blue, hard	9	19
Sandstone, hard	1	20
(Boring in river bottom)		

Table 8.--Logs of wells and test borings in the Holland area.--Continued

	Thickness	Depth
5N 15W 21-35 Alt. 580		
Water	3	3
Sand, yellow and sandstone	1	4
Sandstone, yellow, soft	4	8
Sandstone, yellow, hard	1	9
(Boring in river bottom)		
5N 15W 21-36 Alt. 581		
Sand, yellow to gray, clay and silt	1	1
Sand, brown, fine	1	2
Sandstone, yellow, hard	3	5
5N 15W 21-37 Alt. 584		
Clay	3	3
Sand, very fine	4	7
Sand and clay	5	12
Sand, coarse	2	14
Sandstone	-	-
5N 15W 21-38 Alt. 585		
Clay and soil	3	3
Sand, fine	4	7
Sand and clay	5	12
Sand, coarse	4	16
Sandstone	-	-
5N 15W 21-39 Alt. 584		
Muck	16	16
Sand	2	18
Clay, hard	1	19
5N 15W 21-40 Alt. 596		
Sand, fine	4	4
Sand, coarse	5	9
Clay	5	14
5N 15W 21-41 Alt. 584		
Muck	15	15
Sand and clay	3	18
Clay or stone	1	19
5N 15W 21-42 Alt. 586		
Clay, sandy	7	7
Gravel, coarse, and coarse sand	10	17
Clay, gray, soft	3	20
Clay, blue, sandy	3	23
Clay, gray, sandy	9	32
Sandstone, gray	2	34
5N 15W 21-43 Alt. 584		
Muck and clay	14	14
Sand, very fine, and clay	6	20
Sand	3	23
5N 15W 21-44 Alt. 584		
Muck	2	2
Sand, coarse	10	12
Clay	-	-
5N 15W 21-45 Alt. 583		
Sand, coarse, and clay	2	2
Sand, fine, dirty	14	16
Clay	1	17
5N 15W 21-46 Alt. 583		
No record	13	13
Clay	3	16
5N 15W 21-47 Alt. 600		
Muck	23	23
Sand	1	24

	Thickness	Depth
5N 15W 21-48 Alt. 583		
Gravel	8	8
Clay	-	-
5N 15W 21-49 Alt. 606		
Sand, fine	15	15
Sandstone and shale	-	-
5N 15W 21-50 Alt. 583		
Muck, black, clay, and gravel	21	21
Clay, gray, soft, and gravel	10	31
Sand, medium to coarse, and gravel	2	33
Clay, gray, hardpan	5	38
Clay, gray	6	44
Sandstone	1	45
5N 15W 21-51 Alt. 603		
Sand, fine to coarse	24	24
Clay	1	25
5N 15W 21-52 Alt. 592		
Sand, medium to coarse, gravel	10	10
Clay, sandy	28	38
Clay, gray, hard	14	52
Shale, blue	13	65
5N 15W 21-53 Alt. 604		
Sand, fine to coarse	16	16
Clay	-	-
5N 15W 21-54 Alt. 603		
Sand, fine to coarse	16	16
Clay	-	-
5N 15W 22-1 Alt. 585		
Sand, yellow	4	4
Sand, gray, fine	8	12
Gravel, coarse, sandy	8	20
Clay, blue, hard	4	24
5N 15W 22-2 Alt. 584		
Sand, fine	12	12
Gravel, fine	3	15
Clay, blue, hard	6	21
5N 15W 22-3 Alt. 586		
Soil, sandy	5	5
Clay, blue, sandy, hard	4	9
Gravel, fine	3	12
Clay, blue, hard, stony	9	21
5N 15W 22-4 Alt. 584		
Sand, yellow	3	3
Clay, blue	2	5
Sand, water-bearing	6	11
Gravel, fine	2	13
Gravel, coarse, compact	4	17
5N 15W 27-1 Alt. 607		
Top soil	3	3
Clay, blue, firm	25	28
Clay, blue, and fine gravel	32	60
5N 15W 27-2 Alt. 610		
Soil	5	5
Clay, hard	18	23
Clay, sandy	7	30
Clay, gravelly	10	40
Clay, blue	82	122

	Thickness	Depth
5N 15W 27-3 Alt. 640		
Sand	20	20
Clay	30	50
Sand	3	53
Clay	16	69
Sandstone	3	72
5N 15W 27-4 Alt. 639		
Sand, clean	5	5
Sand and gravel	15	20
Clay, blue, soft, sandy	98	118
Clay, blue, hard	42	160
5N 15W 27-5 Alt. 643		
Soil	2	2
Sand, clean	13	15
Clay, red	3	18
Clay, blue, firm	57	75
Clay, soft, sandy	54	129
Sand, water-bearing	12	141
Clay, blue	5	146
5N 15W 27-6 Alt. 642		
Soil	2	2
Sand, brown	3	5
Clay, blue	43	48
Sand, muddy	7	55
Sand, coarse, clean	25	80
Sand, medium	35	115
Gravel and sand	15	130
Sand, medium	10	140
Sand and gravel	10	150
Gravel, coarse	10	160
Shale	1	161
5N 15W 27-7 Alt. 642		
Soil	2	2
Clay, sandy	8	10
Clay, blue	40	50
Sand and gravel	55	105
Gravel and sand	56	161
Clay	5	166
5N 15W 27-9 Alt. 647		
Soil	2	2
Clay, red	13	15
Clay, blue	30	45
Sand, coarse, and fine gravel	27	72
Sand, sharp	10	82
Gravel, fine, and coarse sand	22	104
Sand, coarse	8	112
Sand, coarse, and gravel	3	115
Gravel, fine, clean	15	130
Sand, coarse, and gravel	1	131
Gravel, fine, clean	16	147
Sand, coarse, and gravel	2	149
Gravel, fine, and sand	21	170
Clay, blue	5	175
5N 15W 27-10 Alt. 655		
Soil	1	1
Clay, brown	4	5
Clay, blue	43	48
Sand, muddy	7	55
Sand, coarse	25	80
Sand and clay, interbedded	27	107
Sand, medium	8	115
Gravel, coarse	15	130
Sand, medium	5	135
Sand and gravel, interbedded	21	156
Sand and gravel	3	159

Table 8.--Logs of wells and test borings in the Holland area.--Continued

	Thickness	Depth
5N 15W 27-10 Cont'd.		
Clay	1	160
Sand and gravel	2	162
Gravel, coarse	4	166
Sand and gravel, clay balls	12	178
Clay	1	179
5N 15W 28-1 Alt. 594		
Soil	1	1
Clay, blue, plastic, pebbly, sandy	3	4
Sand and gravel, clayey	2	6
Sandstone	1	7
Sand and gravel	1	8
Sand, yellow, fine, silty	2	10
Sand, yellow, fine to medium	8	18
Sand, yellow to gray, fine	23	41
Sand and gravel	2	43
Sandstone, soft	1	44
Sandstone, hard	-	-
5N 15W 28-2 Alt. 591		
Soil	1	1
Sand, yellow, fine	2	3
Sand, yellow, fine, gravelly	1	4
Sandstone, soft	1	5
Gravel	2	7
Sand and gravel, silty	1	8
Sand, yellow, fine to medium, gravelly	7	15
Gravel, fine to medium, sandy	5	20
Sand, yellow, fine to coarse	3	23
Sand, yellow, fine	5	28
Sand, gray, fine, silty	1	29
Clay, blue, stiff, sandy	1	30
Sandstone, soft	1	31
Sand, gray, fine, silty, gravelly	1	32
Sand and gravel, compact	1	33
Sandstone, soft	1	34
Sandstone, hard	1	35
5N 15W 28-3 Alt. 599		
Sand, fill	3	3
Clay, yellow to blue	2	5
Clay, blue, silty	1	6
Clay, blue, plastic, sandy	1	7
Sand, gravel, and clay	1	8
Sand, yellow, fine to coarse, silty	9	17
Sand, yellow, coarse	1	18
Sand, yellow, fine	3	21
Clay, blue, stiff	2	23
Sand, gray, fine, and medium to coarse gravel	1	24
Shale, blue	1	25
Sandstone, soft	1	26
Sandstone, gray	3	29
Shale, blue, firm	1	30
Sandstone, gray	2	32
5N 15W 28-4 Alt. 599		
Sand and gravel	5	5
Soil, sandy	1	6
Sand, yellow, medium	1	7
Clay, yellow to blue, firm, sandy, gravelly	3	10
Clay, blue, stiff	1	11
Boulder	8	19
Clay, blue, stiff, sandy, gravelly	1	20
Sand, gray, fine	1	21
Sand, yellow to gray, medium	1	22
5N 15W 28-4 Cont'd.		
Gravel, clayey	1	23
Sand, gray, fine to coarse and coarse gravel	2	25
Sand, gray, fine, silty, and coarse gravel	3	28
Sand, gray, fine, silty	2	30
Sandstone, soft to hard	2	32
5N 15W 28-5 Alt. 597		
Sand, fill	5	5
Clay, yellow to blue, firm	2	7
Sandstone, brown, soft	1	8
Clay, blue, pebbly, sandy	7	15
Sand, yellow, medium to coarse, and gravel	2	17
Sand, gray, fine, silty, and gravel	3	20
Sandstone, soft	1	21
Sand, gray, fine, silty	4	25
Clay, blue, stiff	1	26
Sand, gray, fine, silty	3	29
Sandstone, soft	1	30
Sand, gray, fine, silty, and gravel	3	33
Sandstone, hard	-	-
5N 15W 28-6 Alt. 577		
Drift	135	135
5N 15W 28-7 Alt. 598		
Soil	3	3
Clay, sandy	15	18
Sand, dry	6	24
Sand, sharp, water-bearing	16	40
Sandstone	4	44
Shale, blue	36	80
5N 15W 28-8 Alt. 610		
Sand	58	58
5N 15W 28-9 Alt. 605		
Clay	10	10
Sand, fine	30	40
Sand, coarse	43	83
Sand, coarse, and gravel	13	96
Clay	-	-
5N 15W 28-10 Alt. 606		
Soil	2	2
Clay, hard	14	16
Sand, medium to coarse	95	121
Sand, coarse, and gravel	6	127
Clay, blue	5	132
5N 15W 28-11 Alt. 610		
Soil	2	2
Clay, blue	27	29
Sand, sharp	76	105
Sand, coarse	19	124
Clay, blue	5	129
5N 15W 28-12 Alt. 600		
Soil	5	5
Clay	15	20
Sand, medium	20	40
Gravel	13	53
Sand, medium	51	104
Clay	-	-
5N 15W 28-13 Alt. 600		
Sand, very fine	60	60
Sand, fine	15	75
Sand, coarse	20	95
Gravel, coarse	33	128
Clay	-	-
5N 15W 28-14 Alt. 600		
Soil	20	20
Sand, very fine	55	75
Sand, fine	54	129
Sand, medium, and gravel	5	134
5N 15W 28-15 Alt. 600		
Sand	8	8
Clay	8	16
Sand, medium to coarse	67	83
Sand, coarse	53	136
Gravel	9	145
Clay	-	-
5N 15W 28-16 Alt. 600		
Sand	22	22
Clay, blue, and boulders	10	32
Clay, blue, and gravel	19	51
Clay, blue, soft, sandy	49	100
5N 15W 28-18 Alt. 600		
Sand and gravel	7	7
Clay, blue, sandy	28	35
Sand, water-bearing	52	87
5N 15W 28-19 Alt. 600		
Sand	20	20
Clay	40	60
Shale	3	63
Clay, blue	57	120
Sandstone	1	121
Clay, blue	14	135
Clay	5	140
Clay and shale	40	180
5N 15W 28-20 Alt. 600		
Sand	9	9
Clay, blue	29	38
Sand, water-bearing	40	78
5N 15W 28-21 Alt. 600		
Clay, marsh	11	11
Clay, blue	8	19
Sand, yellow, and gravel	8	27
Sand, water-bearing	52	79
Sand and gravel	3	82
Clay, sandy	6	88
Sand, water-bearing	2	90
Clay, blue	3	93
5N 15W 28-22 Alt. 600		
Clay, marsh	22	22
Clay, blue, soft	5	27
Sand, very fine, water-bearing	48	75
Sand, fine	13	88
5N 15W 28-23 Alt. 600		
Sand	8	8
Clay, blue	39	47
Sand, medium to coarse, water-bearing	50	97
Sand, water-bearing, and blue clay	8	105
Clay, blue	2	107
5N 15W 28-24 Alt. 584		
Muck, black	22	22
Clay, sandy	10	32
Sand, medium	3	35
Boulders	1	36
Sand, fine to medium, silty	68	104
Hardpan	2	106
Clay, blue	6	112

Table 8.--Logs of wells and test borings in the Holland area.--Continued

	Thickness	Depth
5N 15W 28-25 Alt. 600		
Sand	9	9
Clay, blue, and boulders	35	44
Clay, blue, and sand, interbedded	58	102
5N 15W 28-26 Alt. 600		
Sand	7	7
Sand and gravel	27	34
Gravel, clay, blue, and boulders	6	40
Clay, blue, and boulders	7	47
Clay, blue, and sand, interbedded	53	100
5N 15W 28-27 Alt. 600		
Sand	8	8
Sand and gravel	22	30
Gravel and clay, blue	6	36
Clay, blue, and boulders	11	47
Sand	5	52
Clay, blue, soft, and boulders	13	65
Sand	3	68
Clay, blue	15	83
5N 15W 28-28 Alt. 600		
Soil, sandy	16	16
Clay, gravelly	11	27
Sand, gravel, and blue clay	10	37
Sand and clay, interbedded	37	74
5N 15W 28-30 Alt. 600		
Muck	32	32
Sand, coarse	2	34
5N 15W 28-31 Alt. 600		
Muck	32	32
Sand	4	36
Clay	-	-
5N 15W 28-32 Alt. 600		
Muck	34	34
Gravel	2	36
5N 15W 28-33 Alt. 600		
Clay, soft	30	30
Clay, gray, hard	21	51
Clay and gravel	1	52
Clay, gray, and boulders	8	60
Sand, fine, silty	8	68
Clay, blue, and boulders	2	70
Clay, blue, hard	10	80
5N 15W 28-34 Alt. 582		
Clay, soft	32	32
Clay, gray, hard, and boulders	10	42
5N 15W 28-35 Alt. 582		
Clay, blue, soft	32	32
Clay, gray, hard	19	51
Sand and gravel	1	52
Boulders and clay, gray	5	57
Sand, fine to medium, silty, and gray clay	8	65
5N 15W 28-36 Alt. 582		
Clay, gray, soft	22	22
Sand, clay, and silt, water-bearing	10	32
Sand, fine, and gravel	10	42
Silt, clayey	8	50
Clay, gray, hardpan	10	60
Clay, gray	7	67
Clay, blue	-	-
5N 15W 28-37 Alt. 600		
Clay, marsh	22	22
Sand and gravel	9	31
Clay, blue	12	43
Clay, blue, and rock	17	60
5N 15W 28-39 Alt. 608		
Soil	2	2
Sand, fine, and blue clay	15	17
Clay, blue, sand, and gravel	20	37
5N 15W 28-40 Alt. 607		
Soil	2	2
Sand, fine, and blue clay	15	17
Clay, blue, sand, and gravel	13	30
Clay, blue, and boulders	34	64
5N 15W 28-41 Alt. 600		
Clay	30	30
Gravel, fine	5	35
Sand, medium	43	78
Clay	34	112
5N 15W 28-42 Alt. 600		
Soil	10	10
Clay	10	20
Gravel	110	130
5N 15W 28-43 Alt. 600		
Soil	2	2
Sand	3	5
Clay	19	24
Gravel and boulders	20	44
Sand	5	49
Sand, clean	12	61
Gravel, small boulders	12	73
Rock	-	-
5N 15W 28-44 Alt. 600		
Soil	3	3
Sand	5	8
Clay, gray	12	20
Clay and gravel	3	23
Gravel and boulders	25	48
Gravel, fine	14	62
Gravel and stones	73	135
Shale	5	140
5N 15W 28-45 Alt. 600		
Sand, clay, and gravel	8	8
Gravel, clayey	15	23
Sand and gravel, clayey	25	48
Sand and gravel	39	87
Sand, gravel, and clay, interbedded	8	95
Sand and gravel	36	131
5N 15W 28-46 Alt. 600		
Clay, fill	20	20
Gravel, fine	9	29
Sand, coarse	5	34
Sand, medium, and gravel	21	55
Gravel, coarse to fine	28	83
5N 15W 28-47 Alt. 605		
Soil	1	1
Sand and gravel	3	4
Clay, blue	6	10
Clay and gravel	9	19
Sand, fine	7	26
Sand, medium	12	38
Sand, fine, and gravel	9	47
Sand and gravel	5	52
Sand, coarse, and gravel	5	57
Sand and gravel	26	83
Clay, blue, and gravel	-	-
5N 15W 28-48 Alt. 605		
Soil	3	3
Clay, blue, and gravel	15	18
Sand and gravel	9	27
Sand, coarse	12	39
Sand and gravel	11	50
Sand, coarse	9	59
Gravel and boulders	26	85
Clay, blue	2	87
Gravel and boulders	3	90
Rock	-	-
5N 15W 28-49 Alt. 605		
Soil	4	4
Clay	21	25
Sand, coarse	13	38
Gravel	34	72
Sand, gravelly	12	84
Sand, clayey	7	91
5N 15W 28-50 Alt. 605		
Soil	2	2
Clay, very hard	11	13
Sand, fine, and gravel	4	17
Sand, fine	18	35
Gravel, coarse	2	37
Sand, fine, and gravel	33	70
Gravel, very coarse	20	90
Gravel, coarse, and sand	21	111
Clay	3	114
5N 15W 28-65 Alt. 610		
Soil	5	5
Clay, blue, hard	10	15
Sand, coarse, and fine gravel	100	115
Clay, balls, soft	1	116
Sand, coarse	10	126
Sand, fine	8	134
Gravel, coarse, clay	6	140
Clay, blue, hard	2	142
5N 15W 28-66 Alt. 616		
Soils	3	3
Clay, blue, hard	12	15
Gravel, medium	85	100
Sand, coarse, clean	5	105
Sand and gravel	25	130
Clay and gravel	5	135
Clay, blue, hard	5	140
5N 15W 28-67 Alt. 620		
Soil	4	4
Clay	16	20
Sand, coarse	25	45
Gravel, coarse	27	72
Clay	-	-
5N 15W 28-68 Alt. 620		
Soil	4	4
Clay	89	93
5N 15W 28-69 Alt. 634		
Soil	2	2
Sand and gravel	16	18
Clay, blue	14	32
Clay, brown, hardpan	6	38
Clay, gray, hard	23	61
Sand and clay, water-bearing	8	69
Sand, yellow to gray, coarse, fine to coarse, and gravel	41	110
Sand, coarse, medium gravel, and clay balls, silty	10	120
Sand, medium to coarse, and silt	9	129

Table 8.--Logs of wells and test borings in the Holland area.--Continued

	Thick-ness	Depth
5N 15W 28-69 Cont'd.		
Sand, coarse, medium to coarse, gravel, boulders, and silt	9	138
Boulders and medium to coarse gravel	7	145
Sand, coarse, and medium gravel	9	154
Sand, cemented, and gravel	2	156
Clay, blue, hard	4	160
5N 15W 28-70 Alt. 635		
Sand and gravel	15	15
Clay, blue	39	54
Sand, coarse, clean	36	90
Sand, sharp, clayey	4	94
Sand, coarse	6	100
Sand, fine, and gravel	12	112
Gravel, fine, clean	3	115
Sand, coarse, and fine gravel	15	130
Gravel, coarse, and clay	5	135
Clay, blue	5	140
5N 15W 28-72 Alt. 662		
Soil	2	2
Clay, yellow	10	12
Clay, blue	48	60
Clay, red	20	80
Sand	5	85
Clay, red	15	100
Sand and gravel	5	105
Sand, coarse	53	158
Clay, blue	5	163
5N 15W 29-1 Alt. 585		
Sand	27	27
Clay, blue, sand, gravel, and boulders	51	78
5N 15W 29-8 Alt. 601		
Sand	7	7
Sand and gravel	6	13
Sand	2	15
5N 15W 29-9 Alt. 600		
Sand, medium to coarse	6	6
Sand and gravel	21	27
Clay, sandy	7	34
Clay, gray, soft	27	61
Gravel	1	62
Clay, gray, hardpan	17	79
Sand, coarse, coarse gravel and boulders	1	80
Sand and gravel, cemented	1	81
Hardpan	1	82
Sand and gravel, cemented	4	86
Clay, gray, hardpan and boulders	4	90
Sand, coarse, and medium to coarse gravel	4	94
Sand and gravel, hardpacked, clayey, silty	9	103
Gravel, medium to coarse, and coarse sand	4	107
Sand and gravel, clayey, silty, hard	2	109
Sand and gravel, silty, cemented	2	111
Sand and gravel, silty, hard	2	113
Sand, coarse, and medium to coarse gravel	1	114
Sand, coarse, gravel, and clay balls	4	118
Clay, blue, hardpan	2	120
Clay, blue, hard	5	125
5N 15W 29-11 Alt. 600		
Muck, black	19	19
Sand, yellow, fine	8	27
Gravel, coarse	3	30
Clay, blue, soft	20	50
Hardpan, gravelly	28	78
Gravel and clay	6	84
Gravel, coarse	19	103
5N 15W 29-14 Alt. 600		
Soil and cinders	5	5
Clay, sand, and gravel	10	15
Clay, blue, mucky	50	65
Clay, blue, soft, and boulders	10	75
5N 15W 29-15 Alt. 605		
Stone and sand	15	15
Sand	3	18
Sand, fine	7	25
Sand, coarse	7	32
5N 15W 29-18 Alt. 610		
Sand, fill	15	15
Sand, coarse	12	27
Sand, coarse, and gravel	8	35
Clay	23	58
5N 15W 29-19 Alt. 610		
Fill	4	4
Sand, brown	13	17
Sand, coarse, and gravel	15	32
Sand, medium	2	34
5N 15W 29-20 Alt. 610		
Soil	1	1
Sand, medium to coarse	14	15
Sand, coarse, and gravel	5	20
Sand, coarse, and fine gravel	11	31
Clay	-	-
5N 15W 29-21 Alt. 583		
Fill and muck	7	7
Sand	16	23
Silt	20	43
Sand, gas reported	10	53
Sand and gravel	10	63
Clay	-	-
5N 15W 29-22 Alt. 588		
Sand, gray, sharp, peaty	32	32
Peat	16	48
Sand, gray, fine	8	56
Gravel, coarse	2	58
"Impossible to penetrate"		
5N 15W 29-23 Alt. 584		
Sand, gray, sharp, peaty	32	32
Sand, gray, sharp, and peat	2	34
Peat	14	48
Sand, gray, fine	10	58
Gravel, coarse	2	60
"Impossible to penetrate"		
5N 15W 29-24 Alt. 581		
Stones, gray, sharp, peaty	28	28
Peat	22	50
Sand, gray, sharp	4	54
Gravel, wood fragments	1	55
Gravel	6	61
"Impossible to penetrate"		
5N 15W 29-25 Alt. 580		
Sand, gray, sharp	14	14
Gravel	6	20
Sand, very fine, and blue clay	14	34
Clay, blue, soft	11	55
Rock	-	-
5N 15W 29-26 Alt. 583		
Sand, gray, sharp	19	19
Sand and peat	1	20
Gravel	9	29
Sand, very fine, clayey	10	39
Clay, blue, soft	21	60
"Impossible to penetrate"		
5N 15W 29-27 Alt. 583		
Sand, gray, fine, peaty, and fill	10	10
Silt, brown, sandy, peaty	3	13
Silt, brown, peaty, soft	18	31
Sand, gray, medium, and fine gravel, compact, clayey	4	35
Sand, gray, very fine, compact	5	40
Clay, blue, medium to hard, sandy, and fine gravel	32	72
5N 15W 29-28 Alt. 583		
Sand, gray, fine, peaty, and fill	16	16
Silt, brown, peaty, soft	6	22
Sand, gray, medium, compact, and fine gravel	2	24
Sand, gray, very fine, compact	19	43
Clay, blue, medium, very hard, gravelly	39	82
5N 15W 29-29 Alt. 582		
Sand, gray, fine, peaty, fill	5	5
Peat, brown, soft	1	6
Sand, gray, fine to medium, peaty	11	17
Silt, brown, soft, peaty	3	20
Sand, gray, fine, silty	1	21
Sand and gravel, compact, clayey	2	23
Sand, gray, very fine, compact	8	31
Clay, blue	1	32
Sand, gray, very fine, compact	10	42
Clay, blue, medium to very hard, sandy, fine, and medium gravel	42	84
5N 15W 29-30 Alt. 580		
Sand, gray, fine to coarse, fill	4	4
Silt, brown, soft, peaty	1	5
Peat, brown, soft	1	6
Sand, gray, fine, firm	6	12
Peat, brown, soft, silty	1	13
Sand, gray, fine	4	17
Peat, brown, soft, and silt	1	18
Silt, brown, soft	8	26
Sand, gray, fine, compact, clayey, gravelly	5	31
Sand, gray, very fine, compact	9	40
Clay, blue, medium to very hard, sandy, gravelly	44	84

Table 8.--Logs of wells and test borings in the Holland area.--Continued

	Thickness	Depth
5N 15W 29-31 Alt. 580		
Sand, gray, peaty	1	1
Sand, yellow, sharp	14	15
Gravel	1	16
Gravel, clayey, blue	5	21
Clay, blue, soft	15	36
Clay, blue, firm	6	42
Clay, blue, stiff	14	56
Rock, may be boulder	1	57
5N 15W 29-32 Alt. 580		
Muck, silt	1	1
Sand, gray, sharp, peaty	11	12
Sand, gray, fine, and peat	10	22
Peat	16	38
Peat, sandy	5	43
Sand, gray, fine, clayey	2	45
Clay, blue, soft	5	50
Clay, blue, medium firm	2	52
Clay, blue, firm	1	53
Gravel	1	54
Clay, blue, sandy	5	59
Rock	-	-
5N 15W 29-33 Alt. 580		
Sand, gray, sharp, peaty	14	14
Gravel, fine, peaty	7	21
Gravel, clayey, blue	1	22
Clay, blue, soft	20	42
Clay, blue, sandy	8	50
Clay, blue	1	51
Clay, blue, sandy, hard	7	58
Hardpan	-	-
5N 15W 29-34 Alt. 581		
Muck	2	2
Sand, gray, sharp, peaty	17	19
Gravel	2	21
Sand, gray, very fine, clayey	16	37
Clay, blue, soft	17	54
Clay, blue, firm	3	57
Rock	-	-
5N 15W 29-35 Alt. 583		
Sand, gray, peaty	11	11
Sand, gray, gravelly, and peat	8	19
Peat, water-bearing	2	21
Gravel, sandy	2	23
Clay, blue, soft	2	25
Sand, water-bearing	3	28
Clay, blue, soft	6	34
Clay, blue, stiff, and sandstone	26	60
Clay, blue, stiff	-	-
5N 15W 29-36 Alt. 585		
Sand, peaty	20	20
Peat	3	23
Gravel	11	34
Sand, very fine, clayey	7	41
Clay, blue, soft	14	55
Clay, blue, stony	4	59
Sand, yellow	1	60
Clay, blue, stony	3	63
5N 15W 29-37 Alt. 586		
Sand, gray, sharp, peaty	25	25
Peat	4	29
Gravel	5	34
Sand, very fine, clayey	6	40
Clay, blue, soft	10	50
Clay, blue	2	52
5N 15W 29-37 Cont'd.		
Clay, blue, stony	12	64
Sand, gray, sharp	2	66
Rock	-	-
5N 15W 29-38 Alt. 584		
Sand, gray, sharp, peaty	28	28
Peat	1	29
Gravel, water-bearing	6	35
Sand, gray, very fine	4	39
Clay, blue, soft	22	61
Sand, gray, sharp	2	63
Large rock in casing at 65 ft.	-	-
5N 15W 29-39 Alt. 585		
Sand, gray, peaty	28	28
Peat	3	31
Gravel, sandy	6	37
Sand, very fine, clayey, blue	6	43
Clay, blue, soft	31	74
Clay, soft, stony	-	-
5N 15W 29-40 Alt. 583		
Sand, gray, sharp, peaty	23	23
Peat	6	29
Gravel, fine	4	33
Sand, gray, very fine, clayey	4	37
Clay, blue, soft	7	44
Clay, blue	4	48
Clay, blue, soft	12	60
Clay, blue, hard, stony	4	64
"Impossible to penetrate"		
5N 15W 29-41 Alt. 583		
Sand, gray, sharp, peaty	23	23
Gravel	3	26
Sand, gray, very fine, clayey	12	38
Clay, blue, soft	19	57
Sand, sharp, gray	1	58
Clay, blue, soft	3	61
Clay, blue, stony	2	63
"Impossible to penetrate"		
5N 15W 29-42 Alt. 586		
Sand, gray, sharp, peaty	18	18
Peat	5	23
Peat and sand, sharp	5	28
Gravel	6	34
Sand, gray, very fine, clayey	4	38
Clay, blue, soft	19	57
Clay, blue, stony	4	61
Clay, blue, hard, stony	6	67
"Impossible to penetrate"		
5N 15W 29-43 Alt. 580		
Peat	5	5
Sand, gray, peaty	11	16
Sand, gray, peaty	4	20
Gravel, sandy	2	22
Clay, blue, soft	5	27
Sand, water-bearing	1	28
Clay, blue, soft	5	33
Clay, blue, stiff	28	61
5N 15W 29-44 Alt. 585		
Sand, gray, sharp, peaty	16	16
Peat	4	20
Gravel	11	31
Sand, gray, fine, clayey	13	44
Clay, blue, soft	6	50
Clay, blue	16	66
Clay, blue, hard	-	-
5N 15W 29-45 Alt. 587		
Silt	7	7
Sand, gray, and peat	9	16
Peat	4	20
Sand, gray, sharp, peaty	5	25
Sand, very fine, clayey,	7	
blue	17	42
Clay, blue, soft	10	52
Clay, blue, firm, sandy	11	63
Clay, blue, layered, very hard	3	66
Clay, blue, hard	-	-
5N 15W 29-46 Alt. 581		
Peat and silt	5	5
Peat, gray, sandy	9	14
Peat, greenish	3	17
Gravel, sandy	4	21
Clay, blue, soft	4	25
Sand, brown, very fine, water-bearing	2	27
Clay, blue, soft	11	38
Clay, blue, stiff	23	61
5N 15W 29-47 Alt. 589		
Sand, gray, peat, and shells	16	16
Peat, sandy	5	21
Gravel	11	32
Clay, blue, soft	24	56
5N 15W 29-48 Alt. 581		
Silt	4	4
Sand, gray, and peat	12	16
Peat	3	19
Gravel	12	31
Sand, very fine, clayey	2	33
Clay, blue, soft	1	34
Sand, very fine	8	42
Clay, blue, soft	6	48
Clay, firm	14	62
5N 15W 30-1 Alt. 584		
Cinder and coal fill	2	2
Sand and gravel, fragments of wood	8	10
Peat, black, soft	1	11
Sand, yellow, fine, firm, gravelly	4	15
Sand, gray, very fine	15	30
Clay, blue	4	34
Sand, gray, compact	8	42
Clay, blue	8	50
Sand, gray, very fine, compact with thin clay partings	5	55
Clay, blue, medium to hard, sandy, and fine gravel	32	87
Sand, very hard, clayey, and fine to coarse gravel	1	88
Clay, blue, very hard, sandy, and gravel	5	93
5N 15W 30-2 Alt. 583		
Sandstone, cinders, and fragments of wood	5	5
Peat, black, soft, and fine yellow sand	7	12
Sand, yellow, firm, medium, and black peat	4	16
Sand, gray, very fine	20	36
Clay, blue	4	40
Sand, gray, very fine, compact	17	57
Clay, blue, medium to hard, sandy, and fine gravel	26	83

Table 8.--Logs of wells and test borings in the Holland area.--Continued

	Thickness	Depth
5N 15W 30-3 Alt. 585		
Concrete floor	1	1
Sandstone, coal, and cinder fill	7	8
Sand, yellow, fine, firm, peaty	8	16
Sand, gray, very fine, compact	30	46
Clay, blue, medium to very hard, fine, sand and gravel	44	90
5N 15W 30-4 Alt. 586		
Soil, sandy, clayey, and fill	4	4
Sand, and woody fill	3	7
Sand, yellow, medium to compact	10	17
Sand, gray, very fine	27	44
Clay, blue, medium to very hard, sand, and fine gravel	46	90
5N 15W 30-5 Alt. 583		
Sand, gray, and shells	6	6
Sand, gray to brown, gravelly	7	13
Sand, gray, and gravel, peaty	7	20
Sand, water-bearing	1	21
Sand, gray, gravelly	1	22
Sand, gray, very fine	12	34
Clay, blue, stiff	14	48
Clay, blue, soft	8	56
Clay, blue, stiff	12	68
5N 15W 30-6 Alt. 583		
Sand, gray, gravelly, and peat	8	8
Sand, gray, peaty	9	17
Gravel, fine	2	19
Sand, very fine, water-bearing	2	21
Clay, blue	17	38
Clay, blue, soft	4	42
Clay, blue, stiff	42	84
Hardpan	3	87
5N 15W 30-7 Alt. 584		
Sand, yellow	14	14
Sand, gray, fine, and fine gravel	4	18
Sand, very fine	4	22
Sand, very fine, clayey	6	28
Clay, blue	10	38
Clay, blue, soft	24	62
5N 15W 30-8 Alt. 584		
Sand, gray, gravelly, and peat	16	16
Sand, sharp	8	24
Sand, very fine, traces of gravel	3	27
Clay, blue	16	43
Clay, blue, soft	37	80
5N 15W 30-9 Alt. 591		
Sand, yellow, clayey	19	19
Sand, gray, very fine	4	23
Clay, blue, soft	31	54
Clay, blue, stony	14	68
Sand, gray, very fine	6	74
Sand, gray, very fine, clayey	6	80
Clay, blue, stony, hard	3	83
Hardpan	2	85
5N 15W 30-10 Alt. 585		
Sand, yellow, sharp, peaty	8	8
Sand, gray, stony	2	10
Sand, yellow, sharp	9	19
Sand, gray, sharp	2	21
Sand, gray, very fine, clayey	1	22
Clay, blue, soft	26	48
Clay, blue, soft, stony	19	67
Sand, gray, fine, clayey	10	77
"Impossible to penetrate"		
5N 15W 30-11 Alt. 595		
Sand, fill	7	7
Clay	11	18
Sand, fine	14	32
Clay	3	35
5N 15W 30-12 Alt. 595		
Sand, white	20	20
Clay	1	21
Sand, white	1	22
5N 15W 30-13 Alt. 585		
Soil and sand	7	7
Clay, blue, and boulders	58	65
5N 15W 30-14 Alt. 595		
Sand, yellow, fine	8	8
Sand, yellow	2	10
Sand, yellow, coarse	7	17
Sand, yellow, coarse and fine gravel	9	26
5N 15W 30-15 Alt. 595		
Sand, yellow, fine	10	10
Sand, yellow, coarse, gravelly	10	20
Sand, gray, coarse, and gravel	10	30
5N 15W 30-16 Alt. 590		
Sand, yellow, fine	2	2
Sand, yellow and gravel	2	4
Sand, yellow, fine	6	10
Sand, yellow, coarse	6	16
Sand and clay	39	55
Clay, soft	30	85
Hardpan, sandy	25	110
5N 15W 30-17 Alt. 590		
Sand, yellow, clean	4	4
Sand, clean	5	9
Sand, yellow, coarse	3	12
Clay, soft, sandy	18	30
5N 15W 30-18 Alt. 590		
Sand, yellow, fine	8	8
Sand, yellow	2	10
Sand, yellow, coarse	1	11
Sand, yellow, fine, clean	6	17
Sand, yellow, coarse, and fine gravel	5	22
5N 15W 30-19 Alt. 590		
Sand	16	16
Clay, gravelly	55	71
5N 15W 30-21 Alt. 600		
Sand, fine	35	35
5N 15W 30-22 Alt. 605		
Sand, fine	31	31
5N 15W 31-2 Alt. 610		
Sand	17	17
Clay	22	39
Sand	7	46
5N 15W 31-3 Alt. 610		
Sand, dry	2	2
Sand, dark, water-bearing	8	10
Sand, coarse, light	13	23
Clay, soft, sandy	32	55
Clay, gravelly	4	59
Sand and clay	5	64
Clay, sandy	5	69
Sand and clay	9	78
Clay, blue, sand, and gravel	7	85
5N 15W 31-4 Alt. 610		
Soil	2	2
Sand, clean, water-bearing	8	10
Sand and clay	2	12
Sand, coarse, clean	10	22
Sand, coarse, clean, and gravel, fine	1	23
Clay	1	24
5N 15W 31-5 Alt. 605		
Soil, dry	6	6
Sand, water-bearing	19	25
Sand	40	65
Hardpan	15	80
Clay, sandy	35	115
5N 15W 31-6 Alt. 610		
Sand, fine, gravelly	20	20
Clay	18	38
5N 15W 31-7 Alt. 610		
Sand and gravel	22	22
Clay	17	39
Hardpan	5	44
Clay	1	45
5N 15W 31-8 Alt. 610		
Sand and gravel, fine	24	24
Clay, sandy, soft	51	75
Hardpan	14	89
Sand, dirty	6	95
Sand and gravel	22	117
Clay	1	118
Sand, dirty and fine gravel	12	130
Clay, sandy	5	135
5N 15W 31-9 Alt. 610		
Sand and gravel	25	25
Clay	10	35
5N 15W 31-11 Alt. 610		
Sand and gravel	15	15
Sand, coarse, and gravel	13	28
Clay	7	35
5N 15W 31-12 Alt. 610		
Sand and gravel	20	20
Gravel, coarse	3	23
Clay	15	38
5N 15W 31-13 Alt. 633		
Soil	2	2
Sand	4	6
Sand, fine	6	12
Sand and gravel, coarse	6	18
Gravel, coarse	2	20

Table 8.-- **Logs of wells and test borings in the Holland area.**--Continued

	Thick-ness	Depth
5N 15W 31-13 Cont'd.		
Sand, coarse	6	26
Sand, fine	2	28
Clay	-	-
5N 15W 31-14 Alt. 633		
Soil	1	1
Sand, fine to coarse	14	15
Sand, coarse and gravel	6	21
Sand, fine	7	28
Clay	-	-
5N 15W 31-15 Alt. 633		
Sand, fine to coarse	28	28
Clay	-	-
5N 15W 32-23 Alt. 615		
Sand, medium, beach	29	29
Clay, blue, gravelly	3	32
Clay, blue	57	89
Clay, stony	22	111
Gravel, very sharp, water-bearing, mixed with silt	-	-
5N 15W 32-47 Alt. 630		
Soil	3	3
Sand, fine to coarse	24	27
Clay	-	-
5N 15W 32-48 Alt. 632		
Sand, fine	10	10
Sand, coarse, and gravel	5	15
Sand, fine	6	21
Sand, coarse, and gravel	7	28
Clay	-	-
5N 15W 32-49 Alt. 632		
Soil	2	2
Sand, fine	5	7
Sand	3	10
Sand, coarse, and gravel	5	15
Sand, fine	3	18
Sand, coarse	6	24
Sand, fine, and clay	3	27
Clay	-	-
5N 15W 32-50 Alt. 633		
Soil	2	2
Sand	9	11
Sand, sharp	4	15
Sand, fine	5	20
Sand, coarse	4	24
Gravel	4	28
Clay	-	-
5N 15W 32-56 Alt. 630		
Sand	27	27
Clay, blue, sand, gravel, and boulders	35	62
5N 15W 32-61 Alt. 630		
Sand, fine	7	7
Sand, coarse, yellow	5	12
Sand and gravel	18	30
Clay, blue	20	50
Clay, blue, soft	20	70
Hardpan	11	81
Gravel, clayey	6	87
Sand, fine	4	91
Gravel, clayey	2	93
Sand, clayey	7	100
5N 15W 32-62 Alt. 620		
Soil and sand	8	8
Clay, blue, sand, gravel, and boulders	54	62
5N 15W 33-1 Alt. 660		
Clay, yellow	15	15
Clay, blue	25	40
Clay, red	3	43
Hardpan	10	53
Sand and gravel, fine	50	103
Clay, blue	2	105
5N 15W 33-2 Alt. 645		
Clay, yellow	12	12
Hardpan	18	30
Gravel, coarse, and sand	30	60
Clay	3	63
Gravel, coarse	3	66
Hardpan	24	90
5N 15W 33-4 Alt. 680		
Clay, yellow	15	15
Clay, blue	35	50
Clay, red	15	65
Hardpan, gray	10	75
Sand, coarse	13	88
Gravel, fine	4	92
Sand	11	103
Gravel and sand	4	107
Sand, dirty, and gravel	7	114
Gravel, coarse	3	117
Hardpan	3	120
5N 15W 33-5 Alt. 680		
Clay, yellow	22	22
Hardpan	30	52
Clay, red	13	65
Hardpan, gravelly	5	70
Hardpan, sandy	30	100
5N 15W 33-6 Alt. 646		
Soil, sandy	1	1
Sand, vari-colored, medium, clayey, gravelly	3	4
Clay, hard, sandy, gravelly	6	10
Clay, blue, hard, sandy, gravelly	3	13
Clay, blue, and medium sand, gravelly	6	19
Clay, blue, hard, sandy, gravelly	3	22
5N 15W 33- 7 Alt. 653		
Sand, brown, clayey, gravelly	2	2
Clay, hard, vari-colored, sandy, gravelly	18	20
5N 15W 33-8 Alt. 650		
Clay, yellow	25	25
Sand, yellow	15	40
Gravel, dirty	8	48
Gravel, coarse, clean	20	68
Gravel, coarse	5	73
Gravel, coarse, dirty	2	75
Hardpan	10	85
5N 15W 33-10 Alt. 650		
Sand, clayey	1	1
Clay, vari-colored, sandy, gravelly	2	3
Clay, hard, vari-colored, sandy, gravelly	6	9
Clay, hard, yellow, gravelly	6	15
Sand, red, medium, clayey, gravelly	1	16
Clay, hard, blue, sandy, gravelly	2	18
Sand, yellow, medium to coarse, gravelly, compact	2	20
5N 15W 33-11 Alt. 645		
Sand, clayey	2	2
Clay, hard, sandy, gravelly	6	8
Sand, yellow, medium, clayey, gravelly	11	19
Sand, yellow, medium to coarse, gravelly, compact	6	25
5N 15W 33-12 Alt. 649		
Sand, clayey	1	1
Sand, yellow, medium, clayey, gravelly	3	4
Clay, hard, sandy, gravelly	5	9
Sand, yellow, medium, and sand, interbedded	8	17
Sand, yellow, coarse, and gravel, clayey, compact	1	18
5N 15W 33-13 Alt. 653		
Sand, clayey	1	1
Clay, hard, vari-colored, sandy, gravelly	4	5
Sand, yellow, medium, clayey, gravelly	4	9
Clay, hard, vari-colored, sandy, gravelly	4	13
Clay, hard, blue, sandy, gravelly	3	16
Sand, yellow, coarse, and gravel, compact	1	17
5N 15W 33-14 Alt. 656		
Sand, medium, and clay, interbedded	5	5
Clay, hard, blue, sandy, gravelly	15	20
5N 15W 33-15 Alt. 661		
Sand, yellow, clayey, gravelly	11	11
Sand, gray, medium, gravelly	3	14
Clay, hard, blue, sandy, and gravelly	6	20
5N 15W 33-16 Alt. 660		
Clay, yellow	23	23
Sand, yellow, coarse	32	55
Sand, coarse, and gravel	21	76
Sand, fine	2	78
Sand, and gravel	3	81
Hardpan	9	90
5N 15W 33-17 Alt. 655		
Soil, sandy	1	1
Sand, yellow, clayey, gravelly	2	3
Clay, vari-colored, sandy, gravelly	6	9
Clay, soft, yellow, sandy, gravelly	3	12
Clay, blue, sandy, gravelly	2	14
Sand, yellow, coarse, and gravel, clayey, compact	1	15
5N 15W 33-18 Alt. 650		
Soil, sandy	1	1
Sand, clayey	1	2
Clay, hard, yellow, sandy, gravelly	2	4
Clay, medium-hard, vari-colored, gravelly, sandy	6	10
Sand, yellow, coarse, and gravel, clayey, compact	6	16

Table 8.--Logs of wells and test borings in the Holland area.--Continued

	Thick-ness	Depth
5N 15W 33-19 Alt. 647		
Soil, sandy	1	1
Sand, yellow, medium	6	7
Sand, yellow, coarse, and gravel, clayey	1	8
Clay, hard, blue, sandy, gravelly	10	18
Clay, hard, red to blue, sandy, gravelly	1	19
5 5N 15W 33-20 Alt. 655		
Soil, sandy	1	1
Sand, clayey	1	2
Clay, hard, vari-colored, sandy, gravelly	4	6
Clay, yellow, sandy, gravelly	2	8
Clay, hard, yellow, sandy, gravelly	3	11
Sand, yellow, coarse, and gravel, clayey, compact	6	17
5N 15W 33-21 Alt. 662		
Sand, yellow, medium, clayey, gravelly	10	10
Clay, hard, blue, sandy, gravelly	8	18
Sand, yellow, fine, clayey, gravelly, compact	1	19
5N 15W 33-22 Alt. 640		
Soil, peaty	1	1
Sand, medium, dirty	6	7
Sand, gray, fine to medium, gravelly, clayey	7	14
Clay, medium-hard, blue, sandy, gravelly	8	22
5N 15W 33-24 Alt. 669		
Soil	2	2
Clay, yellow	13	15
Clay, blue, firm	20	35
Clay, blue, sandy	45	80
Hardpan, red	80	160
Clay, sandy	50	210
5N 15W 34-12 Alt. 641		
Soil	2	2
Clay, red	12	14
Clay, sand, and gravel	51	65
Sand, clean, and gravel, water-bearing	7	72
Clay, sand, and gravel	113	185
Clay, sandy	20	205
Clay	75	280
Clay, sandy	7	287
Sand, clean, sharp, water-bearing	3	290
5N 15W 34-21 Alt. 641		
Soil	2	2
Clay, red	12	14
Clay, sand and gravel	51	65
Sand, clean, and gravel, water-bearing	7	72
Clay, sand, and gravel	113	185
Clay, sandy	20	205
Clay	75	280
Clay, sandy	7	287
Sand, clean, sharp, water-bearing	3	290
5N 15W 34-22 Alt. 641		
Soil	2	2
Clay, red	12	14
5N 15W 34-22 Cont'd.		
Clay, sand and gravel	51	65
Sand, clean, and gravel, water-bearing	7	72
Clay, sand, and gravel	113	185
Clay, sandy	20	205
Clay	75	280
Clay, sandy	7	287
Sand, clean, sharp, water-bearing	3	290
5N 15W 35-1 Alt. 600		
Sand	17	17
Clay	21	38
Sand	4	42
4N 16W 4-1 Alt. 598		
Sand, fine to medium	25	25
Clay, yellow	1	26
Sand, fine and silt	54	80
Clay, gray, sandy	10	90
4N 16W 4-2 Alt. 605		
Sand, medium	20	20
Sand, medium, gravelly	24	44
Sand, fine, hard, silty	36	80
Clay, gray	4	84
4N 15W 4-4 Alt. 657		
Cinders and sand, fill	8	8
Peat and sand	2	10
Sand, yellow, medium	3	13
Clay, blue, stony	5	18
Clay, blue, soft	9	27
Sand, gray, medium	3	30
Clay, blue, soft	12	42
Boulders, small	1	43
Clay, blue, soft	6	49
Sand, gray	1	50
Clay, blue, hard, sandy	4	54
Sand, fine	3	57
Clay, blue, hard, sandy, stony	5	62
4N 15W 4-5 Alt. 657		
Cinders and sand, fill	7	7
Peat and sand	1	8
Sand, yellow, medium	4	12
Clay, blue, stony	6	18
Clay, blue, soft	12	30
Sand, red, fine	3	33
Clay, blue, soft	7	40
Boulders, small	1	41
Clay, blue, soft, sandy	9	50
Clay, blue, hard, sandy, stony	2	52
4N 15W 4-6 Alt. 656		
Cinders and sand, fill	7	7
Sand, yellow, medium	5	12
Clay, blue, stony	6	18
Clay, blue, soft	12	30
Sand, gray, very fine	3	33
Clay, blue, soft, and boulders	11	44
4N 15W 4-7 Alt. 656		
Cinders and sand, fill	8	8
Sand, yellow, medium	5	13
Clay, blue, stony	5	18
Clay, blue, soft	12	30
Clay, blue, soft, sandy, boulders	8	38
Boulder	-	-
4N 15W 4-8 Alt. 656		
Cinders and sand, fill	8	8
Sand, yellow, medium	5	13
Gravel, medium	2	15
Clay, blue, stony	4	19
Clay, blue, soft	33	52
Clay, blue, hard, stony	1	53
Sand, yellow, medium, hard	3	56
Clay, blue, hard, stony	3	59
Sand, yellow, medium	1	60
Clay, blue, hard, stony	3	63
4N 15W 4-9 Alt. 655		
Cinders, fill	3	3
Sand, yellow, fine to medium	9	12
Clay, blue, stony	6	18
Clay, blue, soft	12	30
Clay, blue, sandy, soft, with small boulders	20	50
Clay, blue, hard, stony	2	52
4N 15W 4-10 Alt. 655		
Cinders and sand, fill	8	8
Sand, yellow, medium	4	12
Clay, blue, stony	6	18
Clay, blue, soft	12	30
Clay, blue, soft, and small boulders	10	40
4N 15W 4-11 Alt. 654		
Cinders and sand, fill	7	7
Sand, yellow, medium	5	12
Clay, blue, stony	6	18
Clay, blue, soft	14	32
Clay, blue, soft, sandy, with small boulders	15	47
Clay, blue, hard, stony	2	49
Boulder	-	-
4N 15W 4-12 Alt. 655		
Cinders and sand, fill	7	7
Sand, yellow, medium	5	12
Gravel, medium	1	13
Clay, blue, stony	6	19
Clay, blue, soft	11	30
Clay, blue, soft, boulders	18	48
Clay, blue, hard, stony	2	50
Boulder	-	-
4N 15W 6-1 Alt. 660		
Clay, red	68	68
Sand	37	105
Clay and sand	10	115
Clay, blue	18	133
Sand and gravel	4	137
Gravel	2	139
Sand	1	140

Table 9.--Chemical analyses of ground-water samples in the Holland area.

Analyst: M - Michigan Department of Health; I - Infilco, Inc.

Well number or pumping station	Analyst	Date	Chemical constituents (parts per million) Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium(Na) and Potassium(K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total solids	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C.)	pH	Temperature (°F.)
Samples from individual wells																		
5N 16W 33-7	-	7-31-24	9.6	0.4	66	14	6.4	252	-	16	10	-	-	252	-	-	-	-
33-10	-	2-10-54	-	0.1	-	-	-	-	-	-	7	0	0	-	150	-	7.4	-
5N 15W 21-25	M	2-12-52	6.7	0.4	68	23	16	281	0	50	18	0	0	328	265	-	7.6	51.3
	M	10-30-52	-	-	-	-	-	262	0	52	18	-	-	-	250	550	-	-
	M	9-28-54	-	-	-	-	-	-	-	-	-	-	-	-	-	570	-	-
27-6	I	6-17-47	15	1.2	78	31	6.0	305	-	64	12	-	-	334	323	-	7.5	-
	M	2- 6-51	7.2	0.7	85	35	11	354	-	74	10	0.2	0	400	357	-	-	-
	M	2-12-52	9.5	0.7	84	37	14	373	0	63	11	0.1	-	412	360	555	7.5	51.4
	M	9- 9-52	11	0.6	88	34	14	372	0	52	15	1.4	-	420	360	750	7.9	-
	M	8-13-53	-	-	-	-	-	-	-	67	-	-	-	-	-	-	-	-
	M	9-27-54	-	-	-	-	-	-	-	-	-	-	-	-	-	790	-	-
28-6	M	2-12-52	6.7	4.2	190	50	26	505	0	285	24	0.1	0	890	680	-	7.2	50.0
	M	10-30-52	-	-	-	-	-	481	-	260	27	-	-	-	650	-	-	-
	M	8-13-53	-	-	-	-	-	-	-	340	-	-	-	-	-	-	-	-
28-43	M	6-26-22	18	-	68	27	9.1	328	-	19	9	-	-	312	-	-	-	-
	M	9-21-23	7.2	-	64	31	6.9	318	-	30	8	-	-	310	-	-	-	-
	M	3-24-26	8.8	2.9	73	31	12	323	-	55	11	-	-	360	307	-	-	-
	M	11- 5-29	9.6	0.6	82	32	6.9	333	0	60	12	-	-	366	330	-	-	-
	M	4-25-31	6.4	1.7	84	37	Tr.	324	0	67	16	-	-	376	355	-	-	-
	M	11- 3-33	6.4	0.6	87	33	11	339	0	77	13	-	-	400	350	-	-	-
	M	10- 1-36	4.0	0.8	98	39	2.7	328	0	119	12	-	-	472	404	-	-	-
	M	12- 8-43	14	1.4	109	40	12	344	0	156	12	-	-	538	435	-	-	-
	I	9-27-45	9.0	1.0	105	32	6.0	336	-	112	17	0.1	-	416	402	-	6.8	-
28-45	M	2- 6-51	5.6	1.4	117	41	15	376	-	158	14	0.8	0	560	460	-	-	-
	M	2-12-52	10	1.3	112	39	18	368	0	150	17	-	-	550	440	-	7.6	50.6
	M	9- 8-52	8.0	1.3	112	41	14	384	0	135	19	0.7	0	540	450	880	7.2	-
	M	8-12-53	-	-	-	-	-	-	-	103	-	-	-	-	-	-	-	-
	M	9-27-54	-	-	-	-	-	-	-	-	-	-	-	-	-	840	-	-
28-47	M	11- 3-33	8.0	0.6	85	34	4.8	349	0	60	8	-	-	374	348	-	-	-
	M	10- 1-36	8.0	0.4	80	34	4.4	343	0	51	9	-	-	358	335	-	-	-
	M	12-22-43	8.8	0.4	83	33	11	349	0	67	8	0.1	-	384	342	-	-	-
	I	9-27-45	8.0	0.3	90	28	1.0	338	-	48	11	0.1	-	343	340	-	7.3	
28-48	M	5- 7-30	20	0.8	71	32	7.8	341	0	30	11	-	-	324	310	-	-	-
28-50	I	3-31-47	14	0.8	64	27	22	315	-	38	16	0.2	-	320	272	-	7.3	-
	M	9- 9-52	12	0.3	80	30	5.8	282	0	91	7	0.1	0	410	325	700	7.4	-
	M	9-27-54	-	-	-	-	-	-	-	-	-	-	-	-	-	710	-	-
28-74	M	5-25-55	15	1.4	76	33	27	368	0	13	47	0	0	444	325	710	7.7	-
30-12	M	8- 2-23	4.0	-	73	18	18	205	-	80	32	-	-	452	-	-	-	-
34-16	M	2-12-52	7.5	0.6	72	28	14	293	0	64	12	0	0	346	295	540	7.5	-
	M	1-23-53	-	-	-	-	-	329	-	75	75	-	-	-	420	900	-	-
	M	9-27-54	-	-	-	-	-	412	-	159	35	-	-	-	510	980	-	-
Composite samples from pumping stations																		
19th Street Station	M	8-22-23	8.8	-	63	17	0	162	-	67	10	-	-	306	-	-	-	-
	M	3-15-26	8.0	Tr.	68	16	Tr.	193	-	57	12	-	-	256	230	-	-	-
	M	11- 5-29	11	1.7	72	18	4.6	221	0	62	13	-	-	364	252	-	-	-
	M	11- 3-33	5.6	-	71	17	7.8	201	0	69	11	-	-	-	248	-	-	-
	M	10- 2-36	7.2	Tr.	75	20	Tr.	212	0	73	12	-	Tr.	336	268	-	-	-
	M	2-12-52	6.7	Tr.	72	20	11	236	0	54	18	0	9	320	260	-	7.7	53.2
	M	9- 9-52	8.3	-	74	20	11	238	0	51	20	1.0	12	348	265	610	7.9	-
	M	9-27-54	-	-	-	-	-	-	-	-	-	-	-	-	-	600	-	-
28th Street Station	M	9-19-23	6	-	32	7.3	4	84	-	43	3	-	-	151	-	-	-	-
	M	5-26-26	10	Tr.	35	8.9	1.8	111	-	24	8	-	-	143	121	-	-	-
	M	11- 3-33	4.8	0	35	9.4	4.6	112	0	29	6	-	-	160	125	-	-	-
	M	10- 2-36	7.2	Tr.	35	9.6	Tr.	101	0	29	8	-	Tr.	162	122	-	-	-

Table 10.--Chemical analyses of surface-water samples in the Holland area.

Analyst: Michigan Department of Health

Pumping station	Date	Chemical constituents (parts per million)													Specific conductance (micromhos at 25°C.)	pH	Temperature (°F.)
		Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium(Na) and Potassium(K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total solids	Hardness as $CaCO_3$			
Black River at Paw Paw Drive	11-14-52	6.3	0.4	62	24	53	250	0	47	81	0.1	18	456	255	800	7.6	-
	8-13-53	-	-	-	-	-	-	-	55	-	-	-	-	-	-	-	-
	9-27-54	-	-	-	-	-	224	-	45	62	-	-	-	240	710	-	-
	2-12-52	4.6	0.5	41	13	15	133	0	46	26	0.1	Tr.	260	156	356	7.8	-
Black River at 120th Avenue	10-30-52	-	-	-	-	-	262	0	52	81	-	-	-	254	780	-	-
Black River at River Avenue	10-30-52	-	-	-	-	-	189	0	36	38	-	-	-	185	523	-	-
Lake Macatawa at Kollen Park	2-12-52	3.3	0.6	27	7.8	9.0	84	0	30	11	-	7	186	100	235	7.6	-
	10-30-52	-	-	-	-	-	165	-	29	30	-	-	-	154	440	-	-
	8-13-53	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-
	9-27-54	-	-	-	-	-	-	-	-	-	-	-	-	-	430	-	-
Lake Michigan, Grand Rapids intake	8-27-52	3	0	34	12	4.3	134	0	21	7	-	-	160	132	360	7.7	-
Abandoned Waverly Quarry	2-12-52	1.3	0.1	34	12	4.0	140	0	24	4	0	0	158	135	260	7.8	-
	10-30-52	-	-	-	-	-	152	0	29	4	-	-	-	146	350	-	-
	9-27-54	-	-	-	-	-	-	-	-	-	-	-	-	-	350	-	-