Ground-Water Supplies of the Ypsilanti Area Michigan

By C. L. McGUINNESS, O. F. POINDEXTER, *and* E. G. OTTON

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By C. L. McGuinness, O. F. Poindexter, and E. G. Otton

ABSTRACT

As of the date of this report (August 1945), the major water users in the Ypsilanti area are: (1) the city of Ypsilanti, (2) the Willow Run bomber plant, built by the Federal Government and operated by the Ford Motor Co., and (3) the war housing project of the Federal Public Housing Authority, designated in this report the Willow Run Townsite. The city, bomber plant, and townsite have required large quantities of water for domestic and industrial uses, and the necessary water supplies have been developed from wells. The Federal Works Agency had the responsibility of deciding whether the existing water facilities were adequate to meet the expected demands and determining the character of any additional public water-supply facilities that might be constructed with Federal assistance. In order to appraise the ground-water resources of the area the Federal Works Agency requested the Geological Survey to investigate the adequacy of the existing supplies and the availability of additional water. The present report is the result of the investigation, which was made in cooperation with the Michigan Geological Survey Division.

The water supplies of the three major users are obtained from wells penetrating glacial and associated sands and gravels. Supplies for the city of Ypsilanti and the Willow Run bomber plant are obtained from wells in the valley of the Huron River; the supply for the Willow Run Townsite is obtained from wells penetrating glacial gravels underlying the upland northeast of the valley. The bedrock formations of the area either yield little water to wells or yield water that is too highly mineralized for most uses.

The water supply for the bomber plant is obtained from three closely spaced, highly productive wells at the northern edge of the Huron River, a little more than 3 miles southeast of Ypsilanti. The water receives complete treatment in a modern treatment plant. River water also can be treated and has been used occasionally in the winter and spring. The average daily pumpage during periods of maximum production at the bomber plant has been 4.5 to 4.75 million gallons. On June 30, 1945, production of bombers was suspended, and the plant went on a maintenance basis.

The water supply of the bomber-plant well field is replenished by recharge from precipitation and from the Huron River. The evidence shows that recharge from the river is one of the principal sources of water and gives assurance both of the adequacy of the present supply and of the availability of additional water if needed. The safe yield of the three existing wells is estimated to be not less than 6 million gallons per day.

The Ypsilanti public water supply is obtained from three tubular wells drilled in 1943, which replaced a number of suction-pumped tubular wells and one large dug well. All the wells penetrate sand and gravel in the bend of the Huron River

in the southeastern part of Ypsilanti. The water is treated in a modern treatment plant completed in 1939. The average daily pumpage in million gallons was about 1.68 in 1942, 1.70 in 1943, and 1.66 in 1944. Considerable water was furnished to the Willow Run bomber plant from the Ypsilanti public-supply system during the period from August 1941 through March 1943.

The available information indicates that the water pumped from the Ypsilanti well field is replenished by ground-water flow from adjacent stretches of the Huron Valley and from the upland areas outside the valley, from precipitation on the valley in the vicinity of the well field, and possibly from the Huron River. It is believed that sufficient water can be obtained from the well field to meet the expected demand for a considerable time. The safe yield of the present wells is estimated to be not less than 3 million gallons per day, and detailed pumping tests might show that still larger supplies could be safely developed.

The water supply of the Willow Run Townsite is obtained from four wells in two well fields about 2 miles apart, one well in the northwest or Prospect and Geddes Road field, and three wells in the southeast or Wiard Road field. The pumpage was originally expected to be 2 to 3 million gallons per day, but it averaged only about 450,000 gallons per day from March 1943 through June 1945.

The evidence afforded by logs of wells and by pumping tests indicates that the water-bearing gravels at the townsite are covered by relatively impermeable materials and thus that the rate of recharge is low. However, only relatively small declines in water level have occurred during more than 2 years' operation of the wells, indicating that recharge may occur nearby. The safe yield of the present wells is estimated to be 1.0 to 1.5 million gallons per day, and detailed pumping tests might show it to be somewhat greater. The water supply of the Willow Run Townsite has the smallest potential capacity of the three major ground-water supplies in the area; however, the demand has been relatively small, and no difficulty should arise unless this demand increases greatly.

The investigation involved the drilling of 13 test wells to locate additional ground-water supplies, on the assumption that the wartime demand for water in the Ypsilanti area might increase beyond the capacity of the present sources. All 13 wells were drilled at sites selected by the Geological Survey. Two wells on the Willow Run Townsite were drilled by the Federal Public Housing Authority and 11 at other sites by the Federal Works Agency. Records of the wells are given in the report and discussed with respect to the availability of water at the different sites; similarly, the results of the controlled pumping tests made on four of the test wells drilled by the Federal Works Agency are analyzed and discussed with respect to the availability of additional water. The combined results of the test drilling and the pumping tests show that emergency supplies of several million gallons per day can be developed at the sites of the test wells. The best site shown by the test drilling is on the south bank of the Huron River opposite the bomber-plant well field, where a well with a capacity of several thousand gallons per minute could be constructed if necessary. Three wells in the outwash-filled valley now occupied by Fleming Creek, on two of which pumping tests were made, show that emergency supplies ranging from a few hundred thousand to a million gallons per day could be developed at these test-well sites if necessary. Smaller supplies ranging from a gallon or two per minute to perhaps 100,000 or 200,000 gallons per day could be developed at the sites of the remaining test wells.

Pumping tests made on the supply wells of the three major water users by the consulting-engineering firms who designed the systems are analyzed and discussed briefly by the authors.

The report includes maps and graphs showing the surficial geology of the area, the location of wells, and fluctuations of water level in selected wells. Also included are tables giving data on water levels and pumpage, chemical analyses of representative ground waters, and records of wells.

INTRODUCTION

LOCATION OF THE AREA

The area treated in this report is that surrounding the city of Ypsilanti, Mich., extending from near Ann Arbor on the west to the Washtenaw County-Wayne County line on the east and from the Fleming Creek valley on the north to a point a few miles south of Ypsilanti. The principal parts of the area discussed are the city of Ypsilanti, the Willow Run bomber plant, and the war housing project of the Federal Public Housing Authority. The formal name of the project is the Willow Run War Housing Community, but the colloquial term "Willow Run Townsite" is used in this report. The report describes the water supplies of the three major users and considers the availability of additional ground-water supplies in other parts of the area.

HISTORY OF THE INVESTIGATION

This report gives the results of investigations, begun in August 1942, of the ground-water supplies of the Ypsilanti area.

Prior to this investigation the Michigan Geological Survey Division had received requests from several agencies for information concerning the availability of ground-water supplies in the Ypsilanti area and had recommended the site of the well field of the Willow Run bomber plant, which was built by the Federal Government and operated by the Ford Motor Co. Then on August 11 and 12, 1942, a conference on ground-water supplies in southeastern Michigan was held at Lansing, as the result of inquiries received by the Federal Geological Survey from the War Production Board, the Public Health Service, the National Resources Planning Board, and the Federal Works Agency. Present at the conference were O. E. Meinzer, geologist in charge of the Ground Water Branch, and the senior author, both of the Federal Geological Survey; R. A. Smith, State geologist; and O. F. Poindexter, of the Michigan Geological Survey Division. During the period August 13–17, 1942, the senior author and Mr. Poindexter visited a number of places in southeastern Michigan and obtained information on the ground-water supplies. The Ypsilanti area, including the Willow Run plant, was the most important; hence most of the time was spent there. The information obtained during the field work was presented in a typed report (McGuinness, C. L., 1942)[1] by the senior

[1] A list of publications and manuscripts cited is given on p. 103.

author, dated September 5, 1942, copies of which were furnished to the interested agencies mentioned.

In November 1942 Mr. Poindexter and the senior author visited the Willow Run bomber plant again and suggested the location of observation wells for detecting the effect of pumping from the bomber-plant wells.

On May 19, 1943, R. D. McGill, regional engineer of region 4 of the Federal Works Agency, and D. M. Hatch, State engineer of the Federal Works Agency for Michigan, called on the Director of the United States Geological Survey at Washington, D. C., to discuss the adequacy of the ground-water supplies of the Ypsilanti area. Also present at that conference were Mr. Meinzer and the senior author. Messrs. McGill and Hatch inquired whether the ground-water supplies that had been developed for the Willow Run bomber plant, the Willow Run Townsite, and the public supply of Ypsilanti might not become inadequate, thus necessitating the construction of a pipe line to bring water to Ypsilanti from the Detroit public-supply system. The available information, they were assured, indicated that the ground-water supplies would hold out at least for a sufficient time to permit an investigation of their long-term adequacy and, if necessary, the planning and construction of a pipe line. It was agreed that the Federal Geological Survey would undertake the investigation on a repayment basis, determining whether the existing supplies would be adequate to meet the expected demand and whether additional supplies could be developed if needed. The Michigan Geological Survey Division was requested to cooperate in the investigation and to assign a geologist to begin field work; hence about June 1, 1943, Mr. Poindexter went into the field and obtained information supplementing that gathered during the summer and fall of 1942. He also arranged for the collection of water-level and pumpage data by the three principal users of ground water. Copies of Mr. Poindexter's report (1943) were furnished to the Federal Works Agency in July of that year.

In September 1943 the senior author and Mr. Poindexter located sites for test wells to be drilled by the Federal Works Agency (see fig. 1), which subsequently arranged for permission to drill on the selected or alternate sites and negotiated a drilling contract. Drilling was started on January 19 and completed on May 6, 1944. The test drilling and pumping tests were supervised by E. G. Otton, of the United States Geological Survey, who was in the field from the early part of January until the test drilling was completed and who afterwards worked on the report in the Washington office until about the end of May.

In January 1944 the Federal Works Agency requested an opinion concerning the adequacy of the existing ground-water supplies of the

Ypsilanti area in advance of the completion of the test-drilling program, and on February 10, 1944, in a memorandum (McGuinness, 1944) prepared by the senior author and sent to the Federal Works Agency, it was stated that the ground-water supplies appeared to be adequate to meet the expected demand at least for the duration of the war.

Progress reports interpreting the current water-level and pumpage data were prepared for the Federal Works Agency at intervals of 1 month to several months, beginning in the summer of 1944 and continuing until June 30, 1945. Preparation of the present report was begun following the completion of the test drilling; in January 1945 it was submitted to the Federal Works Agency in typewritten form (McGuinness et al., 1944). It is the work chiefly of the senior author, who assumes responsibility for the interpretation of geologic conditions made on the basis of data from the test-drilling program and for the conclusions regarding the adequacy of the ground-water supplies.

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Acknowledgments are due many persons and agencies for their cooperation in the investigation. Special acknowledgment is due R. D. McGill, D. M. Hatch, and Mr. Green, of the Federal Works Agency, who handled all the arrangements for the test drilling so that the representatives of the Federal and State Geological Surveys could devote themselves to the technical aspects of the work.

Acknowledgments are also due S. L. Reeder, D. D. Meredith, and S. J. Shank, of the Federal Public Housing Authority. Messrs. Meredith and Shank furnished data on water levels and pumpage at the townsite. Mr. Reeder arranged for the drilling of test wells 23 and 31 (FPHA–USGS 2 and 1, respectively),[2] so that funds of the Federal Works Agency were made available for additional test wells outside the Willow Run Townsite.

C. C. Greim, manager of utilities for the city of Ypsilanti, and Z. L. Mead, superintendent of the Ypsilanti waterworks, furnished information on the Ypsilanti water supply, including data on water levels and pumpage in the Ypsilanti well field. Mr. Mead furnished, also, periodic measurements of water levels in wells 70–3N, 72 (FWA 10), and 73 (FWA 14).

The consulting-engineering firm of Shoecraft, Drury, and McNamee, of Ann Arbor, Mich., furnished maps, charts, and other data on the Ypsilanti public water supply and on private domestic wells in the area. They also made available a copy of their July 1942 report

[2] The wells are numbered according to location by township and section (see note to table 13), and the numbers by which they are known to the agencies cooperating in the investigation are generally given in parentheses after location numbers.

(Shoecraft, Drury, and McNamee, 1942) on ground water for the Ypsilanti public supply.

The consulting-engineering firm of Hubbell, Roth, and Clark, of Detroit, Mich., furnished maps, charts, and other data on the water supplies of the Willow Run bomber plant and the Willow Run Townsite.

J. E. Cooper and others of the medical department of the Ford Motor Co. furnished information on the water supply of the Willow Run bomber plant and, in 1942, data (McGuinness, 1942) on the water supplies of other Ford-operated plants in southeastern Michigan. Mr. Cooper furnished periodic data on water levels in the bomber-plant well field, pumpage from the field, and temperature and chloride content of the water. The Ford Motor Co. gave permission for the drilling of wells 91 (FWA 11), 99 (FWA 12), and 117 (FWA 13) on Ford property. Francis Kallin and others of the medical department made the analyses of water from wells 4 (FWA 6), 43 (FWA 8), 73 (FWA 14), and 117 (FWA 13), from the bomber-plant supply wells, and from the Huron River (table 1).

The Washtenaw County and Michigan State highway departments and the Ypsilanti city authorities gave permission to drill certain test wells on public property: wells 5 (FWA 7), 19 (FWA 4), 43 (FWA 8), 72 (FWA 10), and 73 (FWA 14). Private landowners, including the Detroit Edison Co., gave permission for drilling wells 4 (FWA 6), 16 (FWA 9), and 48 (FWA 3) on their property, and the State Highway Department kindly furnished the maps on which plate 2 is based.

GEOLOGY

INTRODUCTION

The geologic history and formations of the Ypsilanti area are described in United States Geological Survey Monograph 53 and folios 155 and 205 of the Survey's Geologic Atlas (Leverett, Frank, and Taylor, F. B., 1915; Russell, I. C., and Leverett, Frank, 1908; Sherzer, W. H., 1917), and only such discussion as is related to the ground-water conditions of the Ypsilanti area will be given here. The area is in the Eastern Lake section of the Central Lowland province of the Interior Plains.[3] It is underlain by gently dipping Paleozoic sedimentary rocks mantled with glacial drift and associated deposits.

PRE-QUATERNARY HISTORY

The bedrock formations of the Ypsilanti area consist of several thousand feet of Paleozoic sedimentary rocks of marine origin, ranging in age from Mississippian at the top to Ordovician. Sedimentary

[3] See physiographic map of the United States prepared by N. M. Fenneman in cooperation with the Physiographic Committee of the U. S. Geological Survey.

rocks of Cambrian age probably underlie the Ordovician rocks but have not been penetrated by the drill in this area. Below the sedimentary rocks are ancient rocks of the crystalline basement complex. The sedimentary rocks were deposited with low initial dips, but subsequent warping has accentuated the dip, which is northwestward into the Michigan Basin at the average rate of about 35 feet per mile.

At the end of the Paleozoic era the region was uplifted several hundred or perhaps several thousand feet. During Mesozoic time, erosion—perhaps interrupted one or more times by renewed uplift—reduced the area to a nearly featureless plain near sea level, the hard and soft rocks alike being beveled so that in the Ypsilanti area they cropped out in bands striking northeast-southwest, the older rocks cropping out successively to the southeast. Near the beginning of the Cenozoic era the region was again uplifted several hundred feet, and active denudation was resumed. The less resistant rocks were quickly reduced nearly to the new base level, but the more resistant rocks remained as dissected uplands. Another uplift occurred, probably in late middle Tertiary time, and down cutting of both the uplands and lowlands was resumed. This process was interrupted by the advance of the Pleistocene continental glaciers. The Ypsilanti area is part of the so-called Erie-Huron plain, in which the rock surface is now at an altitude of about 600 feet above sea level. This lowland is bounded on the northwest by an escarpment that rises to a plateau underlain by the resistant Marshall sandstone of Mississippian age. The northwest edge of the lowland is along a northeast-southwest line running just southeast of Ann Arbor. The relief between the lowland and the plateau is about 200 feet.

Bedrock formations.—The bedrock formations in the Ypsilanti area yield little or no potable water to wells and so will be described only briefly. In certain areas the water from the bedrock is salty and contaminates the water in the glacial deposits immediately above the bedrock.

The bedrock formations that crop out beneath the glacial drift in the Ann Arbor quadrangle, from the top down, are the Marshall sandstone, Coldwater shale, Sunbury shale, and Berea sandstone of Mississippian age; the Antrim shale of Upper Devonian age; and the limestone and shale of the Traverse formation, Dundee limestone, and Detroit River dolomite of Middle Devonian age. Below the Detroit River dolomite, but not cropping out in the Ann Arbor quadrangle, are the Sylvania sandstone of Middle Devonian age, the Bass Islands dolomite and Salina formation of Silurian age, and older Paleozoic rocks.

The Marshall sandstone underlies only the northwestern corner of the Ann Arbor quadrangle. The Coldwater and Sunbury shales crop out in a broad band running northeast-southwest across the quadrangle. Southeast of this is a band in which the Berea sandstone crops out beneath the drift. The Berea sandstone underlies most of Ypsilanti, but in the areas immediately north and northwest of the city, and in the Willow Run Townsite to the northeast, the Berea is overlain by shales that presumably are the Sunbury and Coldwater shales. Southeast of the outcrop belt of the Berea sandstone is that of the black Antrim shale. The boundary between the Berea and Antrim formations is northwest of well 91 (FWA 11), as the Antrim was penetrated immediately below the drift in that well. Southeast of the outcrop of the Antrim shale is that of the Traverse formation, which consists largely of limestone. The boundary between the two outcrops appears to pass under the Huron River at the bomber-plant well field, as wells 117 (FWA 13) and 121, south of the river, struck limestone or chert of the Traverse formation, whereas the other wells that reached bedrock, all north of the river, penetrated hard black shale or weathered gray shale. The formations that crop out southeast of the Traverse formation in the Ann Arbor quadrangle are the Dundee limestone and the Detroit River dolomite. These formations are of little or no importance with regard to the ground-water conditions in the Ypsilanti area.

The available data give only a general idea of the configuration of the bedrock surface in the Ypsilanti area. It is probable that the surface, though approximating a plain, is rather dissected. According to the available well records, the range in altitude of the bedrock surface is from 544 feet in well 37 to 667 feet in well 27, all altitudes in this report being given in feet above mean sea level. Well 27 penetrated 3 feet of sandstone between altitudes of 667 and 664 feet and ended in the sandstone. However, as bedrock in nearby wells was much lower (at altitudes of 602 feet in well 25 and 615 feet in well 30), the sandstone in well 27 might have been a large boulder. The highest altitude at which bedrock was struck in wells other than well 27 was about 635 feet in wells 16 (FWA 9) and 19 (FWA 4).

Ground water in the bedrock.—The bedrock formations either yield little water to wells or yield water that is moderately to highly mineralized. The Marshall sandstone yields some water to wells but does not underlie the Ypsilanti area proper. The Coldwater and Sunbury shales are essentially impermeable, although the Coldwater contains a number of thin sandstones that might yield domestic supplies of usable water in some places. The Berea sandstone contains salty water at most places, and in areas where it directly underlies the drift the lowermost unconsolidated deposits are contaminated by the salty water.

The Antrim shale supplies water to the municipal wells at Belleville, in the Huron Valley about 8 miles downstream from Ypsilanti. The water is moderately mineralized but soft. A sample analyzed in 1927 showed 561 parts per million of dissolved solids, 85 parts per million of chloride, 461 parts per million of bicarbonate, and a total hardness of 88 parts per million (Michigan Department of Health, 1937).

The unconsolidated deposits above the bedrock at Belleville may consist mostly of sand and gravel. If so, this might explain why potable water is found in the shale at that place. It is not known whether the Antrim shale will yield potable water in places where it is overlain by material of low permeability.

The Traverse and older formations generally yield salty water to wells. Water presumably from the Traverse formation has contaminated the water in the gravel immediately above bedrock in well 113 (bomber-plant supply well 2) and well 117 (FWA 13). Rocks of Silurian age, presumably the Bass Islands dolomite, yield a large amount of highly mineralized water to the Swan well at the south end of Grosse Isle, south of Detroit. An accurate log of the well is not available, but it is believed that the Sylvania sandstone, which overlies the Bass Islands dolomite, was struck at a depth of a little more than 300 feet and was somewhat more than 70 feet thick (Sherzer, 1913). The principal flows were at depths of 420 and 450 feet, and the water was reported to be fresh. The well was continued to a depth of 2,375 feet and yields a large supply of mineral water by natural flow. The water contains a considerable amount of hydrogen sulfide, reported to be from the lower part of the well. The water of the principal flows, though fresh in comparison with the lower waters, is probably rather highly mineralized. The completed well yielded water containing more than 20,000 parts per million of dissolved solids, according to an analysis made in 1905 (Leverett et al., 1906). Thus, although the Swan well shows that large supplies of water can be obtained from the bedrock under favorable conditions, it offers no encouragement with regard to the availability of water of good quality.

QUATERNARY HISTORY

The Quaternary history of the Ann Arbor quadrangle in general and of the Ypsilanti area in particular is discussed at some length because of the importance of the history of the Huron River, in whose valley two of the three major ground-water supplies of the area have been developed: those of the Willow Run bomber plant and the Ypsilanti public-supply system. In the typed reports of the Geological Survey dated September 5, 1942 (McGuinness, 1942), and February 10, 1944 (McGuinness, 1944), it is stated that the Huron River cut down to bedrock during the final retreat of the Wisconsin glacier and that the gravels which furnish the bomber-plant and Ypsilanti water supplies were subsequently deposited by the river. The information afforded by the test drilling indicates that such positive statements concerning the origin of these gravels may not be justified; however, a discussion of the Quaternary history may help to clarify the subject.

During the Pleistocene epoch of the Quaternary period the North Central States were invaded four or five times by continental glaciers that moved outward from collecting centers known as the Keewatin, in central Canada; the Patrician, between Hudson Bay and Lake Superior; and the Labrador, in the Labrador Peninsula. Michigan was invaded at least twice by the Labrador icefield, once during the third or Illinoian stage of glaciation and again during the last or Wisconsin stage. It may have been invaded by the Patrician field previously, but sufficient evidence is not yet available to determine this point.

The first ice sheet picked up the thick mantle of soil and loosened rock at the surface and incorporated it into the ice, together with additional material scraped and plucked from the bedrock uncovered by the removal of the soil. This fragmental material, redeposited in various forms by the ice and the meltwaters issuing from it, largely conceals the features of the bedrock. The principal deposits are moraines or ridges formed at the edges of the ice sheet, including moraines formed between two lobes of the sheet (interlobate moraines), outwash sands and gravels deposited in plains and valley trains heading in the moraines, and the ground moraine (till plain) formed beneath the ice and left in place when the ice melted. Subsequent ice sheets brought additional material and reworked some of that previously deposited.

The margin of the continental glacier was divided into lobes which corresponded to major areas in which the bedrock was relatively low. The lobation was especially marked during the latter part of each stage of glaciation, owing to the fact that the ice was becoming thinner and its movement was therefore affected to a greater extent by the configuration of the bedrock. During the last or Wisconsin stage of glaciation the Ann Arbor quadrangle was occupied mostly by the Huron-Erie lobe of the Labrador icefield, but the Saginaw lobe of that field occupied the northwest corner of the quadrangle and an important interlobate moraine was formed at the junction of the lobes before the final retreat. Similar lobation undoubtedly occurred during the Illinoian stage, and the morainic systems may have been started during that stage, so that the Wisconsin moraines may be only a veneer over moraines of the Illinoian stage. It is difficult to explain certain features of the occurrence of water-bearing sand and gravel except on the assumption that the moraines of the last stage were deposited on those of an earlier stage or stages.

During the building of the moraine between the Huron-Erie and Saginaw lobes of the Labrador icefield, the meltwaters with their load of gravel, sand, and clay escaped westward from the quadrangle past Pinckney and eventually found their way to the Mississippi by way of the Kankakee and Illinois Rivers. The front of the Huron-Erie lobe, which had advanced from the southeast, retreated again toward the southeast, and the front of the Saginaw lobe retreated to the north, out of the Ann Arbor quadrangle. The ice front halted after the reentrant between the lobes reached a point about at the head of the present Huron River drainage, and at that time the Fort Wayne moraine was formed by the Huron-Erie lobe (pl. 1). This moraine crosses the Ann Arbor quadrangle from the northeast corner to the vicinity of the town of River Raisin. During the formation of the moraine the meltwaters still converged to the northwest and left the quadrangle near Pinckney. Part of the drainage passed up the Huron River valley northwest of Ann Arbor. The valley may have been formed at that time or previously. Leverett (Russell and Leverett, 1908, p. 5) believed that the part of the valley above Ann Arbor might have been formed prior to the Wisconsin stage.

The front of the Huron-Erie lobe next retreated a little farther to the southeast, halted, and formed the outer ridge of the Defiance moraine, which passes southeast of Ann Arbor, parallel to the Fort Wayne moraine (pl. 1). At that time the drainage from the northeastern part of the quadrangle was still past Pinckney, but the drainage from the part of the ice front near Ann Arbor was to the southwest, between the ice front and the previously formed Fort Wayne moraine, to the valley of the Raisin River in Bridgewater Township. During this stage of the retreat the Huron River, which was receiving water from precipitation in the area uncovered by the ice and presumably also some glacial meltwater, cut across the Fort Wayne moraine and joined the meltwater from the part of the ice near Ann Arbor. The combined stream then joined the Raisin River, which also had formerly discharged westward, and flowed southwestward along the ice front to glacial Lake Maumee, which in turn discharged past Fort Wayne, Ind., to the Wabash River.

Retreating a little farther southeastward, the ice front then formed the inner ridge of the Defiance moraine. The meltwater from the ice front northeast of Ann Arbor flowed down the Fleming Creek valley to the present position of the Huron River (pl. 1). From that point it either flowed up the Huron Valley and joined the Huron River, which turned south at Ann Arbor, or flowed to the southwest across the present position of the Huron Valley and joined the old

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Huron River about 2 miles north of Pittsfield. If the water flowed up the Huron Valley, one must assume that the part of the valley between the mouth of Fleming Creek and Ann Arbor was already in existence or was cut through the outer ridge of the Defiance moraine during the period when the ice front was retreating to the position where it formed the inner ridge.

The ice front subsequently retreated a considerable distance to the southeast, and the reentrant between the Saginaw and Huron-Erie lobes retreated northeastward past Imlay City, uncovering an outlet to the Grand River and Lake Chicago, known as the Imlay outlet, at a lower altitude than the Fort Wayne outlet, which was abandoned. At that time Lake Maumee was at an altitude of about 800 feet and extended up the Huron Valley to Ann Arbor, where the Huron River, abandoning its southward course, entered the lake and formed a delta whose top is at an altitude of about 812 feet (pl. 1). The ice front retreated a little more and uncovered a lower outlet northeast of Imlay City. With Lake Maumee falling to its lowest level and forming a beach whose present altitude is 755 to 765 feet, the Huron River formed a sizable delta northeast of Ypsilanti, on which the southwestern part of the Willow Run Townsite is now located. The ice then readvanced slightly, covering the lower outlet and raising Lake Maumee so that it again discharged through the Imlay outlet. The altitude of the crest of the beach formed by Lake Maumee at this stage is about 785 to 795 feet, and the Huron River at the same time apparently formed a delta in the northeastern part of Ann Arbor.

Again the ice front retreated, uncovering an area so low as to permit the waters in the Erie Basin to become confluent with those of glacial Lake Saginaw and form what is known as glacial Lake Arkona. This latter lake formed several beaches which are now at altitudes of 695 to 710 feet in the Ann Arbor quadrangle, traversing the lake plain east of Ypsilanti. The Huron River cuts across the Arkona beaches near Rawsonville. During this stage, also, the Huron River cut down through the moraines and the older deltas and formed the extensive Arkona delta (pl. 1).

The ice then advanced once more. It separated the waters in the Saginaw and Erie Basins and formed Lake Whittlesey, whose outlet was past Ubly to Lake Saginaw, which in turn discharged through the Grand River outlet to glacial Lake Chicago. Lake Whittlesey formed a strong beach which now stands at an altitude of 735 to 740 feet in the Ann Arbor quadrangle. The Wiard Road well field of the Willow Run Townsite lies on the low ground just west of this beach. With the readvance of the ice the Huron River presumably stopped the down cutting that was in progress east of Ypsilanti when glacial

Lake Arkona was formed, but continued to deposit sediment in the lake.

The ice front at length withdrew entirely from the "Thumb" of Michigan and permitted the waters of the Saginaw and Erie Basins to join again and form Lake Wayne, whose outlet was south of Syracuse, N. Y., into the Mohawk River, the Grand River outlet being temporarily abandoned. The Wayne beach crosses the southeastern part of the Ann Arbor quadrangle at an altitude of 660 to 665 feet (pl. 1). The ice then readvanced slightly, closing the Syracuse outlet and forming Lake Warren, the discharge of which was again through the Grand River outlet. The Warren beach is at an altitude of 680 to 685 feet and passes northeastward out of the Ann Arbor quadrangle south of the Huron River (pl. 1), which continued to cut down—vigorously during the Wayne stage, less vigorously during the higher, so-called Warren stage of the lake—and to deposit sediment in the lake to form a delta.

With a further retreat of the ice front, the Grand River outlet was abandoned and an outlet to the Mohawk Valley past Rome, N. Y., was opened. The waters of the Saginaw and Erie Basins were confluent, and a lake known as glacial Lake Lundy was formed. This lake persisted for a time at a relatively high stage and formed the Grassmere beach at an altitude of 635 to 640 feet; it then fell to a lower stage and formed the Elkton beach at an altitude of 615 to 620 feet. The Huron River continued to deepen its bed and to deposit sediment in the lake.

Although the further history of the glacial lakes is concerned primarily with the area east of the Ann Arbor quadrangle, one feature of significance remains to be discussed. Lake Erie was formed following the stage of glacial Lake Lundy. It was the first of the Great Lakes to be free of the direct influence of the ice—that is, to have no ice dam. During the first part of its existence it received the discharge of the glacial lake, known as Lake Algonquin, that occupied the basins of the present upper Great Lakes and was nearly as large as at present. In a succeeding stage the discharge of Lake Algonquin was temporarily diverted to Lake Iroquois (now Lake Ontario), and the Port Huron outlet to Lake Erie was abandoned. Lake Erie then received only local drainage and was much smaller and lower than at present. Its level is believed to have been 540 to 550 feet above sea level (Leverett and Taylor, 1915, p. 397). It was during that stage that the Huron River had an opportunity to cut more deeply than at any other into the moraines at Ann Arbor and Ypsilanti and into the lake sediments and glacial drift southeast of Ypsilanti; if it was ever able to cut to bedrock it was at that time.

ORIGIN OF THE WATER-BEARING GRAVELS IN THE HURON VALLEY

The water supplies of the Willow Run bomber plant and of the city of Ypsilanti are obtained from gravels underlying the valley of the Huron River. The prospects of obtaining additional supplies in the valley and, to some extent, the adequacy of the present supplies are related to the distribution of the water-bearing gravels, which in turn depends on their origin. If it can be assumed that the Huron River cut to bedrock and deposited the gravels penetrated by the Ypsilanti and bomber-plant wells, it may be inferred that similar deposits of gravel underlie the valley in most if not all of its course and that successful wells can be located almost anywhere along that course. On the other hand, if the gravels were deposited before the river cut its present valley, their location may be related only in a general way or not at all to the course of the river, and the location of additional ground-water supplies becomes more difficult, necessitating considerable test drilling.

Although there is some question as to whether the water-bearing gravels were deposited by the Huron River, there seems to be no doubt that the river has cut away any impermeable materials that may have overlain the gravels at the bomber-plant well field, so that the gravels at river level are freely connected with those at greater depths. There is also some indication that the river may have cut into the main gravels in the vicinity of the Ypsilanti well field, although silt and clay have been penetrated above the gravels in all the wells drilled in the field for which records are available.

At present most of the available evidence indicates that the water-bearing gravels underlying the Ypsilanti and bomber-plant well fields were deposited prior to the final retreat of the Wisconsin glacier and thus that their distribution was not determined by the present course of the river. Conclusive evidence of a continuous channel along the present river, extending to bedrock and filled with coarse gravel, is lacking, but sufficient test wells have not been drilled to determine positively that a continuous channel does not exist. Wells 68, 71, 72 (FWA 10), 73 (FWA 14), and 92 (pl. 2) penetrated little or no coarse gravel in their lower parts, where such gravel might be expected to occur if the Huron River cut to bedrock and formed a continuous gravel-filled channel during the retreat of the glacier and the lowering of the lakes.

In spite of the lack of positive evidence favoring the deposition of the gravels by the Huron River in its present course, it is possible that they may have been so deposited and that the presence of coarse material at the Ypsilanti and bomber-plant well fields is due to the presence of gravelly morainic drift through which the river cut and which furnished the coarse material to the river. According to this hypothesis the coarse material underlying the Ypsilanti well field would have been derived from the Defiance moraine and that at the bomber-plant well field from the Rawsonville boulder belt which is cut by the river nearby. J. E. Cooper, of the Ford Motor Co., and Mr. Poindexter originated the hypothesis that the Rawsonville boulder belt might be the source of the boulder gravels penetrated by the bomber-plant supply wells. If this hypothesis is correct, a continuous channel filled with coarse material should occupy the valley from Ypsilanti upstream because of the presence of abundant morainic material. The available well records do not show such a channel, but they do not prove its absence.

At present it seems likely that the gravels penetrated by the Ypsilanti public-supply wells may have been deposited, at least in part, prior to the final retreat of the glacier. They may represent outwash material from an ice sheet preceding the final advance of the Wisconsin glacier, perhaps that of an invasion during the early Wisconsin or the Illinoian stage, upon which a coating of late Wisconsin till may have been deposited. If so, the Wisconsin till appears to have been discontinuous or to have been cut through in at least some places by the present river.

The gravels at the bomber-plant well field also may have been deposited during a stage of glaciation preceding the final stage. The portion of the Huron Valley in the vicinity of Ypsilanti and Ann Arbor may have been formed during a previous stage, along roughly the course of the present valley, and may have served to locate the present valley during the final retreat of the ice. This hypothetical ancestral valley may have served as an outlet for glacial meltwater during a prior stage, and the gravels now penetrated by the Ypsilanti and bomber-plant wells may have been deposited at such a time. On the other hand, the late Pleistocene history of glacial retreat and lake formation may have repeated a similar process of earlier date, during which the Huron River may have cut down its valley as the glacier retreated and refilled it with sand and gravel upon which late Wisconsin drift was deposited and afterwards cut away. Another possibility is that the bomber-plant gravels may represent outwash from the glacier during the final retreat, at the time when it is believed to have halted and deposited the Rawsonville boulder belt. At that time the ice front was in a lake, so that normal outwash deposits could not form, but local gravel deposits may have formed at points where major glacial streams escaped from the ice, regardless of the presence of standing water at the ice front. Little evidence, however, is available to support any of these hypotheses.

Although it is not certain whether the coarse gravels penetrated by the bomber-plant wells are confined to the Huron Valley, they apparently have not been struck so far in any wells outside the valley. It does not seem reasonable to dismiss as a coincidence the fact that the most productive water-bearing gravels in the Ypsilanti area have been penetrated by wells in the Huron Valley; thus it is difficult to avoid the conviction that some genetic relation exists between the valley and the coarse gravels that underlie it at some places. Solution of this question must await the accumulation of additional data.

ORIGIN OF THE GRAVELS IN THE FLEMING CREEK VALLEY

The Fleming Creek valley served as a channel for glacial meltwaters at the time that the ice was forming the inner ridge of the Defiance moraine. The valley is underlain by glacial outwash gravels, but, as the thickness of the gravels had never been known, wells 4 (FWA 6), 5 (FWA 7), and 43 (FWA 8) were drilled to test these deposits (pl. 1; fig. 1). The wells show that the outwash deposits formed during the final retreat of the glacier are rather thin: Wells 5 (FWA 7) and 43 (FWA 8) penetrated 37 and 42 feet of sand and gravel, respectively, immediately below the surface, and well 4 (FWA 6) penetrated only about 10 feet of material at the top that probably represents glacial outwash. Wells 4 (FWA 6) and 43 (FWA 8) penetrated thick gravels below clay, and it seems probable that the clay is glacial till deposited during the final retreat of the ice. If so, the gravels below the clay were deposited during a previous stage and thus are not necessarily either confined to the present valley or coextensive with it. Well 5 (FWA 7) penetrated mostly clay below the surficial sand and gravel, showing that the thick lower gravels do not underlie the entire valley.

The Fort Wayne moraine and the outer ridge of the Defiance moraine appear to have been deposited at least in part on older drift (Russell and Leverett, 1908), and the inner ridge of the Defiance moraine also may be only a mantle covering older drift. The older drift is undoubtedly morainic in character and may have been deposited during Illinoian or early Wisconsin time, or both. The Illinoian ice in the Ypsilanti area may have moved in a somewhat different direction from the Wisconsin ice, so that if the early drift is Illinoian the moraines and associated outwash gravels may have little relation to the present surface. Thus, if the lower gravels penetrated in wells 4 (FWA 6) and 43 (FWA 8) are of Illinoian age, they may be related to the Wisconsin deposits only insofar as the Illinoian moraines may have influenced the movement of the ice and the location of the moraines of the Wisconsin stage. If they are of early Wisconsin age, however, one might expect them to be more closely related to the present moraines

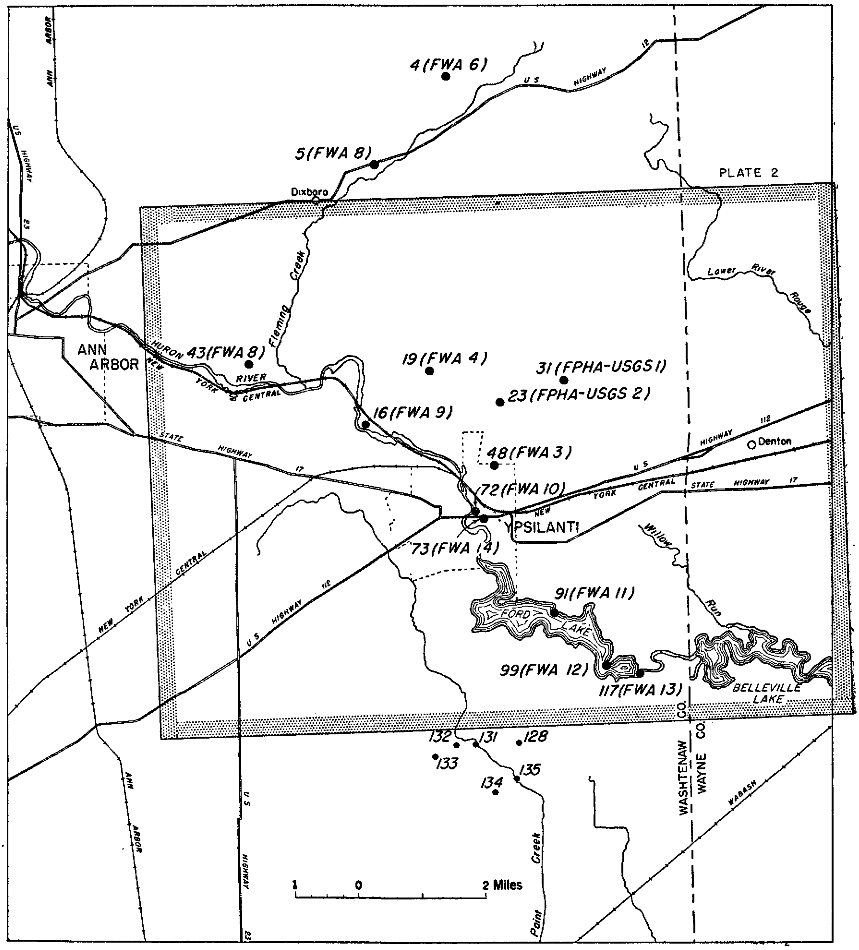

FIGURE 1.—Map of the Ypsilanti-Ann Arbor area, Michigan, showing FWA and FPHA test wells and wells not shown on detailed maps.

and valley. That outwash gravels deposited prior to the last retreat of the Wisconsin glacier may be encountered almost anywhere is shown by the gravels penetrated by the wells at the Willow Run Townsite.

ORIGIN OF THE GRAVELS AT THE WILLOW RUN TOWNSITE

The gravels penetrated by the wells at the Willow Run Townsite are believed to have been deposited prior to the final substage of Wisconsin glaciation. They represent glacial outwash deposits that were formed prior to the present surface and have little or no relation to the present surface features. The deposits penetrated by the Ypsilanti and bomber-plant wells may ultimately be shown to have been deposited at the same time and under the same conditions. The gravels at the Willow Run Townsite are overlain by clay, presumably glacial till of the late Wisconsin stage. However, apparently they are either quite extensive in area or are connected, by means of channels cut through the till, with surficial sands and gravels deposited later, as pumping from the townsite wells has not greatly lowered the ground-water levels at the townsite.

The gravels at the townsite appear to be similar in productivity to the gravel penetrated by well 124, the "unsuccessful" 24-inch well at the edge of the bomber-plant well field, which in a test yielded 875 gallons per minute with a drawdown of about 65 feet. It seems probable that, regardless of the origin of the gravel penetrated by wells 112, 113, and 114 (bomber-plant supply wells 1, 2, and 3, respectively), the gravel penetrated by well 124 had an origin similar to that of the gravels at the townsite.

GROUND-WATER SUPPLIES IN THE YPSILANTI AREA

INTRODUCTION

The potable water supplies of the Ypsilanti area are derived almost exclusively from wells. The only known major exception is at the Willow Run bomber plant, where the treatment plant is designed to use either river water or ground water and where water from the Huron River has been used occasionally during the winter and spring. Almost all the wells in the area penetrate sand and gravel of the glacial drift and associated deposits. Only a few domestic wells penetrate the bedrock, and no industrial or public-supply wells in the Ypsilanti area are known to obtain their supplies in whole or in part from the bedrock. However, the public water supply of Belleville, which is not considered to be in the Ypsilanti area as defined in this report, is obtained from wells penetrating the Antrim shale. The supply is not large, and consideration has been given to a plan to obtain additional water from wells penetrating sand and gravel.

The principal types of sand and gravel deposits are (1) glacial outwash sands and gravels deposited in plains at the edges of moraines and in channels of glacial drainage associated with the moraines and, in many places, covered by younger drift or lake deposits; (2) sands and gravels deposited in the glacial lakes, including beach deposits and delta deposits of streams; and (3) sands and gravels deposited in the channels of streams cutting glacial drift or lake sediments after their deposition, including sands and gravels formed in this way in the Huron Valley.

Private domestic wells in the Ypsilanti area obtain their supplies from all types of glacial and associated deposits. Some relatively shallow dug and bored wells are still in use, obtaining their supplies largely by seepage from lake sediments or glacial drift of low permeability. Most domestic wells are drilled, although some driven (sand-point) wells are in use in places where water-bearing sand lies near the surface and is not overlain by gravelly material that would make driving difficult.

Well records and well logs obtained in the investigation, including records of domestic wells originally collected by Shoecraft, Drury, and McNamee and kindly furnished by that firm, are given in table 13 and on pages 81–102, and the locations are shown in plates 2 and 3 and figures 1, 2, and 4.

QUALITY OF WATER

Water from sand and gravel.—Analyses of water from several wells penetrating sand and gravel are given in table 1, together with an analysis of water from the Huron River for comparison. The ground waters are all of the same general type, moderately hard calcium bicarbonate waters with some magnesium and some noncarbonate (permanent) hardness due largely to the presence of sulfate. The range in total hardness shown in table 1 is from 238 to 397 parts per million (14 to 23 grains per gallon), and the range in noncarbonate hardness shown is from 8 parts per million in the analysis for well 36 (FPHA supply well 2) to 113 parts per million in the 1928 analysis of the Ypsilanti public supply. When completed, well 117 (FWA 13) yielded water with only a few parts per million of noncarbonate hardness, but the exact amount is uncertain.

Chloride is rather low in most wells. The analysis for well 113 (bomber-plant supply well 2) for December 19, 1941, and that for well 117 (FWA 13) for February 25, 1944, when well 117 was at a depth of 100 feet, show 64 and 160 parts per million of chloride, respectively, but these samples show the effect of contamination by water from the bedrock. Note that well 117, when completed, yielded water containing only 11 parts per million of chloride. The chloride content of water from well 113 increased to as much as 164 parts per million in February and March 1943. (See table 3.) Except for the two samples mentioned, the highest content shown in table 1 is 39 parts per million in well 26 (FPHA supply well 5), and the lowest contents are only 3 parts per million in well 4 (FWA 6) and 4 parts per million in wells 36 and 39 (FPHA supply wells 2 and 3, respectively).

TABLE 1.—*Analyses of ground waters in the Ypsilanti area, Michigan, in parts per million, except pH*

	1	2	3	4	5	6	7	8
Date sample taken	Apr. 1, 1944	Apr. 1, 1944	Feb. 1944	Feb. 1944	Feb. 1944	Apr. 21, 1944	May 6, 1944	Nov. 16, 1943
Silica (SiO_2)								7
Calcium (Ca)	66	69				83	88	77
Magnesium (Mg)	23	22				43	23	20
Iron (Fe)	1.0	0.9	0.9	0.9	0.3	1.9	[1]0	0.7
Carbonate (CO_3)	0	0	0	0	0	0	0	
Bicarbonate (HCO_3)	285	290	406	338	265	437	333	301
Sulfate (SO_4)	71	85	53	14	14	47	47	44
Chloride (Cl)	3	3	39	4	4	7	32	19
Nitrate (NO_3)								0
Free carbon dioxide (CO_2)			27	16	16			
Total hardness as $CaCO_3$	259	263	362	285	238	384	314	275
Noncarbonate (permanent) hardness as $CaCO_3$	25	25				26	41	28
Dissolved solids								332
pH			7.4	7.5	7.4			7.5

	9	10	11	12	13	14	15	16
Date sample taken	Dec. 19, 1941	Nov. 16, 1943	Feb. 25, 1944	Feb. 28, 1944	Feb. 29, 1944		1928	Nov. 16, 1943
Silica (SiO_2)	10	8				6	9	5
Calcium (Ca)	64	82	90	75	75	9	111	74
Magnesium (Mg)	30	23	26	19	19	8	29	21
Iron (Fe)	1.5	0.7	0.1	1.5	2.5	0	1.5	0.3
Carbonate (CO_3)	0		0	0	0	17		
Bicarbonate (HCO_3)	316	283	336	322	321	6	346	267
Sulfate (SO_4)	9	73	66	22	34	58	113	40
Chloride (Cl)	64	35	160	11	11	30	17	9
Nitrate (NO_3)	0	0						0.4
Free carbon dioxide (CO_2)	6							
Total hardness as $CaCO_3$	283	299	332	265	265	55	397	271
Noncarbonate (permanent) hardness as $CaCO_3$	24	67	57			22	113	52
Dissolved solids	351	473				186	498	312
pH	7.6	7.5	7.6	7.6	7.6	9.6		7.2

[1] Decanted sample; any iron originally present in sample precipitated out.

1. Well 4 (FWA 6). Sample taken at 10:30 a. m., shortly after beginning of pumping test. Analyzed by Ford Motor Co.
2. Well 4 (FWA 6). Sample taken at 9:20 p. m., just before end of pumping test. Analyzed by Ford Motor Co.
3. Well 26 (FPHA supply well 5). Analyzed by Permutit Co.
4. Well 36 (FPHA supply well 2). Analyzed by Permutit Co.
5. Well 39 (FPHA supply well 3). Analyzed by Permutit Co.
6. Well 43 (FWA 8). Sample taken during pumping test. Analyzed by Ford Motor Co.
7. Well 73 (FWA 14). Analyzed by Ford Motor Co.
8. Well 112 (bomber-plant supply well 1). Analyzed by Ford Motor Co.
9. Well 113 (bomber-plant supply well 2). Analyzed by Ford Motor Co.
10. Well 114 (bomber-plant supply well 3). Analyzed by Ford Motor Co.
11. Well 117 (FWA 13). Sample taken at a depth of 90 to 100 feet. Analyzed by Ford Motor Co.
12. Well 117 (FWA 13). Sample taken from well as completed at a depth of 74 feet, about 3 hours after start of pumping test. Analyzed by Ford Motor Co.
13. Well 117 (FWA 13). Sample taken about 2 hours before end of pumping test. Analyzed by Ford Motor Co.
14. Bomber plant. Typical sample of treated water at bomber plant. Analyzed by Ford Motor Co.
15. Ypsilanti public supply. Sample derived mostly from Spring Street wells but probably in part from open well and associated drilled wells. Analyzed by Michigan Dept. of Health.
16. Sample from Huron River below Ford Dam at Willow Run water plant. Analyzed by Ford Motor Co.

The iron content in wells unaffected by water from the bedrock ranges from 0.3 part per million in well 39 to 2.5 parts per million in one sample from well 117 (FWA 13). The content in most wells is sufficiently high to make iron removal desirable if the water is to be used for domestic purposes, although water from hundreds of private domestic wells is used untreated. Softening is desirable for domestic purposes and almost essential for boiler use. The water is satisfactory for condensing purposes without treatment, although in time scale may form in the condenser tubes.

Water from bedrock.—Analyses of four waters from deep wells penetrating the bedrock are given in table 2, adapted from a table in folio

TABLE 2.—*Analyses of mineral water from wells at Ypsilanti, Mich., in parts per million* [1]

	1	2	3	4
Silica (SiO_2)	24	340	439	15
Iron (Fe)	Tr.	Tr.	14	----------
Calcium (Ca)	1,160	2,167	2,316	1,610
Magnesium (Mg)	496	943	1,064	780
Sodium (Na)	5,374	10,714	14,556	13,576
Potassium (K)	104	295	88	236
Carbonate (CO_3)[2]	379	589	613	496
Sulfate (SO_4)	3,233	3,852	3,659	1,814
Chloride (Cl)	9,368	19,553	26,185	24,221
Bromide (Br)	53	163	180	168
Total solids	20,636	38,679	49,114	42,916
Hydrogen sulfide (H_2S), cc. per liter	91	140	155	67

[1] Adapted from U. S. Geol. Survey Geol. Atlas, Ann Arbor folio (no. 155), 1908.
[2] Presumably in solution both as carbonate, CO_3, and as bicarbonate, HCO_3.

1. Well 81 (Cornwell well, "Ypsilanti Mineral Spring"). Analysis by A. B. Prescott of sample taken Mar. 31, 1883.
2. Well 69 (Moorman well). Analysis by J. H. Shepard of sample taken Sept. 5, 1884. Well cased to 500 feet; water from Dundee limestone.
3. Well 69. Analysis by DeForest Ross of sample taken Sept. 13, 1897. Well cased to 185 feet; some water obtained from Berea sandstone.
4. Well 53 (Atlantis well). Analysis by J. H. Shepard and W. F. Pett of sample taken July 26, 1884, at a depth of about 360 feet.

155 of the Survey's Geologic Atlas (Russell and Leverett, 1908, p. 14). The waters obviously are not potable in the ordinary sense, although small quantities have been consumed. As stated, potable water is obtained from some wells penetrating the Antrim shale, but the quantity is not large and adequate supplies of water of quality suitable for most industrial uses are not available from the bedrock formations in the Ypsilanti area.

WATER FOR PUBLIC SUPPLY AND INDUSTRIAL USES

Until construction of the Willow Run bomber plant was begun, the principal demand for water in the Ypsilanti area was for the public water supply of the city. Only a few private industrial wells are in use in Ypsilanti, and the quantities of water pumped are not large. Many private domestic wells are in use, some of them in the city but most of them outside its limits, and here again the total quantity of water pumped is not large. Construction of the Willow Run bomber plant caused a great increase in the demand for water, not only because of the requirements of the plant itself but because of increased domestic consumption due to the influx of thousands of bomber-plant employees and their families.

A large part of the workers moving into the area found living quarters at the Willow Run Townsite (Willow Run War Housing Community), a war housing project constructed by the Federal Public Housing Authority, and their domestic water requirements were met from wells installed on the townsite. Other workers found living accommodations in Ypsilanti, where water was provided by the Ypsilanti public-supply system; still others, living in privately owned trailers, obtained water from the public-supply system or from neighboring wells. Many of the workers lived in nearby cities, including Ann Arbor and Detroit, and their domestic needs were met largely from the public-supply systems of those cities. However, all the workers of course used water for drinking and sanitary purposes at the bomber plant, and this water was obtained from the bomber-plant wells.

The water requirements of the bomber plant, the Willow Run Townsite, and the Ypsilanti public supply have been a subject of considerable uncertainty, as discussed at some length in the report of September 5, 1942 (McGuinness, 1942, p. 10 et seq.). Most of the uncertainty stemmed from the fact that the number of workers at the bomber plant could not be predicted accurately. At one time it was thought that the number might reach 100,000 to 120,000, but the maximum was revised downward to 60,000, and it is understood that the actual number was never that high. On the basis of a total of 60,000 workers it was assumed that the population of the Willow Run Townsite might be as much as 30,000; however, the authorized population was later set at 22,000, and apparently that figure was never reached. The demand on the Ypsilanti public-supply system was expected to be as much as 3,000,000 gallons of water per day. The requirement for the bomber plant, which was designed as a so-called "dry" plant not requiring large quantities of mill water, was initially estimated to be only 1,000,000 gallons per month, but this figure was soon revised upward (McGuinness, 1942). The water-treatment plant was designed with a rated capacity of 6,000,000 gallons per day.

The total consumption has been considerably less than expected, owing to the fact that the maximum number of workers at the bomber plant was less than anticipated and also to the fact that the per-capita consumption at the townsite has been much less than the figure of 100 gallons per day upon which the initial estimate was based. In

1944 the total daily consumption by the three major water users averaged about 6,130,000 gallons: about 4,000,000 for the bomber plant, 470,000 for the townsite, and 1,660,000 for the public supply of Ypsilanti.

The water supplies of the three major water users, the Willow Run bomber plant, Willow Run Townsite, and Ypsilanti public water-supply system, are obtained from wells penetrating glacial and associated sands and gravels. The bomber-plant and Ypsilanti supplies are obtained from wells in the Huron Valley, and the Willow Run Townsite supply is obtained from wells penetrating sands and gravels underlying the upland northeast of the Huron River. The origin of the gravels penetrated by the wells has been discussed. The supplies are described separately in the following sections.

WILLOW RUN BOMBER PLANT

Source.—The water supply of the Willow Run bomber plant is obtained from wells 112, 113, and 114 (known as supply wells 1, 2, and 3, respectively). The wells are at the north edge of the Huron River, just east of the Rawsonville dam and power plant of the Ford Motor Co. (pl. 3), and they penetrate medium to coarse gravel. The wells are closely spaced, as shown in plate 3, the distance between the outermost wells (112 and 113) being only about 360 feet. They range in diameter from 24 to 26 inches and in depth from 81 to 87 feet (to the bottoms of the screens). Each is equipped with a 50-foot screen. Logs of the wells are given on pages 97–101 together with those of other wells drilled in the well field and vicinity.

The wells are equipped with deep-well turbine pumps with a maximum capacity of about 4,000 gallons per minute each. Ordinarily the supply has been obtained from one or two wells, pumped at rates ranging from about 2,650 to 3,500 gallons per minute for one well and 3,300 to 4,300 gallons per minute for two wells. Wells 112 and 114 (supply wells 1 and 3), only 140 feet apart, were pumped in a 7-day test in November 1943 at a combined rate ranging from 6,350 gallons per minute at the beginning of the test to 5,950 gallons per minute at the end. The three wells probably could be pumped together for at least a short time at the combined rate of about 8,000 gallons per minute. So far it has not been necessary to pump all three wells at once.

Well 113 (supply well 2) yields water relatively high in chloride (table 3; pl. 4). The well struck a bed of hardpan at an altitude of about 580 feet, was drilled through it, and entered a bed of gravel, just above bedrock, in which the water had been contaminated by salt water from the bedrock. An attempt was made to seal the well at the bottom of the main gravel, but it was not entirely successful.

The chloride content of water from well 113 rose to 164 parts per million in February and March 1943. (See table 3.) The content since has been considerably lower (table 3; pl. 4), indicating that the seal at the bottom of the well has become more effective or that the salty gravel has been freshened, or both.

Treatment.—The water receives complete treatment in a modern treatment plant. The plant has six rapid sand filters, each with a capacity of 1 million gallons a day at the rate of 2 gallons per minute per square foot of filter surface. In view of the lack of turbidity in the ground water, the rate possibly could be increased safely to 3 gallons per minute per square foot, giving a total capacity for the plant of 9 million gallons per day. The piping is designed to permit doubling the rated capacity of 6 million gallons per day by adding six more filters and another settling basin and clear-water reservoir. The product of the plant is a soft, stable, iron-free water of high quality. Analyses of the raw and treated water are given in table 1.

The treatment plant has an intake in the Huron River, and river water has been used occasionally in the winter and spring. It is believed that this practice is not strictly necessary at present, but it is helpful in permitting replenishment of the ground water withdrawn from storage in the well field.

Pumpage.—The pumpage from the bomber-plant wells from June 1942 through June 1945 is given in tables 3 and 4, together with data on the water levels in certain wells. The pumpage in 1944 through August averaged a little more than 4 million gallons per day, about the same as for the equivalent period in 1943. The pumpage began to decline in September 1944 as the result of decreased production at the bomber plant. The pumpage in that month was about 3.40 million gallons per day as compared with 4.79 million gallons per day in September 1943. The average daily pumpage was 4.16 million gallons in 1943, 4.00 million gallons in 1944, and 2.90 million gallons in the first 6 months of 1945.

Water levels.—Water levels in certain supply and observation wells in the bomber-plant well field are given in tables 3 and 4 and shown in plate 5. The data show only slight progressive decline in water level that can be ascribed to the pumping, and it is believed that this indicates the existence of local sources of recharge adequate to maintain the supply.

TABLE 3.—*Pumpage for bomber plant, water level in well 112 (supply well 1), and chloride content of water from well 113 (supply well 2), June 1942 to June 1943*

Date	Approximate average water level in well 112, in feet above mean sea level		Total pumpage during month (gallons)	Average chloride content of well 113 (p. p. m.)
	Static level	Pumping level		
1942				
June	646		43,380,500	
July	646		52,605,000	
August	646		48,660,000	
September	646		44,280,000	
October	646		56,175,000	
November	646	640	58,380,000	
December	645		60,495,000	85
1943				
January	644	637	86,295,000	123
February	645		82,065,000	164
March	644.5		111,000,000	164
April	644	633	126,000,000	147
May	643.5		131,940,000	54
June		633	136,830,000	54

Recharge.—The gravels penetrated by the bomber-plant supply wells are recharged by (1) precipitation on the valley floor in the vicinity of the wells, (2) ground-water flow from water-bearing sands and gravels underlying the upland in which the valley is cut, (3) ground-water flow from the upstream and downstream portions of the valley, mainly from the upstream portion, and (4) infiltration from the Huron River. It would be possible to evaluate the importance of the different sources of recharge only by means of a much more comprehensive pumping test than has been made so far, but the available information indicates that recharge from the river is an important source of the water pumped from the wells, perhaps the most important. In view of the small area in which permeable sediments are exposed, the first source mentioned—recharge from precipitation in the immediate vicinity of the wells—probably would be able to supply only a relatively small part of the total quantity of water pumped. With regard to the second and third sources, it is impossible, in view of the uncertainty concerning the origin of the water-bearing gravels and thus concerning their areal distribution, to say which is more important.

TABLE 4.—*Water levels in bomber-plant well field, pumpage from wells, and levels of Huron River, July 1943 to June 1945*

[Asterisk indicates well was being pumped at time water-level measurements were made]

Date	Water levels, in feet above mean sea level										Pumping rate at time of measurement (g. p. m.)	Pumpage since last measurement (million gallons)	Head-water [3]	Tail-race [4]
	Observation wells [1]							Supply wells [2]						
	103 (OW 7)	104 (OW 8)	105 (OW 10)	106 (OW 9)	107 (OW 11)	109 (OW 12)	117 (FWA 13)	112 (1)	113 (2)	114 (3)				
1943														
July 13	655.52	654.17	651.21	652.70	----	----	----	(*)	(*)	----	----	[5] 60±	----	----
July 19	655.52	654.17	651.21	652.70	652.07	----	----	(*)	----	----	3,000	27.97	684.50	----
July 26	655.40	654.09	651.04	650.53	650.44	----	----	(*)	----	----	3,000	32.61	684.50	651.35
Aug. 2	655.35	654.09	651.00	650.28	649.93	----	----	(*)	(*)	----	4,000	31.66	684.42	651.32
Aug. 11	655.10	654.09	651.00	650.11	649.85	648.16	----	(*)	----	----	3,000	41.96	684.62	651.32
Aug. 17	655.35	654.00	650.84	649.95	649.85	648.00	----	(*)	(*)	----	4,000	27.08	684.00	651.35
Aug. 23	655.02	653.84	650.80	649.53	649.44	648.29	----	(*)	(*)	----	4,000	27.58	683.67	651.18
Aug. 30	655.14	653.84	650.81	650.16	650.19	650.20	----	(*)	(*)	----	4,000	34.37	683.38	651.23
Sept. 6	655.14	654.00	651.09	649.74	649.52	647.91	----	(*)	(*)	----	4,000	35.26	684.00	651.31
Sept. 15	655.10	654.38	650.88	649.61	649.23	647.87	----	(*)	(*)	----	4,000	41.49	684.80	651.40
Sept. 21	654.94	654.34	650.96	649.90	649.60	648.28	----	(*)	(*)	----	4,000	26.30	684.65	651.40
Sept. 27	655.27	654.12	650.84	649.73	649.39	648.03	----	(*)	(*)	----	4,000	27.21	684.50	651.37
Oct. 4	655.31	654.12	650.92	649.90	648.68	648.24	----	(*)	(*)	----	4,000	31.40	684.57	651.35
Oct. 11	655.10	653.84	650.84	649.65	649.26	647.66	----	(*)	(*)	----	3,800	32.23	683.49	651.37
Oct. 18	655.31	654.17	650.87	650.07	649.42	648.62	----	(*)	(*)	----	3,800	30.41	683.72	851.35
Oct. 26	655.35	654.17	650.84	649.95	649.69	648.79	----	(*)	(*)	----	3,800	35.56	685.68	651.57
Nov. 1	655.25	653.94	650.86	649.38	648.93	647.22	----	(*)	(*)	----	3,800	26.57	684.73	651.35
Nov. 8	655.39	654.02	650.81	649.52	649.24	647.29	----	(*)	(*)	----	3,800	30.40	684.73	651.13
Nov. 16	656.10	653.09	649.74	647.28	646.49	645.77	----	*634.5	----	(*)	6,000	63.91	684.78	651.15
Nov. 24	655.29	653.61	650.27	649.36	647.77	646.91	----	*643.5	(*)	----	3,333	35.61	684.65	651.30
Dec. 1	656.56	653.54	650.21	649.39	647.81	646.83	----	*643.5	*643.42	646.93	3,333	30.79	684.50	651.15
Dec. 7	655.18	653.52	650.00	647.61	646.85	646.68	----	648.5	*638.95	647.18	3,333	26.29	684.57	651.15
Dec. 15	655.44	654.10	650.17	648.70	647.77	647.50	----	647.5	*641.63	647.05	3,200	33.42	684.65	651.30
Dec. 20	656.10	654.00	649.21	649.32	649.19	648.08	----	*638.5	648.47	647.76	3,100	19.77	683.65	651.10
Dec. 28	655.60	654.14	650.17	648.94	648.35	649.16	----	648.5	*640.13	648.30	3,333	27.49	683.03	651.35
1944														
Jan. 3	656.68	654.14	650.84	649.69	648.77	648.66	----	648.5	*640.38	647.30	3,333	18.99	682.67	651.25
Jan. 10	655.85	653.31	650.17	648.95	648.27	648.16	----	648.5	*639.13	648.72	3,333	27.99	682.45	651.32
Jan. 17	655.35	653.42	650.33	649.11	648.85	647.24	----	*638.5	----	646.72	3,000	27.74	681.76	651.30
Jan. 25	655.44	653.59	649.92	648.86	648.35	646.74	----	*638.5	----	----	3,000	31.71	681.18	651.27
Feb. 8	655.31	653.61	650.21	648.78	648.33	646.55	----	*638.5	----	----	3,000	55.42	684.75	651.25
Feb. 16	655.38	653.63	650.15	648.68	648.44	648.48	----	*638.5	----	646.03	3,000	31.01	684.55	651.35
Feb. 21	655.27	653.72	650.29	649.03	648.65	646.81	----	*638.5	647.38	646.32	2,900	18.97	684.80	651.45
Feb. 29	655.85	653.41	650.42	648.76	648.46	646.54	----	*637.5	----	646.0	2,900	31.29	685.00	651.40
Mar. 6	655.68	653.75	650.38	648.78	648.73	646.58	----	*637.5	----	646.0	2,900	23.02	685.00	651.40

Mar. 13	655.77	653.58	650.42	648.95	648.52	646.66		*637.5		646.0	2,900	26.42	684.75	651.25
Mar. 20	655.94	653.84	650.42	648.69	648.52	646.62		*637.5		646.0	2,900	27.04	684.55	651.35
Apr. 3	655.52	653.50	650.08	648.03	647.60	646.41	648.16		(*)		3,300	52.90	684.85	651.35
Apr. 20	655.60	653.92	650.00	649.03	646.77		648.08	647.5	(*)		2,800	70.02	685.09	651.35
May 2	655.33	653.61	650.36	648.82	648.50	646.64	647.75	*637.5			2,800	47.06	684.40	651.24
May 10	655.50	653.42	650.17	647.43	646.62	646.33	648.56	(*)	(*)		3,333	32.49	684.90	651.25
May 16	655.48	653.50	650.35	647.80	646.93	646.76	649.06	(*)	(*)		3,333	25.05	684.65	651.35
May 23	655.63	653.58	650.55	648.14	647.37	647.12	649.25	(*)	(*)		3,333	29.83	684.60	651.35
June 16	656.27	654.92	649.66	649.61	649.10	647.50	649.17	*641.5	*640.5		4,200	101.22	684.45	651.30
June 23	656.02	654.75	649.66	648.27	647.60	647.00	649.41	*642.5	*640.5		4,200	34.73	685.37	651.50
June 30	656.18	654.92	649.84	648.03	648.01	647.33	649.83	*642.5	*640.5		4,200	35.87	685.45	651.30
July 6	656.35	655.08	650.00	648.19	648.19	647.58	650.00	*642.5	*640.5		4,300	27.38	684.65	651.10
July 15	656.85	655.08	650.09	648.95	648.52	647.66	650.25			(*)	3,500	42.78	682.95	651.38
July 22	655.60	654.25	649.34	649.20	648.27	646.75	649.08			(*)	3,500	32.18	680.94	651.29
July 28	655.02	653.40	650.47	648.83	648.36	645.58	648.27			(*)	3,500	27.29	679.63	651.27
Aug. 4	654.91	653.13	650.18	648.95	647.19	645.89	647.61	(*)	(*)		4,166	33.82	678.68	651.35
Aug. 10	654.73	653.22	650.34	648.47	647.81	645.37	648.04		(*)	(*)	4,000	27.39	678.42	651.25
Aug. 22	655.19	653.31	650.25	648.28	648.02	645.24	647.75	644.5	646.5	*639.0	3,333	55.45	677.23	651.35
Sept. 1	655.02	652.98	650.00	648.19	647.85	645.08	647.58	(*)			3,000	43.01	678.37	652.35
Sept. 8	655.10	652.90	649.92	648.86	648.43	648.58	648.91				0	21.28	677.85	651.12
Sept. 20	655.26	653.39	650.33	649.94	648.27	646.24	648.08	645.5	*638.5	647.0	3,333	42.86	677.87	651.20
Sept. 26	654.68	653.64	650.08	649.03	648.60	647.66	648.50	641.5	648.5	647.0	3,000	20.78	677.63	651.27
Oct. 7	655.18	653.50	650.25	649.03	648.85	647.08	648.67	*641.5	647.5	646.0	3,000	41.07	678.22	651.36
Oct. 12	653.44	652.90	650.00	648.94	648.52	647.24	647.91	(*)			3,000	17.61	678.39	651.29
Oct. 20	654.44	653.33	650.50	648.94	648.60	645.91	647.75	*638.5	648.0	646.0	3,000	27.99	679.32	651.34
Oct. 26	654.85	653.08	650,00	647.45	646.52	645.74	647.91		(*)		3,000	20.42	679.78	651.35
Nov. 8	655.18	653.25	650.17	649.69	648.35	646.66	648.25	(*)			3,000	46.42	678.40	651.36
Nov. 25	655.67	653.42	650.34	647.86	646.85	646.24	648.08			(*)	3,000	62.12	678.35	652.38
Dec. 4	654.35	653.42	649.92	646.61	647.93	644.91	648.25			(*)	3,333	31.09	684.05	651.15
Dec. 16	655.85	653.14	650.50	647.94	645.68	645.58	648.33		(*)		3,100	48.62	682.64	651.11
Dec. 28		653.56				645.41				(*)	3,000	40.07		
1945														
Feb. 21	654.10	652.75	649.67	646.94	649.02	643.08	647.83			(*)	3,333	189.64	679.20	651.30
Mar. 1	653.93	652.92	649.50	646.61	646.02	643.00	647.75			(*)	3,333	25.41	682.25	651.30
Mar. 10	654.18	652.75	649.17	648.61	646.68	647.83	647.91				0	30.99	682.30	651.31
Mar. 15	654.27	653.42	649.17	646.36	645.52	645.00	647.50	643.5	637.5	646.0	3,166	17.83	681.90	651.35
Mar. 23	654.10	652.92	649.00	646.28	646.35	645.33	647.33		(*)		3,166	29.11	683.60	651.17
Apr. 6	655.02	653.25	649.92	646.69	646.68	645.49	647.75			(*)	3,333	49.90	684.70	651.30
Apr. 18	654.18	653.50	647.59	648.69	648.10	646.91	647.91	(*)			2,833	39.73	684.20	651.15
Apr. 28	654.94	653.75	650.00	647.53	648.19	647.00	649.00	(*)			3,000	27.09	684.10	651.30
May 24	655.10		652.00	647.75	651.69	649.58	648.83	(*)			2,666	47.65	684.74	651.42
June 2	655.26	654.92	652.17	651.69	651.52	649.66	649.00	(*)			2,833	12.11	684.90	651.37
June 6	655.10	654.75	651.84	651.78	652.01	650.41	652.08	(*)			2,666	5.15	684.82	651.35
June 13	654.44	654.33	651.17	650.94	651.10	650.16	651.33	(*)			2,666	9.06	684.50	651.70

[1] Measurements made by means of steel tape.
[2] Measurements made to the nearest foot by means of air line and altitude gage, except in wells 113 and 114 from Dec. 1, 1943, to Feb. 21, 1944, inclusive, when a tape or rod was used.
[3] Altitude of Ford Lake at dam, in feet above mean sea level.
[4] Altitude of Huron River at tailrace of dam, in feet above mean sea level.
[5] Approximate pumpage in July 1943 up to July 13.

Evidence of recharge from the river is afforded by (1) temperature and chemical data, (2) absence of any large progressive decline in the water level due to pumping, such as would be likely to occur if the major recharge areas were a considerable distance away, (3) the relation between water levels in the well field and those in the river, and (4) the behavior of the water levels in wells during pumping tests. A discussion of the evidence of recharge follows.

1. Periodic observations of the temperature and chloride content of water from the wells and from the river have been made since February 1944, and the results through June 1945 are shown graphically in plate 4. Temperature and chloride data for the acceptance test on well 114 in November 1943 are given in table 5.

TABLE 5.—*Temperature and chloride content of water from well 114 (bomber-plant supply well 3) during pumping test, November 9–15, 1943* [1]

Date	Time	Temperature (degrees F.)	Chloride (p. p. m.)
1943			
Nov. 9	3:22 p. m.	58	12
9	4:13 p. m.	57	13
10	7:40 a. m.	57	20
10	11:30 a. m.	57	24
10	4:20 p. m.	57	26
11	7:30 a. m.	55	29
11	4:15 p. m.	55	34
12	8:00 a. m.	54	34
12	2:30 p. m.	54	36
13	10:00 a. m.	54	34
13	4:00 p. m.	54	34
14			31
14	5:00 p. m.		34
15	7:30 a. m.	54	34
15	4:30 p. m.	54	34

[1] Average temperature of well 112 (supply well 1) during test, 53° F.; average chloride content, 18 p. p. m. Average temperature of Huron River during test, 47° F.; average chloride content, 8 p. p. m.

Plate 4 shows substantial fluctuations in temperature in all three supply wells. The range in temperature observed in the supply wells from February 1944 through June 1945 was from 48° to 62° F. The temperature of water from wells as deep as the bomber-plant wells generally does not fluctuate more than a degree or two during the year.

Heat could be exchanged between the river and the ground through a short distance by conduction rather than by movement of water, so that a fluctuation in the temperature of the ground water would not necessarily indicate movement of water from the river. However, in view of the fact that fluctuations in temperature of as much as a degree occur to depths of only a few tens of feet as a result of annual fluctuations in mean daily air temperature of 50° or more (Collins, W. D., 1925, pp. 97–98), it is obvious that heat exchange by conduction could not explain the observed fluctuation in temperature in the bomber-plant well field, where the wells are about 40 to 80 feet from the river. Moreover, the large amount of heat represented by a rise of several degrees in the temperature of millions of gallons of ground water could not conceivably be derived from the river water—or from the air—by conduction alone. Thus warm water must have moved outward from the river to cause the observed rise in temperature in the wells during the summer, and, likewise, cold water must move outward from the river during the winter.

Attention is again called to table 5, giving data on the temperature and chloride content of water from well 114 (supply well 3) during a pumping test made from

November 9 to November 15, 1943. The temperature of the water in the river averaged about 47° F. during the test. The temperature of water from well 114 declined during the test from 58° at the start to 54° at the end. The 4-degree decline in temperature indicates recharge from a source of water cooler than that in the ground near the well at the start of the test. The river is the most likely source, although some of the cooling was doubtless caused by admixture of ground water from adjacent areas where the ground water had not been warmed previously by recharge from the river.

The temperature evidence is confirmed by the chloride determinations, which show a downward trend in chloride from the higher content typical of the ground water in this area to the lower content typical of the river water. (See pl. 4.) The water whose relatively low chloride content has reduced the chloride content of the water from the wells is derived both from precipitation and from the river; however, recharge from precipitation would be inadequate to furnish the quantity of low-chloride water required to dilute the more concentrated ground water, so that the river must be the major source of low-chloride water. Some low-chloride water, similar (see table 1) to that from wells 4 (FWA 6), 36, 39, and 43 (FWA 8), might be coming from sands and gravels in the glacial drift near the bomber-plant well field, but evidence as to the existence of such waters in the vicinity of the well field is lacking, and such a source would not be adequate in itself to furnish the large quantities of diluting water that have been required.

The rise in chloride content in well 114 during the pumping test made from November 9 to November 15, 1943 (table 5), appears to contradict the evidence as to river recharge afforded by the decline in temperature. However, it is believed that the high-chloride water was derived from well 113 (supply well 2), which yields water relatively high in chloride. High-chloride water from the contaminated gravel below the hardpan at well 113 is able to enter the well when it is pumped, and it seems reasonable to assume that the lowering in head in well 113 caused by the pumping of wells 112 and 114 in the test was sufficient to cause high-chloride water to enter the bottom of well 113 and pass into the ground through the screen.

2. If recharge from the river were small or nonexistent, the major source of recharge would be precipitation on the upstream and downstream stretches of the valley and the upland area outside the valley. Recharge to replenish the substantial quantities of water pumped for the bomber plant would have to be derived from a rather extensive area, and the water levels would show a progressive decline due to withdrawal of water from storage. This process might be expected to take some time, and before equilibrium between recharge and discharge could be established the water levels might be expected to decline to considerably lower stages than they have. The absence of a large progressive decline suggests that a local source of recharge exists that is nearly or quite adequate to maintain supply. The river is the only source that appears to meet the requirements.

3. With regard to the relation between water levels in the well field and those in the river, attention is called to plate 5. The water level in well 109 showed some recovery during May and early June 1944, in spite of the fact that the pumpage increased and the river levels remained about the same. This could be due in part to recharge from precipitation, but it is believed that warming of the river water, with a resulting decrease in viscosity and therefore of loss in head as the water passes into the ground, is mostly responsible for the rise in water level. Conversely, the slightly lower pumping levels that existed during the latter part of the preceding winter, in spite of reduced pumpage, can be explained by the cooling of the river water and the increase in viscosity during the winter. The flow of ground water is typically laminar (viscous), in contrast with the turbulent flow

that generally occurs in pipes and surface streams. In laminar flow the rate of flow varies inversely in proportion to the viscosity, and a decline in the temperature of the water from 90° to 40° F. approximately doubles the viscosity, thus reducing the rate of flow by about one-half, other conditions remaining the same. The temperature observed in the bomber-plant supply wells from February 1944 through June 1945 ranged from 48° to 62° F., giving a range in viscosity of about 1.35×10^{-2} to 1.09×10^{-2} in C. G. S. units. At 48° F. the viscosity would be 1.35/1.09, or about 1.24 times as great as at 62° F., and the drawdown in a well at a given rate of pumping likewise would be roughly 1.24 times as great. Thus both the temperature of the pumped water and the behavior of the water levels in the well field are such as would be expected if recharge from the river were taking place.

The divergence between the graph of well 105 and that of the river below the dam (tailrace), as shown in plate 5, may be significant. The level of the tailrace has remained nearly constant. In July 1943 the water level in well 105 was nearly as high as the water in the river just below the dam, but the level in the well declined slowly thereafter until reduced pumping caused a rise in the spring of 1945. A slight downward trend in well 104 and in well 109 (which is within the triangle formed by the three pumped wells) is also apparent. A part of the decline from July 1943 to the fall of 1944 might be due to the net decline in the level of the river above the dam in that period (pl. 5). However, in view of the fact that the decline in river level took place chiefly during the last few months of the period, it seems more likely, although recharge from the river was undoubtedly occurring, that the downward trend in wells 104, 105, and 109 shows that water was still being withdrawn from storage and that a condition of steady flow from the river to the wells had not yet been reached for the maximum rates of pumping. This is a point of importance with respect to the amount of additional water that can be obtained in the vicinity of the present wells, but from the low rate of decline in the wells it may be inferred that an "equilibrium" or steady-flow condition would be reached at the highest rates of pumping maintained so far with only slight additional declines.

The rises in water level in wells 104 and 109 from the middle of May to the middle of July 1944, which were quite similar (pl. 5), are somewhat difficult to explain on the basis of the available data. The rise in well 109 may have been due principally to the warming of the river water and the resultant warming of the ground water. The rise in well 104 may have been largely a reflection of that in well 109. The 30 feet of clayey material above the water-bearing sand in well 104 indicates that artesian conditions may exist that would facilitate the rapid transmission to that well of the effects of fluctuations in water level in the vicinity of the pumped wells.

The rises in wells 104 and 109 might be due in some part to recharge from precipitation. However, the heaviest precipitation in the period concerned occurred in the week ending June 23, 1944, during which both wells showed a decline in water level. This fact, with the absence of a rise in water level in well 105, where the material apparently is permeable from the surface down, suggests that the effect of precipitation was not great during the period under consideration.

4. The evidence furnished by the pumping tests with regard to recharge from the river is discussed in the section on pumping tests.

Adequacy of the supply.—Evidence of recharge from the river has been discussed in some detail because the existence of river recharge adequate to maintain the supply that has been developed so far means that additional water can be obtained from wells located near the river and at a sufficient distance from the present wells to minimize interference. Extremely coarse gravels, which yield large supplies of water to wells with small drawdowns, have been penetrated north of the river only in the small area occupied by wells 112, 113, and 114. Well 105 showed material that would give a good yield, although in the opinion of the driller (Layne-Northern Co., Inc.) the yield would not be as large as that of the present supply wells. Nevertheless, a supply well could be located in the vicinity of well 105, preferably somewhat nearer the river, and would not interfere much with the present wells. Additional test wells could be drilled along the edge of the river between wells 106 and 105 to learn whether coarse gravels exist in that stretch.

A supply well could be located at the site of well 117 (FWA 13), and additional drilling south of the river probably would reveal other good sites for supply wells. Assuming proper location of wells to take advantage of recharge from the river, it is believed that supplies substantially larger than have been pumped so far could be developed. It is believed that the combined safe yield of wells 112, 113, and 114 is not less than 6 million gallons per day. For additional wells that may be required, the best site shown by test wells drilled so far is that of well 117 (FWA 13). If it seems desirable not to cross the river, a well near well 105, but preferably nearer the river, would be satisfactory. Well 114, located between wells 112 and 113, proved to be entirely satisfactory, but it is believed that additional wells should not be installed in the small area occupied by the present wells, as the interference probably would be excessive.

CITY OF YPSILANTI

Source.—The public water supply of Ypsilanti is obtained from wells 75, 76, and 77, known as supply wells 1, 2, and 3, respectively, penetrating sand and gravel in the bend of the Huron River in the SE¼ sec. 9, Ypsilanti Township (fig. 2). Wells 75 and 77 are about 1,000 feet apart; well 76 is about 600 feet from well 75 and 900 feet from well 77. The wells were completed in 1943, are 16 inches in diameter and 87 to 102 feet deep (see table 13), and are equipped with 20-foot wire-wound screens. Logs of the wells are given on pages 93 and 94.

The water supply was formerly obtained from a large dug well (well 83) in and adjacent to which several drilled wells were later installed. These drilled wells now are reported to yield little water. Still later, 14 wells 8 inches in diameter and about 70 feet deep were installed along Spring Street (wells 70–1N to 6N and 1S to 8S). All were pumped by suction. They were placed in reserve, to be used only in emergencies, when wells 75, 76, and 77 were completed. The total

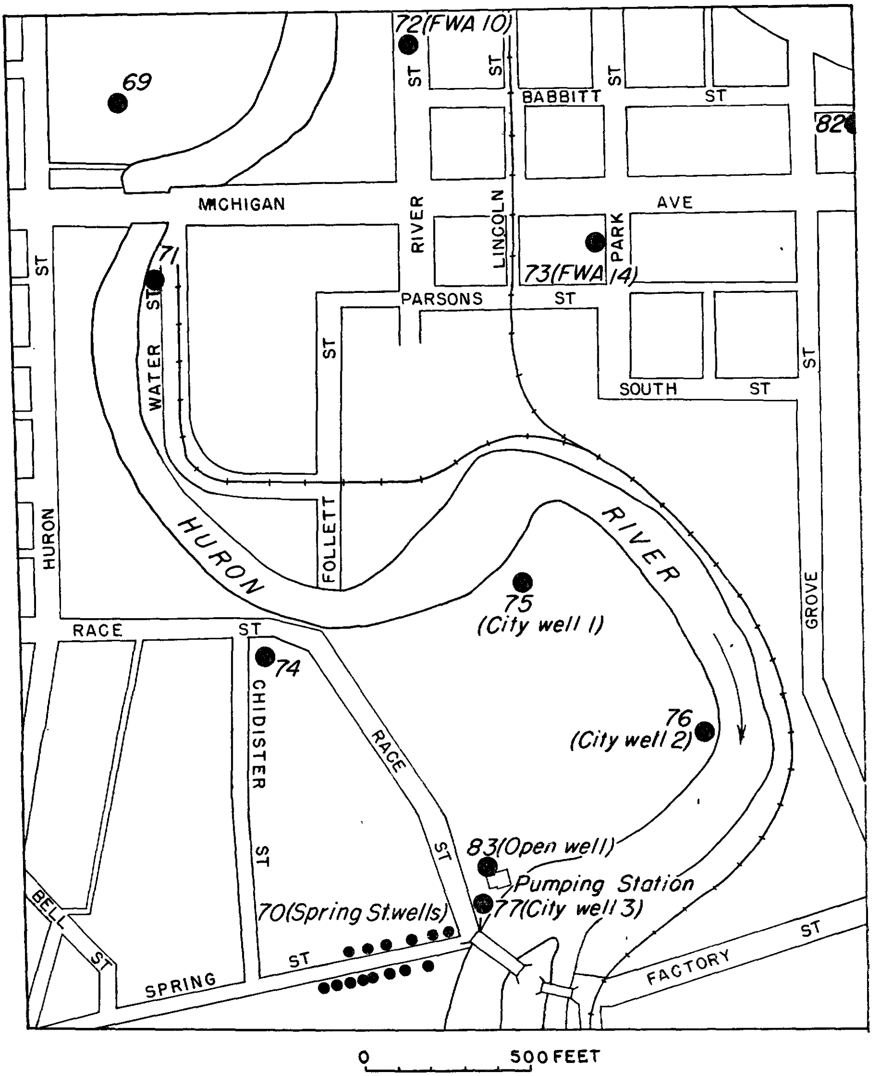

FIGURE 2.—Map showing Ypsilanti public-supply wells and nearby wells.

dependable yield of the old wells is reported to have been about 2.5 million gallons per day (Shoecraft, Drury, and McNamee, 1942, p. 7).

The new wells are equipped with deep-well turbine pumps. The pumps in wells 75 and 77 have a capacity of about 1,500 gallons per minute each; the pump in well 76 has a capacity of about 600 gallons per minute. The three wells apparently have not been pumped together in a test, and their total yield is not known. Pumping tests made on the individual wells are discussed in the section on pumping tests.

Treatment.—Water from the wells is treated in a modern iron-removal and softening plant, installed in 1939. The rated capacity of the plant is 2 million gallons per day, but it can be operated for short periods at the rate of 2.5 million gallons per day (Shoecraft, Drury, and McNamee, 1942, p. 7). An analysis of the treated water is not at hand, but an analysis of untreated water from the old wells is given in table 1. In an emergency river water could be treated in the plant.

Pumpage.—Table 6 shows the average daily pumpage from the Ypsilanti public-supply wells, by months, from January 1939 through June 1945. Data for the period January 1927 through May 1942 are given by Shoecraft, Drury, and McNamee (1942, chart 1, appendix).

TABLE 6.—*Average daily pumpage from public-supply wells at Ypsilanti, Mich., in millions of gallons per day, by months, January 1939 to June 1945* [1]

Month	1939	1940	1941	1942	1943	1944	1945
January	1.38	1.20	1.21	1.72	1.66	1.615	1.639
February	1.35	1.18	1.33	1.78	1.74	1.586	1.645
March	1.19	1.24	1.21	1.80	1.65	1.655	1.643
April	1.22	1.24	1.30	1.79	1.53	1.523	1.542
May	1.21	1.31	1.31	1.65	1.60	1.596	1.543
June	1.22	1.29	1.36	1.62	1.88	1.779	1.630
July	1.46	1.55	1.49	1.82	1.91	2.037	
August	1.30	1.36	[2] 1.46	1.69	1.83	2.000	
September	1.23	1.18	1.40	1.62	1.70	1.555	
October	1.13	1.29	1.46	1.55	1.67	1.507	
November	1.15	1.25	1.54	1.56	1.64	1.511	
December	1.09	1.20	1.56	1.52	1.60	1.531	
Average for year	1.24	1.27	1.39	1.68	1.70	1.659	
Maximum day [3]	2.01	2.12	2.25	2.28	2.42		

[1] Figures for 1942–43 are approximate, based on graph furnished by Shoecraft, Drury, and McNamee.
[2] Figures for August 1941 through May 1943 include amounts of water furnished to the Willow Run bomber plant, averaging approximately, by months, in millions of gallons per day:

1941		*1942*				*1943*	
August	0.05	January	0.43	July	0.19	January	0.20
September	.11	February	.37	August	.21	February	.29
October	.12	March	.37	September	.18	March	.13
November	.26	April	.27	October	.20	April	.01
December	.36	May	.15	November	.17	May	.01
		June	.14	December	.19		

[3] Maximum day occurred in July in 1939, 1940, and 1942; in August in 1941; and in June in 1943.

The average daily pumpage was increasing slowly before the war and, in 1941, began to increase more rapidly as a result of the construction of the Willow Run bomber plant. The average daily pumpage in million gallons was 1.24 in 1939, 1.27 in 1940, 1.39 in 1941, and 1.68 in 1942. The pumpage in 1943 was 1.70 million gallons per day, about the same as in 1942; however, less water was furnished to the Willow Run bomber plant in 1943 than in 1942 (see table 6, footnote 2), so that the figure for 1943 reflects somewhat increased public-supply consumption at Ypsilanti. Little water has been furnished to the bomber plant from the Ypsilanti public supply since March 1943.

The pumpage in 1944 was about 1.66 million gallons per day, slightly less than in 1943, but when the water furnished to the bomber plant is deducted from the totals, 1944 shows a slight increase over 1943. The average daily pumpage was more than 2 million gallons in July and August 1944, the first months on record when the pumpage exceeded that figure.

The average daily pumpage in the first six months of 1945 was 1.61 million gallons.

Water levels.—Only scattered data on water levels are available for the years prior to 1944. Table 7 gives the results of periodic measurements beginning in February 1944 in wells 72 (FWA 10) and 70–3N (Spring Street well 3N) and, from August 1944, in well 73 (FWA 14).

TABLE 7.—*Water levels in observation wells at Ypsilanti, Mich., in feet below measuring point, February 1944 to June 1945*

[Measuring points: wells 72 and 73, top of casing, slightly above land surface; well 70–3N, top of well head, slightly above land surface. See fig. 3 for water-level measurements in well 72 during period Feb. 17–25, 1944]

Date	Well 72 (FWA 10)	Well 73 (FWA 14)	Well 70–3N (Spring Street well 3N)
1944			
Feb. 28	[1] 25.24		[1] 9.72
29	[2] 25.29		
Mar. 1	[1] 25.32		
2	[2] 25.29		
3	[1] 25.34		
4	[1] 25.34		
6	[2] 25.24		[2] 14.30
8	[1] 25.34		
9	[3] 25.40		
10	[3] 25.50		
11	[1] 25.57		
13	[3] 25.38		[4] 9.60
14	[3] 25.45		
15	[3] 25.47		
16	[3] 25.23		
17	[3] 25.12		
18	[3] 25.22		
20	[3] 25.21		[1] 9.78
21	[3] 25.30		
22	[3] 25.32		
23	[3] 25.35		
24	[3] 25.35		
25	[3] 25.30		
27	[3] 25.40		[3] 14.39
28	[3] 25.39		
Apr. 3	[3] 25.38		[3] 14.35
4	[3] 25.40		
5	[3] 25.40		
6	[5] 25.43		
7	[1] 25.45		
10	[1] 25.37		[1] 10.01
11	[1] 25.28		
12	[1] 25.19		
13	[1] 25.09		
14	[6] 25.10		
17	[6] 25.00		[6] 17.96
24	[1] 24.85		

See footnotes at end of table.

TABLE 7.—*Water levels in observation wells at Ypsilanti, Mich., in feet below measuring point, February 1944 to June 1945*—Continued

Date	Well 72 (FWA 10)	Well 73 (FWA 14)	Well 70-3N (Spring Street well 3N)
1944			
May 1	[6] 24.91	----	----
8	[1] 25.95	----	[1] 9.10
15	[1] 25.00	----	[1] 8.50
23	[6] 25.20	----	[6] 19.15
29	[1] 24.90	----	[1] 9.30
June 5	[1] 24.68	----	[1] 9.71
12	[6] 24.90	----	[6] 18.27
26	[1] 24.68	----	[1] 9.79
July 24	[6] 25.87	----	[6] 18.40
Aug. 7	[7] 26.07	----	[7] 18.38
14	[7] 26.26	----	[7] 20.26
21	[1] 26.30	[1] 35.11	[8] 17.94
28	[6] 26.26	[1] 35.06	[6] 16.76
Sept. 11	[6] 26.03	[6] 33.42	[6] 14.13
18	[9] 25.99	[9] 33.53	[9] 14.02
25	[1] 26.51	[1] 34.51	[1] 14.89
Oct. 2	[2] 26.01	[2] 35.55	[2] 15.06
9	[1] 24.98	[1] 33.77	[1] 13.40
16	[6] 24.98	[6] 35.00	[6] 16.92
23	[1] 25.97	[1] 33.78	[1] 13.49
30	[6] 25.69	[6] 34.00	[6] 14.10
Nov. 6	[1] 25.98	[1] 32.80	[1] 11.53
20	[1] 24.76	[1] 33.77	[1] 12.39
27	[1] 25.87	[1] 32.40	[1] 11.32
Dec. 4	[6] 25.98	[6] 35.49	[6] 18.50
11	[6] 26.00	[6] 34.83	[6] 17.67
18	[6] 26.00	[6] 35.21	[6] 17.10
26	[1] 26.00	[1] 35.00	[8] 15.47
1945			
Jan. 2	[6] 26.09	[6] 35.46	[6] 18.06
9	[6] 26.04	[6] 35.10	[6] 18.00
29	[6] 26.30	[6] 35.79	[6] 18.78
Feb. 5	[6] 26.37	[6] 34.59	[6] 14.15
12	[6] 26.39	[6] 35.66	[6] 17.37
19	[6] 26.39	----	[6] 16.88
26	[1] 26.22	[1] 34.65	[8] 14.34
Mar. 5	[1] 26.02	[1] 34.02	[1] 11.96
12	[1] 26.00	[1] 32.90	[1] 11.65
19	[1] 26.04	[1] 33.57	----
26	[1] 26.61	[1] 33.45	[1] 11.59
Apr. 2	[6] 25.62	[6] 34.73	[6] 18.14
17	[6] 25.58	[6] 35.15	[6] 18.30
23	[6] 25.65	[6] 34.65	[6] 18.02
30	[1] 25.50	[1] 31.85	[1] 10.45
May 7	[1] 25.50	[1] 31.78	[1] 10.34
15	[6] 25.20	[6] 34.27	[6] 17.60
21	[1] 23.72	[1] 30.16	[1] 8.88
June 4	[1] 23.58	[1] 30.23	[1] 8.78
11	[6] 24.00	[6] 33.65	[6] 16.53
18	[6] 24.35	[6] 33.52	[6] 16.02
25	[6] 24.60	[6] 34.32	[6] 14.80

[1] Well 76 (city well 2) being pumped at rate of 0.75–0.9 million gallons per day.
[2] Well 75 (city well 1) being pumped at rate of 2.0–2.25 million gallons per day.
[3] Wells 75 and 76 being pumped at combined rate of 2.8–3.0 million gallons per day.
[4] No public-supply wells being pumped.
[5] Wells 75 and 77 being pumped at combined rate of about 4 million gallons per day.
[6] Well 77 (city well 3) being pumped at rate of 2.0–2.25 million gallons per day.
[7] Wells 76 and 77 being pumped at combined rate of 2.8–3.0 million gallons per day.
[8] Well 76 being pumped; well 77 possibly shut off a short time before measurement.
[9] Wells 75, 76, and 77 being pumped; well 77 probably pumped for only a short time prior to measurement.

Notwithstanding the lack of specific data, it is evident that little or no progressive decline in water levels has occurred in the Ypsilanti well field. Good, though not conclusive, evidence of this is the fact that the water levels have not declined beyond the reach of the suction pumps used for the old wells, in spite of the gradual increase in pumpage. In 1941 a test on the old wells showed a yield of 2.1 million gallons per day from fifteen 8-inch wells (the 14 Spring Street wells and 1 other) and the dug well (well 83), with average pumping levels at an altitude of 670 feet. The dug well when operated alone had a yield of 1.5 million gallons per day with the pumping level at 670 feet, and the fifteen 8-inch wells when operated alone yielded 2.0 million gallons per day with an average pumping level at 670 feet (Shoecraft, Drury, and McNamee, 1942, pp. 6–7). In the test made in July 1943, well 75 (new supply well 1) and the old wells were pumped together for 16 hours at the combined rate of about 3.75 million gallons per day (about 1.9 million gallons per day for well 75 and 1.85 million gallons per day for the old wells), and the water level in the dug well declined only to an altitude of about 667 feet. In the test made in September 1943, well 77 (new supply well 3) was pumped at the maximum rate of about 1.8 million gallons per day, and the old wells were pumped at rates ranging from 0.55 to 1.9 million gallons per day, and the water level in the dug well again declined only to an altitude of about 667 feet. Although these data cannot be analyzed quantitatively, they indicate that the water levels in the well field have shown little or no progressive decline.

Recharge and adequacy of the supply.—The logs of wells in the Ypsilanti well field show materials of low permeability above the water-bearing gravels, giving the impression that a continuous layer of such material exists in the area that will reduce or prevent recharge from precipitation and from the river. If such a layer exists, recharge would have to occur largely by underflow from the upstream and downstream parts of the valley and from permeable beds underlying the upland adjacent to the valley. However, the available information indicates that the material of low permeability is absent in some places, so that the lower gravels are accessible to recharge from precipitation and perhaps from the river. The lack of progressive decline in water level in the Ypsilanti well field suggests that local recharge takes place, just as in the case of the bomber-plant wells.

Evidence of interconnection between the main water-bearing gravels in the Ypsilanti well field and permeable materials near the surface is afforded by interference between deep and shallow wells. As stated above, the shallow dug well (well 83) produced about 1.5 million gallons per day, and the Spring Street wells about 2.0 million gallons per day when pumped alone, but when these wells were pumped together the combined yield was only 2.1 million gallons per day, the pumping water levels being at an altitude of 670 feet in all three tests (Shoecraft, Drury, and McNamee, 1942, pp. 6–7). This is clear evidence of interference between the deep and shallow wells. Unless the Spring Street wells are screened in the upper gravel, which is unlikely, it is also evidence of interconnection between the sands and gravels that supply the deep and shallow wells.

It is reported that the yield of the 36-foot well at the Trojan Laundry (well 74) is decreased when the public-supply wells are pumped. It is not certain whether the well is affected when only the deep public-supply wells are pumped or when the pumping of the dug well (well 83) is in progress. However, in view of the other available information it seems reasonable to believe that well 74 is affected by the Spring Street wells and by wells 75, 76, and 77, penetrating the deeper gravels.

Confirmatory evidence of interconnection between deep and shallow gravels is afforded by well 72 (FWA 10), which penetrated sand and gravel from the surface to a depth of 49 feet, below which no permeable materials were penetrated. Water occurs in the sand and gravel under water-table conditions. Fluctuations of water level in well 72 (FWA 10) that could be definitely ascribed to the pumping of the deep public-supply wells would furnish positive evidence of interconnection between the deep gravels and surficial materials accessible to recharge from surface sources, and one of the reasons for drilling well 72 (FWA 10) was to obtain information on this point.

During the period February 17–25, 1944, frequent measurements of water level were made in well 72 (FWA 10), and a record was kept of the pumping rates of wells 75 and 76 (city wells 1 and 2). The results are shown in figure 3. Inasmuch as there are no other wells of large

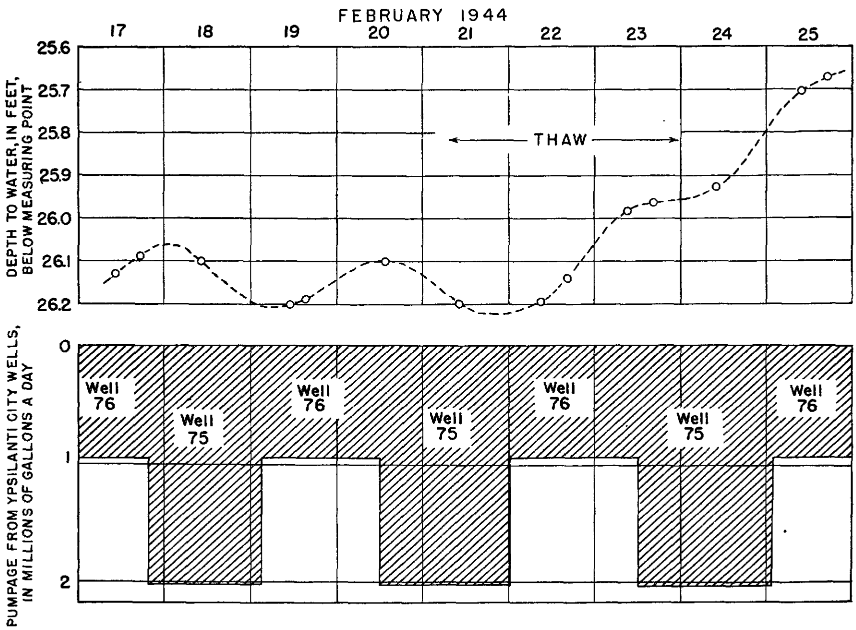

FIGURE 3.—Graph showing relation of fluctuations in well 72 (FWA 10) to pumpage from Ypsilanti public-supply wells, February 17-25, 1944.

capacity in the vicinity that might affect the water level in well 72 (FWA 10), it is apparent that the pumping of the city wells was responsible for the fluctuations shown, except for the rise that began on February 21 or 22, 1944. This rise was due to a thaw that began on February 21. According to data from the Detroit airport, the maximum temperature on that date was 45° F., as compared with 38° on February 20 and 29° on February 19. The minimum temperature on February 21, probably reached before the maximum and not afterward, was 26°, as compared with 21° on February 20 and 7° on February 19. The maximum temperatures were well above freezing during the period February 22–27, inclusive (68° on February 26), and minimum temperatures below freezing occurred only on February 24 and 25 (30° and 29°, respectively). This relatively long warm spell was observed to result in the melting of the frost out of the ground, and as shown by well 72 (FWA 10) the thaw produced substantial ground-water recharge. The pumping of well 75 (city well 1) on February 23, 24, and 25 did not cause a decline in water level, as had the two previous periods of pumping, but it did flatten the rising curve due to recharge (fig. 3).

The existence of interconnection between the deep and shallow gravels does not mean that water is free to travel from one bed to the other with little loss in head. In September 1943, at a time when the Spring Street wells were being pumped, it was observed that the water level in well 77 (city well 3), which was then under construction, was roughly 10 feet lower than the water table, which, as shown by the water level in the annular space outside the well casing, was near the level of the river. Precise observations of the relative positions of the ground-water and river levels were not made. It is stated in folio 155 of the Survey's Geologic Atlas (Russell and Leverett, 1908, p. 15) that the old Ypsilanti public-supply wells originally flowed, indicating sources of recharge some distance upstream or outside the valley that were adequate to produce a head in the lower gravels higher than the head in the shallow gravels. Such a difference in head suggests that the average permeability of the material between the deep and shallow gravels is lower than the permeability of the gravels themselves; that is, the water moves from one bed to the other through material of low permeability or through tongues of permeable gravel encased in material of low permeability. However, it should be pointed out that the simple condition of a deep bed imperfectly connected with a shallow bed in which water occurs under water-table conditions may not exist throughout the Ypsilanti well field. In parts of the field the deep and shallow gravels may be freely connected, but the shallow gravels may be capped by impermeable material. Under such conditions an artesian flow would not necessarily indicate a substantial difference in head between the deep and shallow gravels.

The apparent absence of progressive declines in water level in the Ypsilanti well field indicates that the present pumpage from the field could be increased substantially. Although it is not definitely known whether recharge of the main gravels from the river by way of the shallow gravels can occur, it is possible that such recharge may be taking place. The water now pumped, amounting on the average to less than 2 million gallons per day, could be replenished to a considerable extent by underflow from upstream areas if deposits as permeable as those in the well field extend along the valley for an indefinite distance. If such deposits do not exist, however, it seems likely from the absence of progressive declines in water level that recharge from the river may occur nearby. In view of the relatively small total area of permeable surficial material in the vicinity that is not covered by pavements and buildings, it seems unlikely that precipitation in the immediate vicinity could account for all the recharge that is apparently occurring, although a part of it undoubtedly can be explained in this way.

Whether the bulk of the present recharge is derived from underflow or from the river, or both, it is believed that the rate of pumping could be safely increased to 3 million gallons per day and perhaps to as much as 4 million; such an increase would result in a decline in water levels in the well field, which in turn would increase the rate of recharge. At present it seems unlikely that the demand will exceed an average of 2 million gallons per day for some time to come.

It is not known whether the deep gravels penetrated by the Ypsilanti public-supply wells are directly related to the present valley of the Huron River or whether they were formed previously. If not confined to the present valley, the gravels do not appear to extend far beyond it, as wells outside the valley generally do not strike such coarse material. Whether or not the gravels extend beyond the valley, they appear to be accessible to local recharge, which is the most important point with respect to the adequacy of the present supplies.

Availability of additional water in the Huron Valley.—The available data are not sufficient to indicate whether large additional supplies can be obtained in the Huron Valley upstream from the Ypsilanti well field. Additional development in the area downstream from the field might be practicable but might necessitate drilling wells in Ford Lake, the slack water of which extends nearly to the Ypsilanti well field. However, additional development in the area upstream would depend on the occurrence of gravels in the valley. Whether good deposits of water-bearing gravel exist can be determined only by means of adequate test drilling, which would be a prerequisite for further large-scale ground-water developments in the Huron Valley. The possibility of interference with the present public-supply wells must also be considered in future development.

WILLOW RUN TOWNSITE

Source.—The water supply of the Willow Run Townsite is obtained from wells in two fields: well 26 (FPHA 5), in the northwest or Prospect and Geddes Road field, and wells 32, 36, and 39 (FPHA 4, 2, and 3, respectively), in the southeast or Wiard Road field (fig. 4). Another well in the Wiard Road field, well 34 (FPHA 1), has been completed and tested, but as it showed an apparent specific capacity of only about 2 gallons per minute per foot of drawdown, as compared with specific capacities ranging from about 10 to 22 gallons per minute per foot for the other wells, a permanent pump has not been installed. Well 32 (FPHA 4), though equipped with a pump, has been pumped but little. Logs of the test wells and supply wells on the townsite are given on pages 84–87.

The two well fields are a little less than 2 miles apart. The three wells in the Wiard Road field that are equipped with pumps are spaced about 1,000 to 2,250 feet apart. Well 34 (FPHA 1), which is not in use, is about 300 feet from well 36 (FPHA 2) and 700 feet from well 32 (FPHA 4).

Well 26 (FPHA 5) is 24 inches in diameter and 111 feet deep (108 feet to the bottom of the 30-foot screen). It is equipped with a 25-horsepower deep-well turbine pump and yields about 500 gallons per minute with a drawdown of about 35 feet.

The wells in use in the Wiard Road field are 12 inches in diameter and 92 to 128 feet deep. Well 34 (FPHA 1), which is not in use, is 175 feet deep. The screens in the wells in use range in length from 11 feet in well 39 (FPHA 3) to 22 feet in well 36 (FPHA 2). Well 34 (FPHA 1) has a 25-foot screen. Well 36 (FPHA 2) is equipped with a 40-horsepower deep-well turbine pump and yields about 600 gallons per minute with a drawdown of about 27 feet. Well 39 (FPHA 3) is equipped with a 30-horsepower pump and yields about 550 gallons per minute with a drawdown of about 50 feet. Well 32 (FPHA 4) yields about 550 gallons per minute with a drawdown of about 25 feet; the horsepower of its pump is not known.

The water from the wells is chlorinated but is not treated for iron removal or softening. Analyses of water from wells 36, 39, and 26 (FPHA 2, 3, and 5) are given in table 1.

Pumpage.—The quantities of water pumped from the townsite wells each month from March 1943 through June 1945 are shown in table 8.

On the assumption that the per-capita daily consumption would be about 100 gallons, the total pumpage was expected to be 2 to 3 million gallons per day, but it has never approached these figures. The

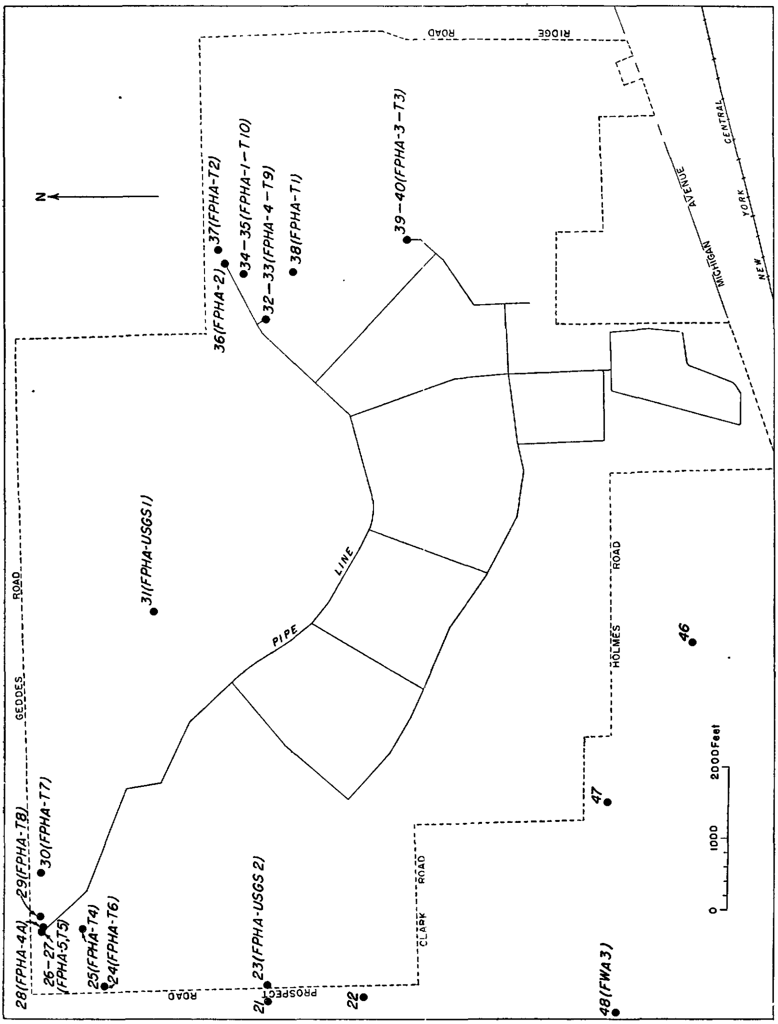

FIGURE 4.—Map showing wells and pipe line on Willow Run Townsite, Washtenaw County, Mich.

average daily pumpage during the 28-month period March 1943 through June 1945 was about 450,000 gallons. The average daily pumpage in 1944 ranged from about 400,000 gallons in March to about 590,000 gallons in August and averaged about 470,000 gallons. The population served in January 1944 was about 13,000; it began to decline in September 1944, as the result of curtailed production at the bomber plant, and in October was about 8,000. The pumpage held up fairly well in the last part of 1944 and the early months of 1945, but by June 1945 it had declined to about 375,000 gallons per day.

Water levels.—Measurements of water level in well 37 (4-inch test well 2), made at intervals of 1 to 5 days from April 16 to June 28, 1943, are given in table 9. Average monthly water levels in well 37 from

TABLE 8.—*Pumpage from wells at Willow Run Townsite, in gallons per month, March 1943 to June 1945* [1]

Month	Wiard Road field		Prospect and Geddes Road field	Total pumpage
	Well 36 (FPHA 2)	Well 39 (FPHA 3)	Well 26 (FPHA 5)	
1943				
March	0	7, 650, 000	0	7, 650, 000
April	0	6, 750, 000	0	6, 750, 000
May	0	6, 300, 000	0	6, 300, 000
June	10, 350, 000	6, 300, 000	0	16, 650, 000
July	4, 750, 000	7, 550, 000	0	12, 300, 000
August	3, 250, 000	4, 850, 000	10, 250, 000	18, 350, 000
September	4, 100, 000	1, 500, 000	10, 400, 000	16, 000, 000
October	75, 000	6, 450, 000	8, 150, 000	14, 675, 000
November	2, 400, 000	1, 200, 000	11, 150, 000	14, 750, 000
December	50, 000	8, 850, 000	4, 200, 000	13, 100, 000
1944				
January	25, 000	7, 550, 000	6, 600, 000	14, 175, 000
February	0	6, 022, 200	6, 123, 600	12, 145, 800
March	0	9, 940, 800	2, 457, 000	12, 397, 800
April	0	8, 932, 800	3, 640, 200	12, 573, 000
May	0	11, 310, 000	3, 330, 000	14, 640, 000
June	5, 086, 500	8, 250, 000	2, 325, 000	15, 661, 500
July	14, 025, 000	2, 130, 000	1, 635, 000	17, 790, 000
August	±13, 500, 000	2, 793, 000	2, 100, 000	±18, 393, 000
September	11, 400, 000	1, 320, 000	1, 440, 000	14, 160, 000
October	11, 868, 750	1, 065, 000	1, 155, 000	14, 088, 750
November	11, 475, 000	1, 335, 000	120, 000	12, 930, 000
December	11, 456, 250	1, 935, 000	60, 000	13, 451, 250
1945				
January	12, 750, 000	2, 550, 000	0	15, 300, 000
February	14, 081, 250	1, 410, 000	0	15, 491, 250
March	14, 100, 000	2, 340, 000	0	16, 440, 000
April	13, 113, 750	2, 400, 000	0	15, 513, 750
May	11, 568, 250	2, 430, 000	0	13, 998, 250
June	9, 487, 000	1, 755, 000	0	11, 242, 000

[1] Figures are approximate. Those for March 1943 to January 1944, inclusive, are based on rates of pumping observed in tests and on consumption of electric current. Figures for February 1944 to June 1945, inclusive, are based on rates of pumping observed in tests and on duration of pumping: 420 gallons per minute for wells 39 and 26 to Apr. 28, 1944, and 500 gallons per minute thereafter; 625 gallons per minute for well 36. These figures are reported by S. J. Shank, of the Federal Public Housing Authority. Figures for wells 39 and 26 for the period prior to Apr. 28, 1944, are not corrected for calibration made on that date.

July 1944 to June 1945, inclusive, are given in table 10. Average monthly water levels in well 26 (FPHA 5) from February to October 1944, inclusive, are given in table 11. Data are available for well 39 (FPHA 3), but, owing to lack of explanation for a reported decline in water level of about 12 feet from March 28 to March 29, 1944, there is doubt as to the accuracy of the measurements, and the data are not included in this report.

TABLE 9.—*Water level in well 37 (4-inch test well 2), in feet below measuring point,*[1] *April–June 1943*

Date	Water level	Date	Water level	Date	Water level
1943		*1943*		*1943*	
Apr. 16[2]	Flowing	18	Flowing	June 12	0.2
19	1.1	19	Flowing	13	.5
21	1.3	20	Flowing	14	1.2
26	1.5	21	Flowing	15	1.4
28	.9	22	Flowing	16	1.4
29	.8	26	Flowing	17	1.5
May 3	.9	June 1	Flowing	18	1.4
6	1.0	2	Flowing	19	2.0
7	1.2	3	Flowing	21	2.5
8	1.0	4	Flowing	22	2.0
10	.8	5	0.7	23	2.0
11	.5	7	.2	24	2.5
12	.0	8	.0	25	2.0
13	.1	9	.2	26	2.5
14	.2	10	.0	27	4.0
15	.5	11	.0	28	3.0
17	Flowing				

[1] Top of 4-inch casing about 0.6 foot above land surface; altitude 729.71 feet above mean sea level.
[2] Well 36 (FPHA supply well 2) put into service Apr. 16, 1943, with 15-horsepower temporary pump.

TABLE 10.—*Average monthly water level*[1] *in well 37 (4-inch test well 2), in feet below measuring point,*[2] *July 1944 to June 1945*

Month	Average water level	Month	Average water level
1944		*1945*	
July	5.5	January	7.5
August	6.5	February	7.9
September	6.9	March	7.9
October	6.4	April	7.9
November	6.4	May	6.7
December	6.5	June	6.8

[1] From measurements made daily, generally just before starting pump in well 36. Measurements reported in feet and inches and converted to feet and tenths. In last part of period measurements apparently were made less accurately than in first part; for example, water level was reported to be 6.8 feet below measuring point (10 feet 6 inches below new measuring point) for each day in June 1945.
[2] Top of 4-inch casing about 0.6 foot above land surface and 729.71 feet above mean sea level. Beginning July 11, 1944, measurements were made below top of 3.7-foot extension added to casing, but all measurements are corrected to original measuring point.

TABLE 11.—*Average monthly water level*[1] *in well 26 (FPHA 5), in feet below measuring point,*[2] *February–October 1944*

Month	Average water level	Month	Average water level
1944		*1944*	
February	47.2	July	38.0
March	43.3	August	41.5
April	46.3	September	41.4
May	44.5	October	38.8
June	40.6		

[1] From daily measurements made just before stopping pump. Measured to nearest half foot by means of air line and altitude gage.
[2] Measuring point is base of pump, about 5 or 6 feet above land surface.

The earliest available measurements of water level in the townsite wells are as follows:

On November 6, 1942, the water level in well 26 (FPHA 5) was 0.8 foot below the top of the 24-inch casing, which was about a foot below the land surface and 780.12 feet above mean sea level; on November 11, 1942, just before a pumping test, the water level was about 0.5 foot below the top of the casing. Water levels shown in table 11 are below a datum about 5 or 6 feet above the land surface.

On November 18, 1942, the water level in well 37 was 1.5 feet below the measuring point; on November 29, 1942, after well 36 (FPHA 2) had been pumped in a test for about 5 days at the rate of about 555 gallons per minute and was still being pumped, the water level in well 37 was 5.6 feet below the measuring point. The pumping water level in well 36 on November 29 was 20.2 feet below the top of the 12-inch casing, which was about at the land surface and 732.0 feet above mean sea level.

On October 9, 1942, the water level in well 39 (FPHA 3) was 3.8 feet below the reference point, which was about at the land surface and 730.94 feet above mean sea level. Measurements discussed later in this section are below a datum about 5 or 6 feet above the land surface.

The water levels in the wells have shown only relatively small declines since pumping started, and no declines indicating possible overdevelopment have been observed. Measurements of the water level in well 26 (FPHA 5) are not available for the period since October 1944. The pumping water level in that well showed a general rise during 1944, as a result of a reduction in average daily pumpage from about 210,000 gallons in January and February to about 68,000 gallons in August, 48,000 gallons in September, and 37,000 gallons in October. The pumping water level averaged about 47 feet below the measuring point in February and about 39 feet in October (table 11). The specific capacity (yield per unit of drawdown) of well 26 apparently has increased since the original pumping test in November 1942, when the drawdown was more than 50 feet at a rate of about 500 gallons per minute.

The water level in the vicinity of well 36 (FPHA 2), as shown by well 37 nearby, has shown only such decline as might be expected in view of the quantities of water pumped from the Wiard Road field. The water level in well 37 was 3 to 4 feet below the measuring point at the end of June 1943 (table 9). During that month well 36 was pumped at the average rate of about 345,000 gallons per day. This was the first month since November 1942, when the original test was made, in which a large quantity of water was pumped from well 36. In June 1945 the water level in well 37 averaged about 7 feet below the measuring point, after well 36 had furnished about 83 percent of the water for the townsite for a year and the Wiard Road field had furnished essentially all the water for 8 months.

As stated, the pumping water level in well 39 (FPHA 3) showed a sudden apparent decline of about 12 feet from March 28 to March 29, 1944. It is not known whether a gradual decline occurred and was finally registered by the air line and altitude gage, which may have been obstructed, or whether a change in the reference datum was made and not reported by the Federal Public Housing Authority. It is unlikely that such a decline actually occurred in the well in a day.

According to the available data, the pumping water level in well 39 during the original test in October 1942 was more than 60 feet below the datum of the present altitude gage at a rate of 555 gallons per minute. The pumping level was reported to be 70 feet below the datum at the end of August 1944, which seems reasonable in view of the fact that well 39 was the principal source of water for the town site from March until the middle of June 1944, when heavy pumping of well 36 was begun. Just before the pumping of well 36 began, the pumping water level in well 39 was reported to be about 66 feet below the datum. When the pumping from well 39 was reduced and the pumping of well 36 was begun, the pumping water level in well 39 is reported to have recovered to about 63 feet. It then began to decline again, presumably as the result of the pumping of well 36. It should be pointed out that well 39 is the least productive well in use at the townsite, so that larger declines in water level would be expected at given rates of pumping than would occur in the other wells. Well 39 also has a smaller available drawdown than the other wells, as it is the shallowest.

The available data on water levels do not show whether there is interference between the pumped well in the Prospect and Geddes Road field and those in the Wiard Road field. Such interference, if it exists, would be small in view of the considerable distance between the well fields and the relatively small quantities of water pumped. Well 31 (FPHA–USGS 1), directly between the two well fields, showed almost no permeable material between the surface and bedrock, indicating a probability that little connection through permeable material exists between the two well fields.

Recharge.—The water-bearing sands and gravels underlying the Willow Run Townsite are relatively thin and are overlain by apparently continuous deposits of clay and silt. It would appear from the logs of the wells that the water-bearing sands and gravels come to the surface at a considerable distance, if at all, and thus that the rate of recharge from surface sources is low. There are no sizable streams in the vicinity of the townsite wells; thus recharge from streams would not be large even if a connection existed between the surface and the water-bearing sands and gravels.

If a continuous blanket of impermeable material overlies the water-bearing sands and gravels, it would be expected that the water levels would have declined considerably since the original pumping tests, owing to withdrawal of water from storage. The moderate declines in water level in the townsite wells suggest that local recharge probably occurs. However, the evidence for local recharge is scant, and it is possible that the relatively small quantities of water that have been pumped so far may have been derived from storage.

Adequacy of the supply.—The results of pumping tests on the wells at the Willow Run Townsite are discussed in the section on pumping tests.

The fact that only small declines in water level occurred in the wells at the Willow Run Townsite during more than 2 years of operation indicates that the present rates of pumping can be maintained indefinitely. Whether much larger supplies could be pumped safely is not known, but on the basis of past performance it is believed that the safe yield of the present wells is 1.0 to 1.5 million gallons per day.

It seems probable that a total perennial supply of about 2 million gallons per day could be obtained from the present wells and additional, properly located wells on the townsite.

If it ever appears that the demand for water at the Willow Run Townsite may increase to as much as 2 million gallons per day, it is believed that a controlled pumping test should be made on all the wells to obtain as much information as possible on the geologic conditions as shown by the behavior of the water levels. Several shallow observation wells should be installed and measured to determine whether interconnection exists between the main water-bearing gravels and shallower materials accessible to recharge from precipitation. Only such a test would make it possible to predict the maximum amount of water that can be produced for a specified period and with specified pumping levels in the wells. Also, several additional test wells should be drilled to bedrock in and near the townsite to locate sites for additional supply wells if needed. It should be pointed out that the ground-water supply of the Willow Run Townsite has a smaller potential capacity than the other two major supplies, because the thickness and permeability of the gravels are less, their areal distribution is irregular, and conditions of recharge are not as favorable as for the other two supplies and eventually may prove to be rather unfavorable.

If a large additional supply is needed for the townsite and adequate drilling and pumping tests show it to be impracticable to develop the water in or near the townsite, consideration could be given to a plan to obtain the needed water from the Willow Run bomber plant and possibly to some extent from the Ypsilanti public supply. Consideration should also be given to the areas tested in the drilling program of the Federal Works Agency. (See the sections on the test-drilling program and the pumping tests, with respect to the availability of additional supplies in the areas tested.)

TEST-DRILLING PROGRAM

INTRODUCTION

In December 1943 the Federal Works Agency awarded a contract for the drilling of approximately 10 test wells to the Dunbar and Sons Drilling Co. of Delta, Ohio. The contractor was equipped with two Bucyrus-Erie cable-tool rigs capable of drilling 6-inch holes to a depth of 1,000 feet. In addition, use was made of equipment capable of pumping a 6-inch well at the maximum rate of about 350 gallons per minute.

The drilling of the first well was begun on January 25, 1944, and the eleventh and last well was completed on May 6, 1944. Locations of the test wells are showr in plate 1 and also on the detailed well maps (pls. 2 and 3; figs. 2 and 4).

In addition to the wells drilled by the Federal Works Agency, two 4-inch test wells, wells 23 (FPHA–USGS 2) and 31 (FHPA–USGS 1), were drilled by the O. Corsaut Drilling Co. on the Willow Run Townsite at locations selected by the Geological Survey. The cost of the two wells was paid by the Federal Public Housing Authority.

DESCRIPTION OF WELLS

In the following sections the test wells are described and discussed in a general way. The detailed logs are given on pages 81–100.

Well 4 (FWA 6).—This well was drilled approximately in the middle of the Fleming Creek valley, in the SE¼NW¼ sec. 4, Superior Township. The altitude at the site is about 830 feet. Wells 4 (FWA 6), 5 (FWA 7), and 43 (FWA 8) were drilled to test the outwash deposits in the Fleming Creek valley, which on the basis of the available information formed one of the most promising areas for further ground-water development in the vicinity of Ypsilanti.

The uppermost 10 feet of material in well 4 (FWA 6) is clay, sand, and gravel of alluvial origin. Below this is 30 feet of silt and clay with a few small pebbles. This 30 feet of material may represent till deposited by an ice sheet, but might have been deposited in ponded water. The material between 40 and 135 feet beneath the surface appears to be glacial outwash sand and gravel. If the material between 10 and 40 feet is glacial till, the gravel from 40 to 135 feet presumably was deposited during a stage prior to the final stage of glaciation. Below a depth of 135 feet is sandy and silty clay, probably glacial till. The well was stopped at a depth of 190 feet without reaching the base of the Pleistocene deposits, owing to the necessity of conserving funds for other wells. However, it is probable that the well ended not far above the bedrock and that little or no permeable material lies below a depth of 190 feet.

The outwash sand and gravel contains two beds of fine to coarse permeable gravel, between 90 and 98 feet and 105 and 120 feet, separated by 7 feet of sandy silt. Relatively fine gravel with sand lies above the upper gravel and below the lower gravel. The sand and gravel constitute a rather permeable aquifer from which a substantial supply of water, up to a million gallons per day, could be developed at this site. A pumping test made on well 4 (FWA 6) is discussed in a later section of this report. Following the pumping test the casing and screen were removed, and the well was abandoned.

Analyses of two samples of water from the well, taken during the pumping test, are given in table 1. The water is hard and contains about 1 part per million of iron; it would be suitable for emergency use without treatment, except for chlorination if necessary. For long-term use iron removal would be desirable; softening would also be desirable, though not essential.

Well 5 (*FWA 7*).—The well was drilled in the SE¼SW¼ sec. 8, Superior Township, on the south side of U. S. Highway 12 about 0.5 mile east of the highway bridge over a tributary of Fleming Creek. The altitude at the site is approximately 820 feet. This well also is approximately in the middle of the Fleming Creek valley.

The uppermost 37 feet of material consists of alluvial sand and gravel, representing glacial outwash material deposited between the inner and outer ridges of the Defiance moraine. From 37 to 150 feet the well penetrated silty clay containing occasional rounded pebbles that might be cavings from the surficial sand and gravel. It is not clear whether this material is glacial till or represents relatively fine grained sediments deposited in ponded water, but its great thickness indicates that it is probably till. At a depth of 150 feet the material becomes sandy, and below this depth the well apparently is in glacial outwash deposits. Fine to medium sand with a little gravel lies between depths of 180 and 190 feet, and fine to medium gravel with sand from 190 to 202 feet. A mixture of sand and gravel with clay extends from 202 to 216 feet. The well did not completely penetrate the Pleistocene deposits, but the bedrock probably is not far below the bottom of the well, and it seems likely that little permeable material lies at a depth greater than 216 feet. The well was abandoned at a depth of 216 feet, and the casing was withdrawn.

The sand and gravel extending to a depth of 37 feet is favorably situated for absorbing water from precipitation. However, the zone of saturation is probably thin, as the nearby streams have cut into the surficial materials to altitudes of 800 to 810 feet and the sand and gravel may be rather thoroughly drained. The principal function of the shallow sands and gravels would be to recharge any permeable materials at greater depths with which they may be connected.

The bed of sand and gravel between 180 and 202 feet would yield a moderate supply of water to a properly constructed well, preferably screened through the entire thickness of the bed. It is not known whether the deeper sands and gravels are connected with the shallow materials in the immediate vicinity, but it is possible that at least a distant connection exists. It should be possible to develop a supply of a few hundred thousand gallons per day at this site for at least a year or two. If it is necessary to develop additional supplies in the Fleming Creek valley for the Willow Run Townsite or other users at Ypsilanti, the site of well 4 (FWA 6) would be preferable to that of well 5 (FWA 7). Additional good sites in the valley doubtless could be located by drilling more test wells.

Well 16 (FWA 9).—The well was drilled in the SW¼SW¼ sec. 32, Superior Township, on the property of the Detroit Edison Co. The altitude of the site is about 720 feet. The well was drilled to determine whether permeable deposits underlie the Huron River valley throughout its course above Ypsilanti. It penetrated no permeable sand and gravel except near the surface. Below a depth of 10 feet the material is clay and silt with some muddy sand and gravel. It is not certain whether all the material is of fluviatile origin or whether some of it is glacial till. Two interpretations are possible: either the Huron River has not cut away deposits of glacial drift at the well site, or, if the river has cut away the drift, it has been replaced by fine-grained material deposited in ponded water. The well, although it penetrated no highly permeable water-bearing material, had a slight flow under artesian pressure. However, this does not help to identify the material penetrated. The artesian head could be derived from a part of the valley some distance upstream, if the deposits are alluvial, or from the upland on either side of the valley if the material is glacial drift that has not been removed by the river.

Bedrock apparently was struck in well 16 (FWA 9) at a depth of about 85 feet. The rock is greenish-gray sandstone, presumably a sandstone in the Coldwater shale or the Berea sandstone. The well was abandoned at a depth of 96½ feet, and the casing was withdrawn.

Well 19 (FWA 4).—The well is in the NW¼NW¼ sec. 33, Superior Township, on LeForge Road about 50 feet south of the intersection with Geddes Road and at an approximate altitude of 792 feet. The well is in a shallow valley cut into Wisconsin till (boulder clay). It was drilled to test the area of ground moraine (till plain) between the edge of the glacial lake beds to the southeast and the morainic area to the northwest.

The uppermost 10 feet of material is oxidized yellow clay, below which is gray till to a depth of 80 feet. An arm of glacial Lake Maumee formerly extended up the valley in which the well is situated, perhaps to the well site; thus the topmost material may be lake clay. From 80 to 130 feet the drift consists of sand and gravel with a matrix of silt and clay, except between depths of 97 and 103 feet where clean permeable gravel was penetrated. From 130 to 158 feet clayey till was penetrated, and at 158 feet light-gray clayey shale, possibly the Coldwater shale, was penetrated. The well was abandoned in shale at a depth of 170 feet, and the casing was withdrawn.

The gravel between depths of 97 and 103 feet might yield from a hundred to several hundred gallons per minute to a properly constructed well. However, the bed of sand and gravel may occupy only a small area, and if so the yield of the well might decline considerably after a time. The site is about a mile from the northwest corner of the Willow Run Townsite, and development of a water supply would be justified only if the demand for water at the townsite becomes very great. Possibly better sites could be located by drilling test wells along Geddes Road between well 19 (FWA 4) and the northwest corner of the townsite.

Well 23 (FPHA–USGS 2).—The well was drilled in the NW¼NW¼ sec. 34, Superior Township, on the Willow Run Townsite, just east of Prospect Road and 0.4 mile north of Clark Road. It was located near the top of the first or highest beach ridge of glacial Lake Maumee at an altitude of about 795 feet. The site is across Prospect Road from a successful domestic well, and the test well was drilled to determine whether the water-bearing material is sufficiently thick, permeable, and extensive to permit development of additional supplies for the townsite if necessary.

The uppermost materials penetrated by the drill are lake sands and clays, which overlie deposits of glacial drift that consist of clay with some sand. The boundary between the lake beds and the glacial drift is uncertain but may be at a depth of about 60 feet. From 60 to 80 feet the well penetrated medium to fine gravel with sand and silt. This material was stated by the driller to be "dry" but undoubtedly contained water. However, its texture is such that it probably would yield water slowly. From 80 to 91½ feet the well penetrated medium sand, called "water sand" by the driller. No permeable material was penetrated below 91½ feet. Sandstone, presumably a sandstone in the Coldwater shale but possibly the Berea sandstone, was struck at 190 feet. The well was abandoned at a depth of 197 feet, and the casing was withdrawn.

The material above a depth of 91½ feet might yield a moderate supply of water to a properly constructed well, perhaps 50 to 100 gallons per minute. Probably a large supply is not available at this site.

Well 31 (FPHA–USGS 1).—The well was drilled on the Willow Run Townsite in the SW¼NW¼ sec. 35, Superior Township, at a location about 270 feet east of Harris Road and about 0.4 mile south of Geddes Road. The altitude at the site of the test well is approximately 760 feet. It was drilled to test a previously untested part of the townsite.

The uppermost materials penetrated by the drill are deposits of lake sand and clay. According to the geologic map in folio 155 of the Survey's Geologic Atlas (Russell and Leverett, 1908), the well is on or near the lowest beach of glacial Lake Maumee. Below a depth of 60 feet is silty and gravelly clay, apparently unstratified, to a depth of 185 feet, where the bedrock was penetrated. The uppermost materials of the bedrock are blue clay and shale, presumably representing the Coldwater or Sunbury shale.

No permeable water-bearing sand or gravel was penetrated by the well, so that additional water supplies for the townsite are not available at this site. The casing was withdrawn, and the well was abandoned.

Well 43 (FWA 8).—The well was drilled in the S½SW¼ sec. 25, Ann Arbor Township, on Geddes Road about 100 feet west of a schoolhouse. The altitude of the site is about 810 feet. The well is at the junction of the Fleming Creek valley with the present valley of the Huron River.

The surficial material at well 43 (FWA 8) is similar to that penetrated by wells 4 (FWA 6) and 5 (FWA 7). It comprises glacial outwash sand and gravel and extends to a depth of 42 feet. From 42 to 80 feet the well penetrated pebbly clay, which appears to be glacial till but might be, in part, fine-grained material deposited in relatively quiet waters. From 80 to about 183 feet is a thick section of outwash gravel with considerable sand in the interstices. Below a depth of 183 feet fine gravel with silt and clay extends to the bottom of the well at a depth of 197 feet. The drillings from depths greater than 190 feet contained fragments of sandstone, and it is possible that the base of the Pleistocene may have been reached at a depth of 190 feet. However, the sandstone may exist as pebbles or boulders in the drift, so that bedrock may be somewhat deeper.

A 10-foot screen was set between depths of 167½ and 177½ feet, and a pumping test was made on the well. The pumping test and the water-bearing characteristics of the sand and gravel are discussed in a later section. The casing and screen were left in the hole.

An analysis of a sample of water taken from the well during the pumping test is given in table 1. The high iron content and hardness would make iron removal and softening desirable, but the water could be used in an emergency without treatment, except for chlorination if necessary.

Well 48 (FWA 3).—The well is in the NE¼SE¼ sec. 4, Ypsilanti Township, near the southwest corner of Holmes and Prospect Roads. The altitude at the site is about 770 feet. The well is in an area in which several successful domestic wells have been constructed. It was drilled to determine whether supplementary supplies could be developed for the townsite, if necessary, without going far from the townsite boundary.

The uppermost 30 feet of material consists of sand and gravel, presumably part of a delta deposited in glacial Lake Maumee. Below the delta deposits is glacial drift containing about 10 feet of fine silty sand between 90 and 100 feet. Sandstone, presumably the Berea sandstone, was penetrated at a depth of about 161 feet. The well was abandoned at a depth of 163 feet, and the casing was withdrawn.

The sand and gravel above a depth of 30 feet may be rather thoroughly drained. It might yield sufficient water for domestic wells, but the water probably is subject to pollution from surface sources. The fine sand between depths of 90 and 100 feet might yield an adequate supply to domestic wells, but moderate or large supplies could not be obtained at this site.

Well 72 (FWA 10).—The well was drilled in the NE¼ sec. 9, Ypsilanti Township, in the center strip of River Street south of the intersection with North Street. The altitude at the site is 710 feet. The well was drilled to obtain information on the areal extent of the gravels penetrated by the Ypsilanti public-supply wells, the possibility of developing additional supplies if needed, and the conditions under which the gravels penetrated by the Ypsilanti public-supply wells are recharged.

The uppermost 49 feet of material consists of alluvial sand and gravel, presumably deposited by the Huron River. However, the lower part of the material may be glacial outwash. Below a depth of 49 feet is gray clay, which extends to bedrock at a depth of 90 feet. The bedrock is gray sandstone, presumably the Berea sandstone. Rather coarse gravel was penetrated between 20 and 34 feet and between 44 and 49 feet. The water table is about 25 feet below the surface, so that the uppermost part of the coarse material between 20 and 34 feet is unsaturated.

A 3-foot screen was set between depths of 46 and 49 feet, and the well was left in place for observation purposes. A pumping test was initially planned but was not made because of the relatively small thickness of saturated sand and gravel and the desirability of saving funds for other tests. A domestic or small industrial supply of water could be obtained at this site, but the available quantity of water would be inadequate for a public-supply or other large-capacity well.

Measurements of water level made in well 72 (FWA 10), shown graphically in figure 3, indicate that the water-bearing gravels penetrated by the Ypsilanti public-supply wells are accessible to recharge from surficial sands and gravels. This is discussed in the section on the Ypsilanti public supply.

Well 73 (FWA 14).—The well is in the SE¼ NE¼ sec. 9, Ypsilanti Township, at the south end of the State Police building in Gilbert Park at the southwest corner of Michigan Avenue and Park Street. The altitude at the site is about 710 feet. The well was drilled to obtain information concerning the continuity of the gravels penetrated by the Ypsilanti public-supply wells.

Sand and gravel similar to that in well 72 (FWA 10) was penetrated from the surface to a depth of 30 feet. From 30 to 50 feet the well penetrated pebbly gray clay. It is not certain whether this material is unsorted alluvium or glacial till. From 50 to 75 feet is fine to coarse sand. Five feet of silt and fine sand was penetrated between 75 and 80 feet, below which is 3 feet of gravel. Next below this is 7 feet of pebbly sand, silt, and clay, ending at 90 feet. Between 90 and 95 feet is 5 feet of clean gravel, below which is pebbly silt and clay to a depth of 125 feet. Bedrock, consisting of gray-green sandstone, presumably the Berea, is believed to have been struck at 125 feet. The drillings from 125 to 130 feet also contained clay and water-worn pebbles, which probably were cavings. If the clay and pebbles were in place, bedrock obviously was not reached and the sandstone was also in the form of pebbles. The well was stopped at a depth of 130 feet.

The lower part of the sand and gravel that extends from the surface to a depth of 30 feet is probably saturated with water, but only small supplies could be recovered from this material by means of wells. Below a depth of 30 feet the only water-bearing gravels are those from 80 to 83 feet and from 90 to 95 feet. These gravels, together with the sand between 50 and 75 feet, would yield a moderate supply of water to a properly constructed well, but a large supply could not be obtained.

A 5-foot screen was set in the gravel between 90 and 95 feet, and a pumping test was made. The results of the test are discussed in another section. A sample of water was taken during the pumping test, and an analysis of it is given in table 1. The water is moderately hard. The iron content is shown as zero; the sample for determination of iron was decanted from the main sample, and any iron that may have been in solution had been precipitated. The water would be suitable for emergency use without treatment, but only a relatively small supply could be developed at this site.

Periodic measurements of water level in well 73 (FWA 14) have been made since August 1944 (table 7). The measurements indicate that the water level in well 73 is affected by the pumping of the Ypsilanti public-supply wells. This in turn indicates that the water-bearing materials penetrated by well 73 are connected with those penetrated by the public-supply wells, as are those penetrated by well 72 (FWA 10).

During the period April–June 1945 the water level in well 73 ranged from 30.16 to 31.85 feet below the measuring point when well 76 (city well 2) was being pumped and from 33.52 to 35.15 feet when well 77 (city well 3) was being pumped. It is believed that the fact that the water level in well 73 is consistently lower when well 77 is pumped than when well 76 is pumped is good evidence of connection between the materials penetrated by well 73 and those penetrated by the public-supply wells. The reason for the lower water level during the pumping of well 77, which is farther from well 73 than is well 76, is that well 77 yields about 2 million gallons per day as compared with about 0.8 million gallons per day for well 76.

In March 1945 the water level in well 73 ranged from 32.90 to 34.02 feet below the measuring point when well 76 was being pumped. This approaches the range observed later when well 77 was pumped. However, it is believed that this is explained by the fact that the water levels in all the observation wells in Ypsilanti were at or near their seasonal low stages in March.

Well 91 (FWA 11).—The well is in the SE¼SE¼ sec. 15, Ypsilanti Township, about 15 feet north of Ford Lake on a point of land jutting into the lake. The altitude at the site is about 687 feet. Wells 91 (FWA 11) and 99 (FWA 12) were drilled to determine whether coarse gravels such as those penetrated by the bomber-plant wells extend beyond the area flooded by the lake; both wells showed that the gravels do not underlie the terrace at the north edge of the lake, although they may underlie the lake itself.

The uppermost 25 feet of material in well 91 (FWA 11) consists of yellow sand, gravel, and silt, probably deposited by the Huron River. From 25 to 85 feet the well penetrated pebbly clay, probably glacial till. From 85 to 113 feet is fine to medium sand, some of it silty. From 113 to 125 feet is sticky gray clay, possibly weathered shale, below which is hard dark-brown shale, probably the Antrim shale. Domestic supplies of water could be obtained from the sand between 85 and 113 feet, but industrial supplies would not be available at this site. The well was abandoned in shale at a depth of 140 feet, and the casing was withdrawn.

Well 99 (*FWA 12*).—The well is in the NW¼SE¼ sec. 23, Ypsilanti Township, at the extreme southwest end of a point jutting into Ford Lake, about 0.5 mile west of the Ford Rawsonville dam. The altitude at the site is about 685 feet.

Silty yellow alluvium, probably deposited by the Huron River, was penetrated from the surface to a depth of 15 feet. From 15 to 60 feet the well penetrated silty and sandy clay. Fine silty sand was penetrated between 60 and 75 feet, and pebbly clay, probably till, from 75 to 95 feet. Gray clay with pebbbles of shale was penetrated between 95 and 100 feet, below which was weathered shale to the bottom of the well at 115 feet. The base of the Pleistocene deposits probably is at a depth of 100 feet.

The well penetrated no materials of moderate or high permeability. It was abandoned at a depth of 115 feet, and the casing was withdrawn.

Well 117 (*FWA 13*).—The well is in the E½SW¼ sec. 24, Ypsilanti Township, 50 feet south of the Huron River and just east of the toe of the Ford Rawsonville dam, opposite the bomber-plant well field. The altitude at the site is 658 feet. The well was drilled to determine whether large-capacity wells could be obtained at the south side of the Huron River.

The uppermost material penetrated by the well consists of alluvial sand and gravel, most of it somewhat silty. Clean sand and gravel was penetrated between 30 and 78 feet, where cemented gravelly hardpan 2 feet thick was struck. The hardpan is equivalent to that struck at the same altitude in well 113 (bomber-plant supply well 2). Below the hardpan to a depth of 95 feet is sand and gravel, some of it cemented and of low permeability, containing water relatively high in chloride. Bedrock, consisting of limestone with chert, was struck at 95 feet and penetrated to a depth of 100 feet, where the well was stopped. The bedrock formation is presumably the Traverse formation.

The sand and gravel between 30 and 78 feet includes about 30 feet of medium to coarse clean gravel of high permeability. A 5-foot screen was set between depths of 69 and 74 feet, and a pumping test was made. The water-bearing characteristics of the sand and gravel are discussed in the section on pumping tests. The casing and screen were left in place for observation purposes.

A sample of water taken when the well was at a depth of 100 feet represents the water from the section between 90 and 100 feet. Two samples were taken during the pumping test, representing water in the main gravel above a depth of 78 feet. The analyses are given in table 1. The water from the sand and gravel below the hardpan contained 160 parts per million of chloride, whereas the two samples from the main water-bearing gravel contained only 11 parts per million of chloride. The deeper water is higher in both total and noncarbonate hardness than the shallower but contains less iron. The samples taken from the main gravel near the beginning and end of the pumping test contained 1.5 and 2.5 parts per million of iron, respectively, whereas that from the deeper gravel contained only 0.1 part per million of iron. The reason for the difference in iron content between the two samples taken from the main gravel during the pumping test is not known, but the difference probably is not significant.

Well FWA 5.—A site for a well to be known as well FWA 5 was tentatively located on Cherry Road 0.25 mile east of Stommel Road in the S½ sec. 16 or N½ sec. 21, Superior Township. The well was intended to test the morainic deposits between the till plain on the southeast and the glacial deposits in the Fleming Creek valley to the northwest. However, in view of the desirability of saving funds for wells 117 (FWA 13) and 73 (FWA 14), well FWA 5 was not drilled.

Summary.—Table 12 summarizes the availability of additional water at the sites of the FWA and FPHA test wells. The estimates are based on the thickness and general appearance of the water-bearing materials penetrated by the wells. Estimates for wells 4 (FWA 6), 43 (FWA 8), 73 (FWA 14), and 117 (FWA 13) are also based on the pumping tests.

TABLE 12.—*Availability of additional water at FWA and FPHA test-well sites*

Well No.	Approximate quantity of water initially available (gallons per day)	Prospects for continued supply at initial rate
4 (FWA 6)	Up to 1,000,000	Fair.
5 (FWA 7)	Few hundred thousand	Fair to poor.
16 (FWA 9)	Domestic supply	Satisfactory for domestic use.
19 (FWA 4)	100,000 to 200,000	Poor.
23 (FPHA-USGS 2)	Possibly 100,000	Fair to poor.
31 (FPHA-USGS 1)	Little or none	
43 (FWA 8)	500,000 to 1,000,000	Do.
48 (FWA 3)	Domestic supply	Satisfactory for domestic use.
72 (FWA 10)	Up to 100,000	Fair.
73 (FWA 14)	Possibly 50,000	Do.
91 (FWA 11)	Domestic supply	Satisfactory for domestic use.
99 (FWA 12)	Possibly domestic supply	Do.
117 (FWA 13)	Up to a few million	Good.

PUMPING TESTS

INTRODUCTION

Pumping tests were made on 4 of the 11 test wells drilled by the Federal Works Agency in order to determine the transmissibility (ability to transmit water) of the water-bearing sands and gravels penetrated by the wells. The wells selected for pumping tests were wells 4 (FWA 6), 43 (FWA 8), 73 (FWA 14), and 117 (FWA 13).

The test wells were drilled mainly for geologic information, and comprehensive pumping tests were not planned because of lack of time and personnel and because it appeared that development of supplementary ground-water supplies in the areas tested would be necessary only if the demand for water became considerably greater than at the time the wells were drilled. Arrangements therefore were made for only such tests as could be made on the test wells themselves. Three of the tests were reasonably successful, but the fourth, that on well 73 (FWA 14), was inconclusive.

Tests made on the bomber-plant and Willow Run Townsite wells by Hubbell, Roth, and Clark, and on the new Ypsilanti public-supply wells by Shoecraft, Drury, and McNamee, also are discussed in this section.

Two of the fundamental properties of a water-bearing material with respect to its ability to yield water to wells are its permeability and storage capacity. Permeability is defined as the volume of flow per unit time per unit cross section of the material per unit hydraulic gradient. For field use permeability may be expressed as the number of gallons of water per day that will flow through each mile of the water-bearing bed (measured at right angles to the direction of flow) for each foot of thickness of the bed and each foot per mile of hydraulic gradient under the prevailing conditions of temperature.

The product of the permeability and the thickness of the water-bearing bed is termed transmissibility. The transmissibility of an aquifer may be expressed as the rate of flow, in gallons per day, through each mile of water-bearing bed (measured at right angles to the direction of flow) for each foot per mile of hydraulic gradient.

The storage capacity of an aquifer is measured by its coefficient of storage, which is defined as the volume of water released from storage in a vertical prism of the aquifer of unit cross section by a unit decline in head. For field use the coefficient of storage may be expressed as the amount of water, in cubic feet, released from storage in each vertical prism of the aquifer with a cross-sectional area of 1 square foot as the head declines 1 foot. Under water-table conditions the coefficient of storage approaches the specific yield, which may be expressed as the ratio of (1) the volume of water which, after being saturated, the material will yield by gravity to (2) its own volume.

Through the use of formulas developed for ground-water work under the direction of C. V. Theis, L. K. Wenzel, C. E. Jacob, and others of the Geological Survey, the transmissibility and storage coefficient of an aquifer can be determined by means of pumping tests and can be used to predict the effect of pumping a given quantity of water for any given period, both on the pumped wells themselves and on other wells penetrating the aquifer (Wenzel, L. K., 1942). The formulas also can be used to determine the quantity of water that can be pumped from a given well or wells with specified drawdowns in the pumped wells or in other wells. It is evident, therefore, that adequate pumping tests permit making quantitative estimates of the water supply of any aquifer.

In order to determine the coefficient of storage it is necessary to have at least one observation well in addition to the pumped well. The transmissibility can be determined from measurements made in one or more observation wells or in the pumped well itself if other wells are not available. It was not practicable to provide observation wells in addition to the pumped wells drilled by the Federal Works Agency, and therefore it was not possible to determine the coefficients of storage for the materials penetrated by the pumped wells. However, the value for transmissibility alone is useful in indicating the productiveness of the material and the spacing required between wells for given rates of pumping. The coefficients of storage determined from the results of pumping tests made by Hubbell, Roth, and Clark and by Shoecraft, Drury, and McNamee are given in the discussion of those tests at the end of this section.

TESTS ON FWA WELLS

Well 4 (FWA 6).—This well was equipped with a 10-foot screen with 0.125-inch slots (so-called 125-slot screen), set at a depth of 109 to 119 feet below the floor of the rig (roughly 108 to 118 feet below the land surface), in the coarsest and cleanest gravel penetrated by the well. On April 1, 1944, the well was pumped for 6 hours at the average rate of 180 gallons per minute, followed by 6 hours at the average rate of 310 gallons per minute, after which the pump was stopped and the water level was allowed to recover. Measurements of the depth to water level were made at intervals before, during, and after the periods of pumping (see fig. 5) below the top of the well casing, 0.5 foot above the rig floor and 1.4 feet above the land surface.

Computations of transmissibility from the drawdown curves give values of about 55,000 to 60,000 gallons per day per foot. Computation from the latter part of the recovery curve gives a value of about 75,000 gallons per day per foot, but the first part of the recovery curve gives values ranging from 116,500 to 133,500, depending on the selection of the points through which straight lines are drawn when the drawdown is plotted against the logarithm of time (Jacob, C. E., 1946). It seems probable that the higher values are more nearly correct, as indicated below.

Although it is not possible to determine the coefficient of storage S without data from another well, the product r_w^2S (effective radius of the well, squared, times the coefficient of storage) can be determined

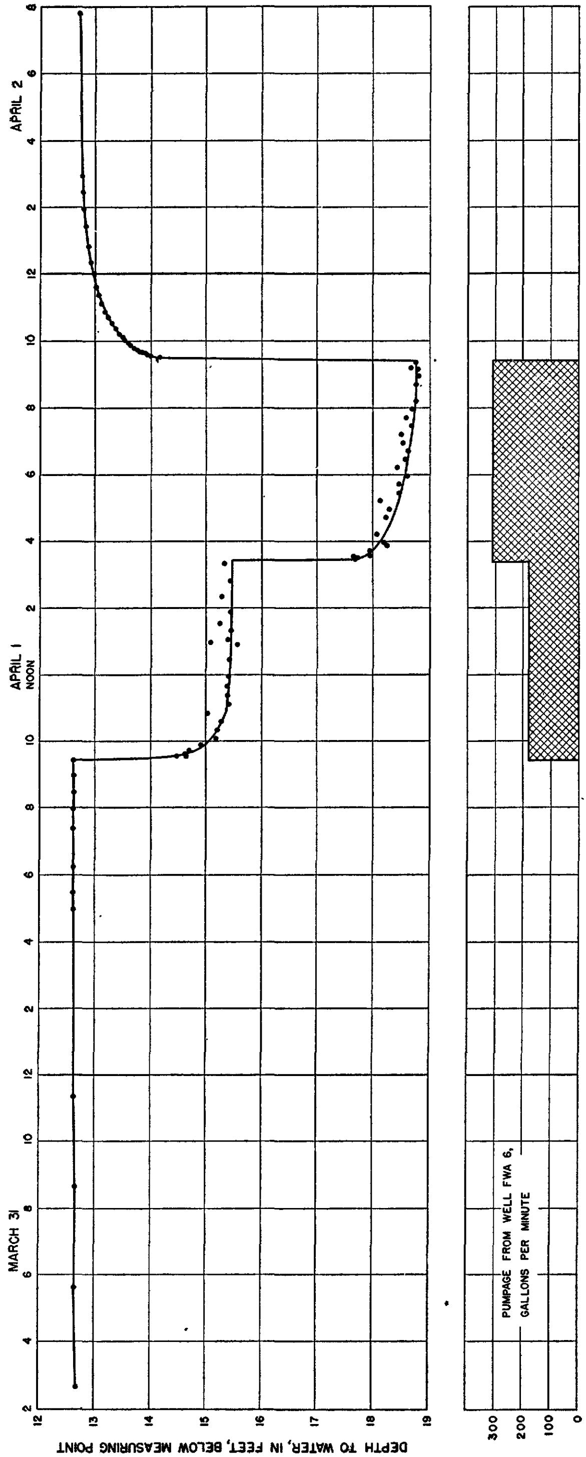

FIGURE 5.—Hydrograph of well 4 (F W A 6) during pumping test, March 31–April 2, 1944.

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from the pumped well if the head loss in the screen (screen loss) is known (Jacob, 1946). It is possible to estimate the screen loss when the well is pumped at more than one rate. This was done for well 4 (FWA 6), and the screen loss was found to be about 1 foot at the rate of 180 gallons per minute and about 3 feet at the rate of 310 gallons per minute.

If the drawdown or recovery, minus screen loss, is plotted against the logarithm of the time of pumping or recovery, the intersection of a straight line drawn through the plotted points with the line of zero drawdown or recovery gives the value of $r_w{}^2S$ (Jacob, 1946). Use of the lines giving values of 55,000 to 60,000 gallons per day per foot for transmissibility gives a value of about 8.5 for $r_w{}^2S$, an improbably high value because, for any reasonable value of S, the effective radius would be several feet. In view of the fact that the well was screened through only 10 feet of the aquifer, the effective radius may be even less than the actual radius—that is, less than 0.25 foot. Use of the line giving a value of about 75,000 gallons per day per foot for transmissibility gives a value of about 3.25 for $r_w{}^2S$, still an improbably high value. Use of a transmissibility of 133,500 gallons per day per foot, the highest that can reasonably be obtained from the observed data, gives a value of about 0.47 for $r_w{}^2S$. This still seems rather high, as a value of about 0.25 for S, which would indicate water-table conditions in a coarse and uniform material, would require an effective radius of 1.37 feet, which is doubtless too high.

Inasmuch as lines on the graph that would give more probable values of $r_w{}^2S$ would indicate a transmissibility considerably higher than 133,500 gallons per day per foot, the general conclusion is that the values for transmissibility determined from the observed data are less than the true value. From this conclusion it is inferred that the aquifer at well 4 (FWA 6) may be quite limited in areal extent, because such a limitation would tend to cause the apparent value of transmissibility obtained from a pumping test to be less than the true value. The 23 feet of coarse material in well 4 (FWA 6) appears to be coarser and more permeable than the coarse material in well 117 (FWA 13), which is believed to have a permeability of 10,000 gallons or more per day per square foot. A transmissibility of 133,500 gallons per day per foot at well 4 (FWA 6) would limit the average permeability of the 23 feet of coarse material to less than 6,000 gallons per day per square foot. If the true value for permeability is considerably greater than this, as seems likely from visual comparison of the material with that from well 117 (FWA 13), the transmissibility would be greater than 133,500 gallons per day per foot, which tends to support the inference drawn from the observed values of $r_w{}^2S$.

Although the coarse gravels penetrated by well 4 (FWA 6) may extend over only a small area, it is believed that the glacial material underlying the Fleming Creek valley contains many lenses and stringers of coarse gravel deposited from glacial meltwaters and that these gravels may be largely interconnected. That the sand and gravel found in well 4 (FWA 6) between depths of 85 and 135 feet does not persist at these depths throughout the Fleming Creek valley is suggested by the results of the pumping test and confirmed by the log of well 5 (FWA 7), which shows gravel only near the top and bottom. On the other hand, it is not certain that the coarse gravels are limited to the present valley, which has an average width of slightly more than half a mile. Leverett (Leverett and Taylor, 1915; Russell and Leverett, 1908) believed that the bulk of the glacial moraines in the area were deposited during a stage preceding the final stage of glaciation. Thus the intermorainic strip now occupied by Fleming Creek may have been wider during the previous stage, so that permeable deposits may extend beyond the limits of the present valley.

At best, however, the gravels underlying the Fleming Creek valley constitute an aquifer of limited extent, and the prospects of developing large supplies of water from wells in the valley depend on the recharge conditions. The logs of wells 4 (FWA 6), 5 (FWA 7), and 43 (FWA 8) indicate that moderately permeable sands and gravels lie at the surface and are accessible to recharge from precipitation. Less permeable materials lie below the surficial sands and gravels, but these materials may not persist as an unbroken stratum throughout the valley, so that at some places the deeper-lying sands and gravels may be connected with, and accessible to recharge from, the surficial materials. Additional test drilling and pumping tests might reveal some places near Fleming Creek where the upper and lower gravels are of substantial thickness and are interconnected. In addition to recharge from precipitation, recharge from Fleming Creek would occur at such places if wells were drilled near the stream and pumped heavily.

The results of the pumping test on well 4 (FWA 6) and the available information on the geologic conditions indicate that, although a large initial supply of water could be developed at this site, the yield would decrease in time, owing to the limited extent of the aquifer. Nevertheless, it is believed that a supply of about a million gallons per day could be developed for at least a few years. If a large-capacity well is installed for water supply, several observation wells should also be drilled and a thorough pumping test made to determine the quantity of water available and the distance at which additional wells, if any, should be spaced.

Well 43 (FWA 8).—The well was equipped with a 10-foot 125-slot screen set at a depth of 168½ to 178½ feet below the rig floor or about 167½ to 177½ feet below the land surface. The screen was set near the base of a thick bed of sand and gravel, which extended from about 80 to 183 feet below the surface. On April 21, 1944, the well was pumped for 12 hours at the average rate of 300 gallons per minute, after which the pump was stopped and the water level was allowed to recover. Measurements of the depth to water level were made before, during, and after pumping (see fig. 6) below the top of the casing, 0.18 foot above the rig floor and 1.0 foot above the land surface.

The drawdown curve for well 43 (FWA 8) indicates that the aquifer is limited in extent. When the drawdown is plotted against time on semilogarithmic paper, the points should fall on a straight line, but for well 43 (FWA 8) the points trace a curve that becomes steeper with time, which would be expected if the aquifer is bounded by material of low permeability within a short distance of the well. Depending on the selection of points through which a straight line is drawn for the graphical determination of transmissibility, the values determined from the drawdown curve range from 4,500 to 15,000 gallons per day per foot.

The recovery curve, as shown in figure 6, is abnormal in appearance. When the recovery is plotted against time on semilogarithmic paper, the points do not follow a straight line and the curve falls a considerable distance from that for the drawdown, whereas the two curves should coincide. The value for transmissibility determined from the slope of the first part of the recovery curve is about 40,000 gallons per day per foot, and that determined from the latter part of the curve is about 10,000 gallons per day per foot. Probably the higher value is more nearly correct. The data suggest that the coefficient of storage changed considerably during the test, which would tend to throw off the value for transmissibility determined from the observed data. Also, the water level recovered to the original static level within about 40 hours after pumping stopped and continued to rise, reaching a position 0.15 foot above the original static level at the time of the last measurement, 62 hours after pumping stopped. This might indicate that fluctuations in water level due to extraneous factors, such as fluctuations in atmospheric pressure, occurred during and after the test. However, the fact that the water level was nearly constant before pumping started shows that barometric fluctuations would be small and measurable fluctuations due to pumping of other wells probably would be nonexistent. It therefore appears that a change in the coefficient of storage during the test is the most probable cause of the abnormal recovery in water level. Such a change might be due to compaction of the water-bearing material or associated sediments

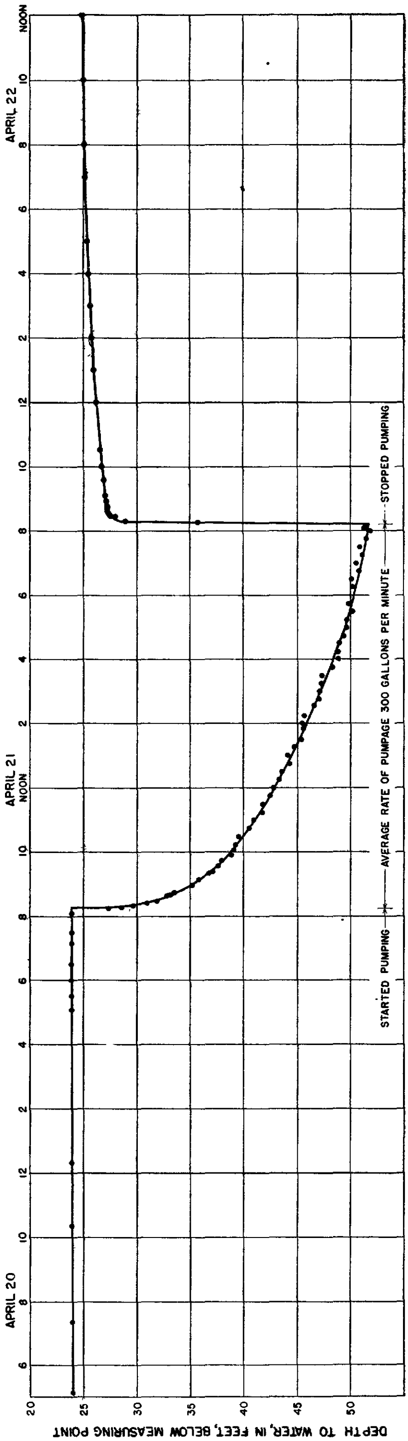

FIGURE 6.—Hydrograph of well 43 (FWA 8) during pumping test, April 20–22, 1944.

as a result of the lowering in water level caused by pumping. Well 43 (FWA 8) is probably the first well of moderately large capacity ever installed and pumped in the vicinity.

The general conclusion from the pumping test on well 43 (FWA 8) is that the true value for transmissibility is higher than the observed values, but that the aquifer is limited in areal extent. This limitation would reduce the perennial yield of a well at this site, perhaps to a low figure. However, it is believed that, owing to the thickness of the aquifer, the amount of water in storage must be quite large even if the areal extent of the aquifer is small, and a supply of 500,000 gallons a day or more probably could be pumped at this site for at least a year.

The main water-bearing sand and gravel at well 43 (FWA 8) is overlain by about 40 feet of clay and silt, above which is about 40 feet of sand and gravel extending to the surface. The conditions appear to be favorable for recharge of the shallow sand and gravel from precipitation, but if the bed of silt and clay above the lower gravel is persistent the conditions may not be so favorable for recharge of that gravel. Owing to the necessity for circulating water in the well to prevent freezing during the nightly shut-downs when the well was being drilled, it was not possible to make an accurate measurement of the depth to the water table in the shallow sand and gravel; but there is some indication that it is more than 25 feet below the surface—that is, below the level to which the water from the lower gravel rose in the well. If so, water exists in the lower gravel under artesian pressure, indicating that the recharge areas are some distance away, probably in the adjacent moraines and to the north along the Fleming Creek valley. The existence of artesian pressure would not prove that the main aquifer at well 43 (FWA 8) is connected with distant recharge areas through highly permeable materials, but it would be a strong indication of connection through at least moderately permeable materials. At best, however, it would appear that an attempt to develop a supply of as much as a million gallons per day at the site of well 43 (FWA 8) should be made only in an emergency and with the understanding that it might not be possible to pump a million gallons per day for as much as a year. If a well is installed for water supply, several test wells should be drilled to outline the aquifer, and a more comprehensive pumping test, utilizing the additional test wells for observations of water level, should be made to determine the quantity of water available.

Well 73 (FWA 14).—The well was equipped with a 5-foot, 50-slot screen (slots 0.05 inch wide) set at a depth of 90 to 95 feet opposite a bed of medium to coarse gravel. However, the well yielded little water, indicating that the bed of gravel is only a small lens encased in clay or that fine material from above worked its way along the screen and partially clogged it. Pumping was started at 8:12 a. m. on May 6, 1944. The static water level just before pumping started was 34.49 feet below the measuring point, which was 0.75 foot below the top of the casing and about 0.15 foot above the land surface. By 8:14 a. m. the water level was more than 70 feet below the measuring point. The well pumped air after a short time, so that it is presumed that the pumping water level was at the bottom of the pump bowls at a depth of 88 feet below the surface. The well yielded about 40 gallons per minute for 90 minutes, after which it was decided to stop the pump and discontinue the test. The water level recovered within 30 minutes to a position 0.04 foot higher than the stage just before pumping started. This and the fact that the water level was declining slowly for several hours before the pumping started make it impossible to compute the transmissibility from the recovery measurements. The drawdown to a constant stage at the bottom of the pump bowls was so rapid that measurements could not be obtained for computing the transmissibility from the drawdown curve.

The log of the well and the unfavorable results of the pumping test indicate that only a relatively small supply of water could be developed at this site.

Well 117 (FWA 13).—The well was equipped with a 5-foot 100-slot screen, set at a depth of 70.3 to 75.3 feet below the rig floor, or about 69 to 74 feet below the surface, near the base of a bed of medium to coarse clean gravel and above a bed of hardpan that was struck at an altitude of about 580 feet. The hardpan is equivalent to that struck at the same altitude in well 113 (bomber-plant supply well 2). Below the hardpan in both wells is sand and gravel containing water relatively high in chloride. Well 117 (FWA 13) was plugged with cement below the bottom of the well screen to prevent contamination of the main gravel.

The pump in well 117 (FWA 13) was started at 4 p. m. on February 28, 1944, but stopped twice for short periods. Uninterrupted pumping began at 4:41 p. m. and continued for 12 hours at the average rate of about 295 gallons per minute, after which the rate was reduced to an average of about 160 gallons per minute and the well was pumped for an additional 12 hours. The pump was then stopped, and the water level was allowed to recover. Measurements of the depth to water level in the pumped well were made at intervals during the test (see fig. 7) below the top of the casing, 2.03 feet above the rig floor, 3.1 feet above the land surface, and 660.33 feet above mean sea level.

Computation of the true value for transmissibility at well 117 (FWA 13) is difficult or impossible because of (1) irregular fluctuations in water level that make extrapolation of the hydrographs

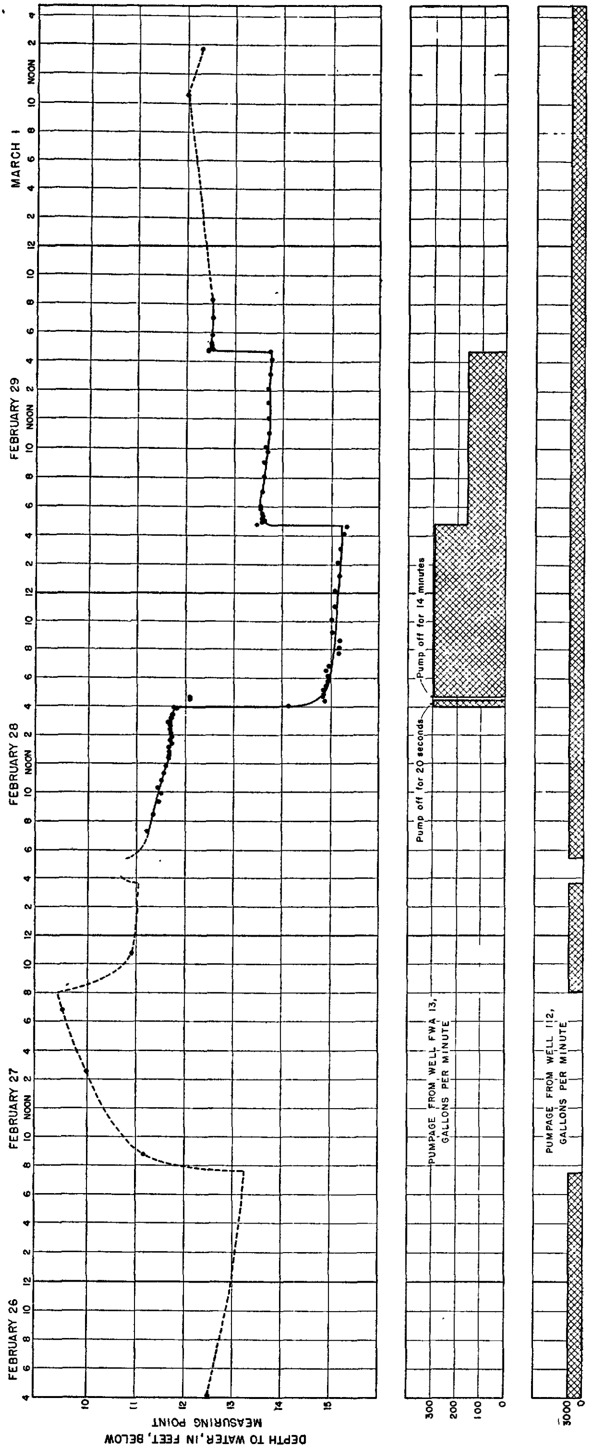

FIGURE 7.—Hydrograph of well 117 (FWA 13) during pumping test, February 26–March 1, 1944.

difficult, owing partly to small changes in the rate of pumping and partly to extraneous factors not related to the well itself; (2) the probability that recharge from the river occurred during the test; and (3) the fact that the aquifer is limited in extent by less permeable materials to the south and also to the north, across the river. Factors 2 and 3 vitiate certain assumptions on which the computation of transmissibility by means of a nonequilibrium formula is generally based, namely, those of unlimited extent of the aquifer and of no recharge. Owing to the influence of factors 2 and 3, the value for transmissibility obtained from the pumping test may be quite different from the true value. It is possible that the effect of recharge from the river might just balance the effect of the limited extent of the aquifer, so that the data from a test might plot normally and give an apparently reliable value for transmissibility, but this relation would be fortuitous and would not hold for longer or shorter tests or for different rates of pumping.

The values for transmissibility obtained from the recovery curves range from less than 100,000 to more than 1,000,000 gallons per day per foot, depending on the extrapolation of the hydrograph for the period before pumping started. The graph of the water level in well 117 (FWA 13), which was declining before pumping started, could reasonably be extrapolated in a number of different ways, which would result in differences in the computed values for transmissibility.

The pumping of well 112 (bomber-plant supply well 1) caused the decline in well 117 (FWA 13) before the pumping test began and, apparently, much of the decline during the latter parts of the two pumping periods of the test. That well 117 (FWA 13) is affected by the pumping of the bomber-plant wells is shown by the pronounced rise in water level in well 117 (FWA 13) after the shut-down of well 112 from 7:30 a. m. to 8 p. m. on February 27, 1944 (see fig. 7), and also by the fact that the water level in well 117 (FWA 13) remained consistently below river level when any of the bomber-plant wells was being pumped (table 4).

It is difficult to make computations of the transmissibility from the drawdown curves for the same reasons that make computation from the recovery curves difficult, namely, erratic fluctuations of the water level in well 117 (FWA 13) and uncertainty as to the extrapolation of the graph. By determining the drawdown from the extrapolation most likely to be correct—which is a smooth curve drawn through the points observed before pumping started and a little above those observed for several hours after pumping stopped—approximate values for transmissibility can be obtained by inserting the values for drawdown into the Theis nonequilibrium formula (Wenzel, 1942) and solving for transmissibility, assuming different values for the coefficient of storage. In order to do this it is necessary to estimate the screen loss, which, according to the method devised by Jacob (1946), was apparently 0.4 foot or a little less at 160 gallons per minute and roughly 1.2 feet at 295 gallons per minute. For a correct solution it is also necessary to take into account the effect of partial well penetration, but data are not available for a quantitative estimate of that effect. Also, although well 117 (FWA 13) was pumped for 12 hours at each of two rates, the cone of depression may have reached equilibrium form within a considerably shorter time as a result of recharge from the river. This is suggested by the fact that, after 2 or 3 hours of pumping, the drawdown curves (fig. 7) are approximately parallel to the extrapolation of the prepumping hydrograph most likely to be correct. This indicates that the decline after a few hours may have been due more to the pumping of well 122 (bomber-plant supply well 1) than to the pumping of well 117 (FWA 13) itself.

Allowing for screen loss but neglecting the effect of partial penetration, assuming pumping periods ranging from 2 to 12 hours at 295 gallons per minute, storage coefficients ranging from 0.01 to 1.0, and an effective well radius equal to the actual radius (0.25 foot), the values for transmissibility obtained from the drawdown range from about 200,000 to 300,000 gallons per day per foot. The effect of partial well penetration is to increase the drawdown because of convergence of the streamlines and because of the increased distance that water from the upper part of the aquifer must travel to reach the screen, to some extent through material of lower-than-average permeability, such as that between depths of 55 and 60 feet in well 117 (FWA 13). Thus partial penetration results in an apparent value for transmissibility smaller than the true value. Because of this the true value for transmissibility is obviously greater than the values shown above, and it may be as high as 400,000 or 500,000 gallons per day per foot. As shown later, the transmissibility of the materials penetrated by the bomber-plant supply wells across the river appears to be about 400,000 or 500,000 gallons per day per foot.

At well 117 (FWA 13) most of the transmissibility is probably accounted for by the 30 feet of material between depths of 40 and 55 feet and 60 and 75 feet. Assuming that the 30 feet of material has a transmissibility of 300,000 to 400,000 gallons per day per foot, this gives an average permeability of about 10,000 to 13,000 gallons per day per square foot, which is quite high. It is obvious that the material is highly productive, and it is undoubtedly comparable to that penetrated by wells 112, 113, and 114 (bomber-plant supply wells 1, 2, and 3). As stated, the screen loss in well 117 (FWA 13) is estimated to be about 1.2 feet at the rate of 295 gallons per minute. When this is deducted from a total drawdown of about 3.1 feet (fig. 7), the specific capacity of the well is shown to be roughly 150 gallons per minute per foot of drawdown. This is extremely high for a 6-inch well with only 5 feet of screen. Probably a properly constructed large-diameter well with about 50 feet of screen would have a yield and drawdown comparable to those of wells 112, 113, and 114. If additional wells are needed for the bomber plant, the site of well 117 (FWA 13) would be a good location. As shown by the effect of well 112 on well 117 (FWA 13), wells on opposite sides of the river would interfere with each other to the extent of a few feet, but in view of the large additional supply of water that could be obtained from a well on the south side of the river the interference would be relatively unimportant.

It was hoped that the pumping test on well 117 (FWA 13) might give quantitative information concerning the extent of recharge from the river, but owing to the relatively small drawdown and the magnitude of extraneous fluctuations in water level, the test was not of much value in this respect. Nevertheless, it gave significant information of a general nature. As stated, the values for transmissibility determined from the recovery curves depend on the extrapolation of the hydrograph of well 117 (FWA 13) before pumping started. The extrapolation most likely to be correct gives very small residual drawdowns after short periods of recovery, which when used in the recovery formula give values for transmissibility ranging from a million to several million gallons per day per foot. It seems probable that the true value for transmissibility is about 500,000 gallons per day per foot. If so, the low residual drawdowns indicate that recharge from the river occurred during the test. This is also indicated by the parallelism between the drawdown curves of well 117 (FWA 13) and the most likely extrapolation of the prepumping hydrograph. That recharge from the river does occur is also indicated by the pumping tests on the bomber-plant supply wells and is confirmed by the temperature and chemical evidence cited.

The fact that the water level in well 117 (FWA 13) is affected by pumping from the bomber-plant supply wells on the other side of the river indicates that a partially effective confining bed exists above the main water-bearing gravels. If the material were of high permeability from the surface down to the bottoms of the wells, the pumping of the bomber-plant wells would cause water to flow from the river into the gravels, but, assuming that the level of the river remained constant, it would have little effect on wells across the river. However, the substantial evidence of recharge from the river afforded by the pumping tests and temperature and chemical data indicates that the confining bed does not consist of impermeable material but is simply material of lower permeability than that tapped by the wells.

The logs of the wells, showing finer sand and gravel at river level than at greater depth, with some silt at places, confirm this conclusion. The material, although it acts as a confining bed in permitting high rates of pumping from the bomber-plant wells to affect wells across the river, is able to admit large quantities of water from the river when the water table is drawn substantially below river level by heavy pumping.

MISCELLANEOUS PUMPING TESTS

Acceptance tests were made on the bomber-plant and Willow Run Townsite wells by Hubbell, Roth, and Clark, and on the new Ypsilanti public-supply wells by Shoecraft, Drury, and McNamee. It has not been possible to make a thorough analysis of the results of these tests because of variations in the rates of pumping during the tests, but a few computations have been made and are discussed briefly in the following paragraphs. The pumping-test data, copies of which were furnished to the Geological Survey by the consulting-engineer firms named, are not given in this report.

Bomber plant.—The uncertainties present in the analysis of the pumping test on well 117 (FWA 13) are present to an even greater extent in the analysis of the tests on the bomber-plant supply wells (wells 112, 113, and 114), partly because the higher rates of pumping tended to induce recharge from the river to a greater extent than during the test on well 117 (FWA 13).

Computation of transmissibility by means of the Thiem formula, an "equilibrium" or steady-flow formula (Jacob, 1946), gives values ranging from 400,000 to 600,000 gallons per day per foot. Graphical determination by means of a nonequilibrium formula gives values ranging from a little less than 400,000 to nearly 900,000 gallons per day per foot.

Recharge from the river apparently occurred during the pumping tests on the bomber-plant wells. This is indicated by the fact that when the drawdowns are plotted against the logarithm of time, the points, instead of falling on a straight line, fall on a curve that becomes less steep with time. This indicates that the aquifer penetrated by the wells is being recharged from some source, which at this place can be only the river. Under these conditions the values for transmissibility obtained by giving greater weight to the early part of the period of pumping or recovery—that is, the lower values—are more likely to be correct. Thus it is probable that the lower values given above are more nearly correct than the higher values, and it seems likely that the true value is about 400,000 or 500,000 gallons per day per foot. However, even these values indicate a highly productive aquifer, which together with the existence of recharge from the river gives assurance of a continuing supply.

As explained previously, an artesian effect exists because of the lower permeability of the sand and gravel overlying the main gravel and because of the high rate of pumping. However, the pumping tests on the bomber-plant wells give coefficients of storage ranging from 0.01 to 0.03, sufficiently large to indicate that water-table conditions exist but lower than would be expected in permeable materials under water-table conditions. The relatively low values for the storage coefficient may be due in part to the fact that the water table fluctuates in the relatively fine grained material near the surface. They might also indicate that artesian conditions exist in some parts of the well field and water-table conditions in others. Furthermore, the tests lasted only a few days, and it is probable that longer tests, allowing more time for draining the unwatered material, would have given larger coefficients of storage.

Willow Run Townsite–Prospect and Geddes Road field.—A pumping test was made on well 26 (FPHA supply well 5) during the period November 11–18, 1942. During the test the pumping rate varied to such an extent that it is not practicable to determine the transmissibility by means of the drawdown curve. However, by assuming that the pumpage, which amounted to about 6,500,000 gallons in a 169-hour period, was at the constant rate of 500 gallons per minute for 217 hours, it is possible to obtain from the recovery curve a rough value for transmissibility. The recovery curve indicates that the transmissibility is about 40,000 gallons per day per foot and that the aquifer is of limited extent, because when the recovery is plotted against the logarithm of time the points for the latter part of the recovery period follow a curve that becomes steeper with time. It is known that the aquifer is limited by impermeable material on the east, south, and southwest, as wells 28, 29, and 30 on the east and wells 24 and 25 on the south and west showed little permeable material.

It is not possible to determine the storage coefficient from the recovery curve because the screen loss and effective diameter of the well are not known. The driller's log indicates that artesian conditions probably exist near the well, but the apparent lack of progressive declines in water level in well 26 suggests that recharge from a nearby source may occur. Possibly the aquifer is connected at no great distance with the sand that lies at or near the surface in wells 24 to 29, inclusive.

Willow Run Townsite–Wiard Road field.—A test was made on wells 32 and 36 (FPHA supply wells 4 and 2, respectively) during the period November 18–24, 1943. Tests were made on wells 36 and 39 (FPHA supply wells 2 and 3, respectively) in October and November 1942, but the results have not been analyzed. The test made in November 1943 gives values for transmissibility ranging from 77,000 to 96,000 gallons per day per foot. The effect on well 40 of pumping well 36 gives a transmissibility of 77,000 gallons per day per foot; the effect of this pumping on well 38 gives a value of 96,000 gallons per day per foot. These values indicate that the transmissibility at well 40, which is adjacent to well 39 (supply well 3), is less than at well 38, which is near wells 32 and 36 (supply wells 4 and 2). (See fig. 4.) This conclusion is supported by the fact that well 39 has a larger drawdown for a given yield (smaller apparent specific capacity) than wells 32 and 36. For example, in October 1942 the drawdown in well 39 was about 40 feet after it was pumped for 6 days at the rate of about 420 gallons per minute. On November 23, 1943, after well 32 had been pumped for 5 days at an average rate of about 550 gallons per minute and well 36 had been pumped for 3 days at a rate of about 600 gallons per minute, the drawdown in well 32 was about 26 feet and that in well 36 about 27 feet.

The value for transmissibility determined from the drawdown in well 36 is about 82,000 gallons per day per foot; but the points obtained by plotting the drawdown against the logarithm of time are rather scattered, and the line whose slope gave the value of 82,000 is not the only line that might reasonably be drawn through the plotted points. However, the line gives approximately equal weight to the different plotted points, and the value of 82,000 gallons per day per foot for transmissibility falls in the range of values determined from the effect of well 36 on wells 38 and 40.

The storage coefficient obtained from the effect of well 36 on well 38 is 3.4×10^{-4}, and that obtained from its effect on well 40 is 1.0×10^{-4}. These coefficients indicate that artesian conditions exist in the vicinity of the wells, but the apparent lack of progressive declines in water level as a result of pumping suggests that recharge may occur at no great distance. The test wells and pumping tests show that the aquifer in the Wiard Road field is more extensive than the aquifer in the Prospect and Geddes Road field, and, even if recharge does not occur nearby, the values for transmissibility and storage coefficient indicate that the rates of pumping in 1944 and 1945 can be maintained indefinitely in the Wiard Road field.

Ypsilanti public-supply wells.—Analysis of the pumping tests on the Ypsilanti public-supply wells gives rather inconclusive results. Because of varying rates of pumping the test on well 77 (supply well 3) could not be analyzed in the available time. However, the yield and drawdown of well 77 are similar to the yield and drawdown of well 75 (supply well 1), and these wells also appear to affect each other substantially when pumped. Probably both wells lie in the same buried channel and penetrate material of about the same permeability, whereas well 76 penetrates material of lower permeability.

The drawdown in well 75 at rates of 500, 1,000, and 1,300 gallons per minute gives values for transmissibility averaging about 240,000 gallons per day per foot, and it seems probable that this is near the true value. When the data for the period during which 1,000 gallons per minute was pumped are plotted on semilogarithmic paper, the points for the latter part of the period follow a curve that becomes steeper with time, indicating that the aquifer is bounded by material of relatively low permeability. It is known from the logs of wells that the aquifer is bounded on the east and west by material of low permeability, and it may be so bounded on the north and south.

Apparent values for transmissibility can be obtained from the effect of well 75 and well 76 on each other. However, in view of the fact that the transmissibility probably is much lower at well 76 than at well 75, these values are only approximate averages and do not represent the real transmissibility at either well. Because well 76 was operated during its test at a constant pumping level with a varying discharge, it was not practicable to determine the transmissibility at the well from the drawdown, and no recovery measurements were made. The values for transmissibility obtained from the interference between wells 75 and 76 range from about 80,000 to about 125,000 gallons per day per foot. Because the true value for transmissibility at well 75 is probably about 240,000 gallons per day per foot, as indicated by the drawdown in well 75, the transmissibility at well 76 may be lower than any of the values shown by the interference between the two wells—that is, less than 80,000 gallons per day per foot.

The values for the storage coefficient obtained from the interference between wells 75 and 76 range from 4×10^{-4} to 6×10^{-5}, indicating artesian conditions at the wells. The logs of the wells show material of low permeability above the main gravels, so that this would be expected. However, evidence discussed previously in connection with wells 72 (FWA 10) and 73 (FWA 14) indicates that the main gravels are connected with the surficial materials at least to the north, and recharge of the main gravels from the surficial materials undoubtedly occurs to some extent. The surficial materials are recharged by precipitation and in some places may be accessible to recharge from the Huron River.

SUMMARY

ADEQUACY OF EXISTING SUPPLIES

It is believed that the safe yield of the present wells supplying the three major ground-water users is not less than 10 million gallons per day: about 6 million for the bomber plant, 3 million for the Ypsilanti public water supply, and 1 million for the Willow Run Townsite. Of the three supplies, that of the Willow Run Townsite has the smallest potential capacity and is most uncertain with respect to adequacy at rates of pumping much higher than those maintained so far. However, it is probable that a total perennial supply of about 2 million gallons per day could be obtained from the present wells and additional properly located wells on the townsite. The future consumption of water at the bomber plant cannot be predicted. During the period of maximum activity at the plant the consumption of ground water averaged 4.5 to 4.75 million gallons per day. It is believed that the safe yield of the present wells is not less than 6 million gallons per day, and a total supply substantially larger could be obtained if additional properly located wells were constructed. If desired, untreated water from the wells could be used, and river water could be treated in the plant. Thus, a total supply of about 12 million gallons per day could be obtained from the present installations.

The water supply of the Ypsilanti public-supply wells appears to be adequate to meet the present demand and the expected future demand for some time. The safe yield of the wells is believed to be at least 3 million gallons per day, which is 1 million gallons per day in excess of the rated capacity of the treatment plant.

If the consumption of ground water for public supply increases to such an extent that an average demand of more than 3 million gallons per day seems likely, a thorough pumping test with special reference to the conditions of recharge would be desirable to determine the availability of additional water in the present well field. If the tests show that the water is not available, a comprehensive program of test drilling would be advisable to locate sites for additional wells outside the present well field.

The yields of the existing wells in the Ypsilanti area may decrease in time as the result of incrustation of the well screens. Such decreases in yield can be distinguished from those caused by declines in ground-water levels by means of periodic measurements of the "static" (nonpumping) water level in each supply well and by measurements in observation wells. The ground waters are not excessively hard and should not give trouble through incrustation for at least a few years after wells are installed. The Spring Street wells of the public-supply system have retained their productivity for years, indicating that incrustation is not serious when drawdowns are moderate. The largest drawdowns in the wells supplying the major water users are those in the wells of the Willow Run Townsite, and these wells may be the first to show incrustation.

AVAILABILITY OF ADDITIONAL SUPPLIES

The question remains as to the availability of ground water for new industries or institutions in the Ypsilanti area. In view of the evidence of recharge from the river at the bomber-plant well field, it is believed that additional supplies can be developed in the Huron Valley downstream from the bomber plant at any place where sufficiently coarse gravels are located by test drilling and proved by means of pumping tests to be accessible to recharge from the river. Probably no large supply should be developed within half a mile of the bomber-plant wells except if needed for additional supplies for the bomber plant itself. Owing to the backing up of water by the Belleville dam, it might be necessary to drill wells in the water in order to strike the most permeable gravels.

It is possible that additional supplies of a million gallons or more per day could be developed safely in the stretch of the Huron Valley between the bomber-plant and Ypsilanti well fields, but there also the areas underlain by the most permeable gravels may be flooded, so that the wells might have to be drilled in the water.

So far no highly productive areas have been discovered in the Huron Valley between the Ypsilanti well field and the mouth of Fleming Creek, but additional test drilling might reveal promising areas. Any attempt to develop a supply of several million gallons per day in the valley for a new industry should involve an adequate program of test drilling and pumping tests.

The occurrence of productive water-bearing gravels beneath the uplands appears to be quite erratic, and such gravels can be located only by means of test wells, possibly supplemented by geophysical surveys. Even if productive gravels are located, as in some of the wells at the Willow Run Townsite, plans to develop a supply of a million gallons or more per day should involve a pumping test to obtain as much information as possible on the conditions of recharge and on interference with existing wells. Probably no large additional supply should be developed on the upland within a mile of the Willow Run Townsite unless it is certain that the requirement for the townsite will not exceed 2 million gallons per day.

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TABLE 13.—*Records of wells in the Ypsilanti area, Michigan*

[In table 13 and on the well maps (pls. 2, 3; figs. 1, 2, 4) the wells are numbered by townships, beginning at the upper right, and within the townships by sections. The order of the townships is as follows:

Civil name	*Township and range number*
Canton	T. 2 S., R. 8 E.
Superior	T. 2 S., R. 7 E.
Ann Arbor	T. 2 S., R. 6 E.
Van Buren	T. 3 S., R. 8 E.
Ypsilanti	T. 3 S., R. 7 E.
Pittsfield	T. 3 S., R. 6 E.]

Well No.	Location: Township	Location: Section	Owner	Owner's designation	Date completed	Altitude (feet above m.s.l.)	Diameter (inches)	Depth (feet)	Position of screen (feet)	Use	Remarks
1	Canton	E½ 30	George Simmons					62		Domestic	Clay, 0–58 ft.; gravel, 58–62 ft.
2	do	SW¼NW¼ 32				709		53		do	See log.[1]
3	do	SW¼NW¼ 33				691		86		do	Blue clay, 0–70 ft.; gravel, 70–86 ft.
4	Superior	SE¼NW¼ 4	Federal Works Agency.	Test well 6	Mar. 29, 1944	830±	6	190	109–119	Test well, pulled and abandoned.	See log [1] and description of pumping test.
5	do	SE¼SW¼ 8	do	Test well 7	Apr. 8, 1944	820±	6	216		do	See log.[1]
6	do	SE¼SW¼ 16	John Meyer			859		72		Domestic	Clay, 0–62 ft.; gravel, 62–72 ft.
7	do	SE¼SE¼ 19	Gale School					184		do	See log.[1]
8	do	SW¼SW¼ 21	Frank Wilson			823		90		do	Clay, 0–86 ft.; gravel, 86–90 ft.
9	do	SE¼SE¼ 21	E. C. Meyer			818		65		do	See log.[1]
10	do	NW¼NW¼ 22	Charles Sweitzer			829		157		do	Do.
11	do	NE¼SE¼ 23	Kercher			767		80		do	Clay, 0–77 ft.; gravel, 77–80 ft.
12	do	NE¼NE¼ 27	Charles Lidke			807		113		do	See log.[1]
13	do	NE¼SW¼ 28	H. Bennett			812		160		do	Do.
14	do	NW¼SE¼ 30	E. E. Williams			857		156		do	Do.
15	do	NE¼SE¼ 31	Detroit Edison Co		Many years ago	730±	6	80		Industrial	
16	do	SW¼SW¼ 32	Federal Works Agency.	Test well 9	Apr. 29, 1944	720±	6	96½		Test well	See log.[1]
17	do	SE¼SE¼ 32				758		76		Domestic	Do.
18	do	NE¼SE¼ 32	Ypsilanti Development Co.	F. Voorhees well 1		788		280±		Oil test	Do.
19	do	NW¼NW¼ 33	Federal Works Agency.	Test well 4	Mar. 25, 1944	792±	6	170		Test well	Do.
20	do	NE¼NW¼ 33				821		121		Domestic	Clay, 0–116 ft.; gravel, 116–121 ft.
21	do	NE¼SE¼ 33	Fred Block			791		106		do	Clay, 0–94 ft.; gravel, 94–106 ft.

22	do	SE¼SE¼ 33	Pryce			804		160		do	See log.[1]
23	do	NW¼SW¼ 34	Federal Public Housing Authority.	USGS test well 2	Apr. 1 (?), 1944	795±	4	197		Test well	Do.
24	do	NW¼NW¼ 34	do	Test well 6	1942	779	4	170		do	Do.
25	do	do	do	Test well 4	1942	783	4	185		do	Do.
26	do	do	do	Supply well 5	1942	781	24	111	78–108	Public supply	Do.
27	do	do	do	Test well 5	1942	779	4	115		Test well	Near well 26. See log.[1]
28	do	do	do	Well 4A-12″	1944	773±	12	119		Abandoned	Unsuccessful supply well; no screen installed. See log.[1]
29	do	do	do	Test well 8	1943	779±	4	135		Test well	See log.[1]
30	do	NE¼NW¼ 34	do	Test well 7	1943	791±	4	184		do	Do.
31	do	SW¼NW¼ 35	do	USGS test well 1	Mar. 10, 1944	760±	4	193½		do	Do.
32	do	NW¼SE¼ 35	do	Supply well 4	1943	733.5	12	128	110–128	Public supply	Do.
33	do	do	do	Test well 9	1943	734±	4	171		Test well	Near well 32. See log.[1]
34	do	NE¼SE¼ 35	do	Supply well 1		728	12	175	150–175	Unused public-supply well.	Yielded 300 g. p. m. with drawdown of 145 ft.; no permanent pump installed. See log.[1]
35	do	do	do	Test well 10	1943	728±	4	179		Test well	A few feet from well 34 See log.[1]
36	do	do	do	Supply well 2	1942	732	12	119	97–119	Public supply	See log.[1]
37	do	do	do	Test well 2	1942	729	4	190±		Test well	About 200 ft. northeast of well 36. See log.[1]
38	do	SE¼SE¼ 35	do	Test well 1	1942	728	4	170±		do	See log.[1]
39	Superior or Ypsilanti.	SE¼SE¼ 35 or NE¼NE¼ 2	do	Supply well 3	1942	731	12	92	81–92	Public supply	See log [1] of well 40.
40	do	do	do	Test well 3	1942	731	4	151		Test well	Near well 39. See log.[1]
41	Ann Arbor	N½NE¼ 24	Floyd Parker					65		Domestic	See log.[1]
42	do	NW¼NE¼ 25	E. Sleet			822		76		do	Clay, 0–68 ft.; water sand, 68–76 ft.
43	do	S½SW¼ 25	Federal Works Agency.	Test well 8	Apr. 13, 1944	810±	6	197	168½–178½	Test well	See log [1] and description of pumping test.
44	do	SE¼NE¼ 36	Ann Arbor sewage-treatment plant.		1935	739		114	96–106	Municipal	Flowed 9 g. p. m. when at depth of 91 ft. See log.[1]
45	Van Buren	SE¼NE¼ 5				694.5		60		Domestic	Flows. See log.[1]
46	Ypsilanti	NE¼SE¼ 3	Hewitt Apartments.			753		127		do	See log.[1]
47	do	SW¼NE¼ 3	Kirkshaven			764		88		do	Do.
48	do	NE¼SE¼ 4	Federal Works Agency.	Test well 3	Mar. 15, 1944	770±	6	163		Test well	Do.
49	do	NE¼NE¼ 4	George Freeman			787		140		Domestic	Do.
50	do	E½NE¼ 5	Peninsular Paper Co.					106		Test well(?)	Near Huron River. See log.[1]
51	do	SE¼NE¼ 5	do			705		102		Test well	Do.
52	do	do	do	do				127		do	600 ft. south of office. See log.[1]

[1] See pp. 81–102 for logs of wells.

TABLE 13.—*Records of wells in the Ypsilanti area, Michigan*—Continued

Well No.	Location: Township	Location: Section	Owner	Owner's designation	Date completed	Altitude (feet above m.s.l.)	Diameter (inches)	Depth (feet)	Position of screen (feet)	Use	Remarks
53	Ypsilanti	SE¼NE¼ 5	T. C. Owen		Before 1907	785		808		Test for oil or mineral water.	"Atlantis" well of U. S. Geol. Survey Geol. Atlas folio 155. See log.[1]
54	do	SW¼NE¼ 5	E. Campbell			777		81		Domestic	See log.[1]
55	do	NE¼ 6	Lipke			808		225½		do	Do.
56	do	SW¼SE¼ 6	Harry Gilmore			811		93		do	Do.
57	do	do	Paul Wolf			815		135		do	Do.
58	do	do	Schaefer Crane			816		80		do	Do.
59	do	do	O. C. Beals			809.5		100		do	Do.
60	do	SW¼SW¼ 6				808		43		do	Do.
61	do	NW¼NW¼ 6	Grant Wilson			818		268		do	Do.
62	do	SW¼SW¼ 8	Walker			792		200		do	Do.
63	do	Center SW¼ 8	Otto Lidke			767		70		do	Do.
64	do	N½SW¼ 8	Oliver Houston			792		95		do	Do.
65	do	SE¼SW¼ 8	Harry Rominski			766		67		do	Do.
66	do	SW¼SE¼ 8	City of Ypsilanti	Test well 8	1941 or 1942	767		177		Test well	Do.
67	do	NE¼SW¼ 8	Warner Dairy			783		103		Industrial	Do.
68	do	NW¼NE¼ 9	City of Ypsilanti	Test well 7	1941 or 1942	700		87		Test well	Do.
69	do	SW¼NE¼ 9			Before 1907	703±		950		Abandoned(?)	"Moorman" mineral well of U. S. Geol. Survey Geol. Atlas folio 155.
70	do	SE¼ 9	do	Spring St. wells	1904 and later	690±	8	70±		Public supply	14 wells, now reserved for emergency use.
71	do	SW¼NE¼ 9	do	Test well	1941 or 1942	695		112		Test well	Test well drilled after three attempts. See log.[1]
72	do	NE¼ 9	Federal Works Agency.	T. D. 4-5-6 Test well 10	Feb. 4, 1944	710	6	97	46–49	Test and observation well.	See log.[1]
73	do	SE¼NE¼ 9	do	Test well 14	May 5, 1944	710±	6	130	90–95	do	See log [1] and description of pumping test.
74	do	NW¼SE¼ 9	Trojan Laundry		1942	691		36		Industrial	At rear of building. See log.[1]
75	do	NE¼SE¼ 9	City of Ypsilanti	Supply well 1	1943	688	16	102	82–102	Public supply	See log.[1]
76	do	SE¼ 9	do	Supply well 2	1943	687	16	87	67–87	do	Do.
77	do	do	do	Supply well 3	1943	689	16	94	74–94	do	Do.
78	do	NE¼SE¼ 9	do	Test well 1	1941 or 1942	687		106		Test well	Near well 75. See log.[1]
79	do	SE¼ 9	do	Test well 2	1941 or 1942	688		90		do	Near well 76. See log.[1]
80	do	N½NE¼ 16	Banner Oil & Gas Co.		1904–5	682		1,200±		Oil test	See log.[1]

81	do	S½SE¼ 9			Before 1907	680±		750		Test for mineral water.	"Cornwell" well of U. S Geol. Survey Geol. Atlas folio 155. See log.[1]
82	do	SE¼NE¼ 9	Ypsilanti Dairy			749		187		Industrial	See log.[1]
83	do	SE¼ 9	City of Ypsilanti	Open well	Before 1940	690±				Public supply	Large dug well with several drilled wells in bottom, now reserved for emergency use.
84	do	W½NE¼ 10				748		133		Domestic	Clay, 0–100 ft.; fine gravel, 100–133 ft.
85	do	W½E½ 10	H. A. Disbee			735		100		do	See log.[1]
86	do	NE¼NE¼ 10	Plank Road Farm			756		97		do	Do.
87	do	SE¼SE¼ 10	Robert Smith			730		150		do	Clay, 0–120 ft.; water sand, 120-150 ft.
88	do	NE¼SE¼ 11				731		102		do	See log.[1]
89	do	NE¼SE¼ 12	Ford Motor Co		Aug. 23, 1939			300		Test well	Test well for water supply for Willow Run Boys Camp. See log.[1]
90	do	NW¼NW¼ 12	do	Test well 44 (Wiard test).	1941 or 1942	736		140		do	See log.[1]
91	do	SE¼SE¼ 15	Federal Works Agency.	Test well 11	Feb. 2, 1944	687±	6	140		do	Do.
92	do	NE¼ 16	City of Ypsilanti	Test well 3	1941 or 1942	690		80		do	Do.
94	do	NW¼NW¼ 18	Fred Persons			833		181½		Domestic	Do.
95	do	SE¼SE¼ 20	Thorn School			760		181		do	Do.
96	do	NW¼NW¼ 21	Charles Rossbach			768		126		do	Clay, 0–120 ft.; gravel, 120-126 ft.
97	do	SE¼NE¼ 21	Hammond			731		127		do	See log.[1]
98	do	SE¼NW¼ 22	Nettie Smith			743		148		do	Clay, 0-140 ft.; gravel, 140-148 ft.
99	do	NW¼SE¼ 23	Federal Works Agency.	Test well 12	Jan. 30, 1944	685±		115		Test well	See log.[1]
100	do	SW¼SE¼ 23	Campbell			716		122		Domestic	Do.
101	do	SE¼NW¼ 24	Ford Motor Co	Test well 46	1941 or 1942	715±		140		Test well	Do.
102	do	W½ 24	do	Test well 47	1941 or 1942	695±		99		do	Do.
103	do	SE¼NW¼ 24	do	Observation well 7.	June 12, 1943	692		95	71–75	Test and observation well.	Altitude of measuring point, 694.10. See log.[1]
104	do	NE¼SW¼ 24	do	Observation well 8.	June 19, 1943	665		87	77–80	do	Altitude of measuring point, 668.56. See log.[1]
105	do	NW¼SE¼ 24	do	Observation well 10.	July 2, 1943	653		68	15½–18½	do	Altitude of measuring point, 655.50. See log.[1]
106	do	E½SW¼ 24	do	Observation well 9.	June 30, 1943	665		68	50½–53½	do	Altitude of measuring point, 668.11. See log.[1]
107	do	do	do	Observation well 11, test well 4.	July 16, 1943	664		78	50–53	do	Observation well drilled at site of test well 4. Altitude of measuring point, 666.85. See log.[1]
108	do	do	do	Test well 3	1941 or 1942	663		50		Test well	See log.[1]
109	do	do	do	Observation well 12.	July 29, 1943	665		85	74½–76½	Test and observation well.	Altitude of measuring point, 666.66. See log.[1]
110	do	do	do	Dam test well D5		652		40		Test well	See log.[1]
111	do	do	do	Foundation test well B2.	1941 or 1942	684		35		do	Do.

[1] See pp. 81-102 for logs of wells.

TABLE 13.—*Records of wells in the Ypsilanti area, Michigan*—Continued

Well No.	Location: Township	Location: Section	Owner	Owner's designation	Date completed	Altitude (feet above m.s.l.)	Diameter (inches)	Depth (feet)	Position of screen (feet)	Use	Remarks
112	Ypsilanti	E½SW¼ 24	Ford Motor Co	Supply well 1	1942	668	24	87	37–87	Industrial	Altitude of pump-house floor, 672.5. See log.[1]
113	do	do	do	Supply well 2	1942	661.5	24	97	31–81	do	Altitude of pump-house floor, 667.5. See log.[1]
114	do	do	do	Supply well 3	1943	665±	26	82	30–80	do	Altitude of pump-house floor, 667.5. See log.[1]
115	do	do	do	Dam test well D4		650		40		Test well	See log.[1]
116	do	do	do	Dam test well D7		654		40		do	Do.
117	do	do	Federal Works Agency.	Test well 13	Mar. 15, 1944	658	6	100	70.3–75.3	Test and observation well.	See log [1] and description of pumping test. Altitude of measuring point, 660.33.
118	do	do	Ford Motor Co	Dam test well D9		660		40		Test well	See log.[1]
119	do	do	do	Dam test well D11.		657		40		do	Do.
120	do	W½SW¼ 24	do	Dam test well D10.		657		40		do	Do.
121	do	do	do	Dam test well D1		654		104		do	Do.
122	do	do	do	Dam test well D3		653		40		do	Do.
123	do	do	do	Dam test well D6		660		40		do	Do.
124	do	do	do	Test well 2, well W2.	1942	686.5	24	133	50–100	Now used as observation well.	Unsuccessful supply well drilled at site of test well 2. See log.
125	do	E½SW¼ 24	do	Foundation test well B1.	1941 or 1942	683		33		Test well	See log.[1]
128	do	SE¼SW¼ 27	C. H. Raymond			707		143		Domestic	Clay, 0–140 ft.; gravel, 140–143 ft.
129	do	NW¼NW¼ 27	James Moore			721		121		do	See log.[1]
130	do	SW¼NE¼ 28	O. R. Beal			712		120		do	Clay, 0–118 ft.; gravel, 118–120 ft.
131	do	SW¼SE¼ 28	Wardle			707		74		do	Clay, 0–72 ft.; gravel, 72–74 ft.
132	do	SE¼SW¼ 28	Wageman			721.5		116		do	Clay, 0–111 ft.; gravel, 111–116 ft.
133	do	NW¼NW¼ 33	Merritt			739		119½		do	Clay, 0–117 ft.; gravel, 117–119½ ft.
134	do	NE¼SE¼ 33	Claude Eaton			708		30		do	See log.[1]
135	do	SE¼NW¼ 34	Gorton			701		116		do	Do.
136	Pittsfield	NE¼SW¼ 1	E. LaPointe	Well 3		838		273		do	Sandy clay, 0–271 ft.; gravel, 271–273 ft.
137	do	SE¼NW¼ 1	MacDonald			823.5		165		do	See log.[1]
138	do	SW¼ 1	E. LaPointe	Well 2		835		238		do	Do.
139	do	SW¼NW¼ 1	Watts			828		257		do	Do.
140	do	SE¼SE¼ 14	Ypsilanti airport			837		163		Industrial	Do.

[1] See pp. 81-102 for logs of wells.

LOGS OF WELLS IN THE YPSILANTI AREA

The logs of the 13 wells drilled by the Federal Public Housing Authority and the Federal Works Agency are based on examination of drill cuttings by E. G. Otton. The remaining logs are based on reports of well drillers or owners. The logs of all domestic wells, the Ypsilanti public-supply and test wells, and certain industrial wells were obtained from the firm of Shoecraft, Drury, and McNamee. Other sources were the Federal Public Housing Authority, the Ford Motor Co., the firm of Hubbell, Roth, and Clark, and the Michigan Geological Survey Division.

In the logs the altitudes are given in feet above mean sea level, as reported by the sources from which the logs were obtained. Estimated or approximate altitudes are marked with the symbol ±.

Most of the logs of domestic wells obtained from Shoecraft, Drury, and McNamee showed the depth to water level, but, as the dates of measurement are not given and some of the reported depths to water are only approximate, these data are not included here. They are given, however, in the report by Mr. Poindexter (1943) dated July 1943.

Thickness and depth of material are given in feet unless inches are indicated.

Logs showing only two strata, generally clay above and sand or gravel below, are given in the last column of table 13.

2 (SDM[1] well C-32-1). Altitude, 709

	Thickness	Depth		Thickness	Depth
Clay	3	3	Quicksand	10	50
Gray sand	4	7	Water gravel	3	53
Blue clay	33	40			

[1] Shoecraft, Drury, and McNamee.

4 (FWA 6). SE¼NW¼ sec. 4, Superior Township, approximately 200 feet north and a little west of road corner at center of sec. 4. Altitude, 830±

	Thickness	Depth		Thickness	Depth
Brown clay; sand; medium gravel	5	5	Medium sand; some fine gravel, clean, permeable	5	80
Brown to buff silt and clay	10	15	Medium to coarse sand; some clayey ("tight") gravel	10	90
Buff to gray silt; few small pebbles	20	35	Clean fine to medium gravel	8	98
Gray silty clay	5	40	Gray sandy silt; some fine gravel	7	105
Fine silty sand, gray; few small pebbles	5	45	Medium to coarse clean gravel	15	120
Brown-gray medium sand, fairly clean and permeable	5	50	Medium to fine clean gravel and sand	8	128
Fine clayey sand; some fine gravel	5	55	Medium to fine gravel; clay	7	135
Gray medium sand and silt	5	60	Gray sandy clay	10	145
Very fine buff sand, well sorted	10	70	Gray silty clay	15	160
Fine sand; medium to fine gravel; angular fragments of chert and limestone	5	75	Gray sandy clay (base of Pleistocene not reached)	30	190

5 (FWA 7). SE¼SW¼ sec. 8, Superior Township, south side of United States Highway 12 about 0.5 mile east of small highway bridge over tributary of Fleming Creek. Altitude, 820±

	Thickness	Depth		Thickness	Dept
Reddish-brown sand and gravel	5	5	Fine gray silty sand	20	170
Medium to coarse sand; fine gravel	10	15	Gray silty clay	10	180
Medium sand; fine gravel	10	25	Fine to medium grayish-brown sand; little gravel	10	190
Medium to coarse gravel; some sand	5	30	Fine to medium gravel; sand	12	202
Fine clean gravel	7	37	Gray clay; sand; fine gravel (base of Pleistocene not reached)	14	216
Gray silty clay; occasional pebbles	113	150			

7 (SDM well S–19–2). Gale School, owner

	Thickness	Depth		Thickness	Depth
Yellow clay	12	12	Putty clay	50	175
Blue clay	6	18	Blue clay	7	182
Gray sand	57	75	Water gravel	2	184
Quicksand	50	125			

9 (SDM well S–21–1). E. C. Meyer, owner. Altitude, 818

	Thickness	Depth		Thickness	Depth
Clay	40	40	Hardpan	8	63
Quicksand	15	55	Water gravel	2	65

10 (SDM well S–22–2). Charles Sweitzer, owner. Altitude, 829

	Thickness	Depth		Thick ness	Depth
Clay	73	73	Clay	79	154
Quicksand; water	2	75	Gravel	3	157

12 (SDM well S–27–3). Charles Lidke, owner. Altitude, 807

	Thickness	Depth		Thickness	Depth
Clay	108	108	Gravel	4	113
Hardpan	1	109			

13 (SDM well S–28–3). Bennett, owner. Altitude, 812

	Thickness	Depth		Thickness	Depth
Clay	150	150	Gravel	6	160
Stone (probably boulder clay or large boulder)	4	154			

14 (SDM well S-30-2). E. E. Williams, owner. Altitude, 857

	Thickness	Depth		Thickness	Depth
Clay	20	20	Blue clay and gravel	30	130
Sand; gravel	40	60	Clay	20	150
Blue clay	30	90	Water gravel	6	156
Quicksand	10	100			

16 (FWA 9). SW¼SW¼ sec. 32, Superior Township, near west line of section, approximately 200 feet south of dead-end gravel road. Altitude, 720±

	Thickness	Depth		Thickness	Depth
Medium to fine brown gravel	10	10	Gray sandy clay; some fine gravel	30	70
Gray gravel; some stiff silty clay	5	15	Fine to medium clayey sand	5	75
Tough gray silty clay; some small gravel	10	25	Gray clay (base of Pleistocene)	10	85
Gray sandy clay	15	40	Greenish-white sandstone; some gray clayey shale	11½	96½

17 (SDM well S-32-4). Altitude, 758

	Thickness	Depth		Thickness	Depth
Gravel; hardpan; clay	55	55	Gravel	3	76
Hardpan	18	73			

18 (Fred Voorhees 1). Ypsilanti Development Co., owner. NE¼SE¼ sec. 32, Superior Township, 2,945 feet from north line and 339 feet from east line of section. Altitude, 788

	Thickness	Depth		Thickness	Depth
Soil	10	10	Mud, gray; pebbles	34	154
Mud, blue, plastic	30	40	Mud, gray, plastic	12	166
Gravel; water	7	47	Gravel; fine sand	21	187
Mud, blue, plastic	18	65	Coarse gravel	13	200
Fine sand and gravel; water	55	120	Limestone, gray, sandy (Berea)	80	280

19 (FWA 4). NW¼NW¼ sec. 33, Superior Township, on LeForge Road about 50 feet south of intersection with Geddes Road. Altitude, 792±

	Thickness	Depth		Thickness	Depth
Red and brown silty clay; gravel	10	10	Fine to coarse clean gravel; some pebbles up to 3 inches in diameter. High permeability	6	103
Buff silty clay; occasional small pebbles	20	30	Gray silt; clay; fine gravel	12	115
Gray clay; some gravel	5	35	Fine gravel; coarse sand; silt	5	120
Gray silty clay; few small pebbles	30	65	Cemented gravel and silt (hardpan). One boulder struck	10	130
Gray clay (boulder struck at 75 feet)	15	80	Gray to buff silty clay (base of Pleistocene)	28	158
Fine gravel; some clay (hardpan)	10	90	Light-gray clayey shale	12	170
Gray sand; clay; fine gravel	5	95			
Coarse sand; fine gravel; sufficient silt to reduce permeability	2	97			

22 (SDM well S-33-6). Pryce, owner. Altitude, 804

	Thickness	Depth		Thickness	Depth
Gravel	85	85	Water gravel	10	160
Blue clay	65	150			

23 (FPHA-USGS 2). NW¼SW¼ sec. 34, Superior Township, east side of Prospect Road 0.4 mile north of Clark Road. Altitude, 795±

	Thickness	Depth		Thickness	Depth
Brown sandy clay and soil	7	7	Medium sand, gray, fairly clean, permeable	1½	91½
Stiff gray clay; occasional small pebbles	13	20	Medium sand; some clay. Low permeability	8½	100
Fine silt, tan to buff	10	30	Medium sand; gray clay	5	105
Fine brown silty sand	30	60	Fine sandy clay	15	120
Medium to fine gravel; some fine sand and silt ("dry")	20	80	Gray silty clay	65	185
Gray medium sand, fairly well sorted (water sand)	5	85	Gray silty clay; small fragments of rock	4	189
Medium water sand, well sorted, permeable	5	90	Gray clay (base of Pleistocene)	1	190
			Fine gray sandstone	7	197

24 (test well 6 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 779

	Thickness	Depth		Thickness	Depth
Clay	5	5	Sand rock (boulder?)	6	119
Wet sand	15	20	Hard clay	16	135
Sand; clay	5	25	Clay	14	149
Sand; fine gravel	5	30	Sand	1	150
Gravel	5	35	Hard clay	7	157
Stony clay	23	58	Gravel	1	158
Stony hard clay	55	113	Hard clay	12	170

25 (test well 4 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 783

	Thickness	Depth		Thickness	Depth
Clay; sand	10	10	Stony clay	22	64
Coarse sand and clay	5	15	Hard clay	96	160
Coarse sand	5	20	Clay; sand	21	181
Sand; gravel	9	29	Shale	4	185
Sand; fine gravel	5	34	Rock	Entered	--------
Sand	8	42			

26 (supply well 5 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 781

	Thickness	Depth		Thickness	Depth
Sand; water	35	35	Coarse gravel	3	105
Stony clay	38	73	Sand; gravel	6	111
Gravel	20	93	Clay	Entered	--------
Boulder clay	9	102			

27 (supply well 5 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 779

	Thickness	Depth		Thickness	Depth
Fine sand	5	5	Stiff clay	5	75
Sand	5	10	Coarse sand	5	80
Coarse sand	10	20	Coarse gravel	15	95
Fine sand	10	30	Coarse sand	5	100
Clay	20	50	Sand; gravel	5	105
Hardpan	5	55	Pea gravel	5	110
Moist sandy clay	4	59	Gravel	2	112
Sandy clay	11	70	Sandstone	3	115

28 (unsuccessful supply well 4A at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 778±

	Thickness	Depth		Thickness	Depth
Fine gravel	28	28	Clay	1	61
Clay	21	49	Clay; gravel	14	75
Clay; gravel	11	60	Hardpan	44	119

29 (test well 8 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 779±

	Thickness	Depth		Thickness	Depth
Gravel	29	29	Hardpan	73	125
Clay	23	52	Clay; gravel	10	135

30 (test well 7 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 791±

	Thickness	Depth		Thickness	Depth
Soil; clay	15	15	Hardpan	3	132
Blue clay	15	30	Dirty vein (sand?)	2	134
Clay	18	48	Hardpan	17	151
Hardpan	4	52	Hard clay	21	172
Hard clay	26	78	Hardpan	4	176
Hardpan	38	116	Gray shale	8	184
Dirty sand	13	129			

31 (FPHA-USGS well 1). SW¼NW¼ sec. 35, Superior Township, about 272 feet east of Harris Road and 0.4 mile south of Geddes Road. Altitude, 760±

	Thickness	Depth		Thickness	Depth
Brown gravelly soil	1	1	Gray silt and clay; few small pebbles	10	115
Brown sticky clay; occasional pebbles	20	21	Gray stiff clay	10	125
Buff to gray silt and clay	23	44	Gray clay (drillers' "medium" hardpan)	15	140
Gray sand, very fine, well sorted	16	60	Gray clay; few small pebbles (medium hardpan)	15	155
Gray silty clay	10	70	Gravel; clay. Low permeability	25	180
Gray clay and gravel	5	75	Sand; clay; some fine gravel	5	185
Gray silty clay	5	80	Blue clay; blue shale	8½	193½
Gray clay; fine gravel	20	100			
Gray fine gravel and clay. Low permeability	5	105			

32 (supply well 4 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude 733.5

	Thickness	Depth		Thickness	Depth
Clay	42	42	Dirty sand	4	99
Sand	16	58	Sand	13	112
Clay; gravel	35	93	Gravel	16	128
Clay	2	95			

33 (test well 9 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 734±

	Thickness	Depth		Thickness	Depth
Yellow clay	10	10	Gravel; sand	14	127
Blue clay	8	18	Medium sand	37	164
Dirty putty sand	41	59	Fine gravel	2	166
Blue gravelly clay	23	82	Gravel	1	167
Clay hardpan	22	104	Shale	4	171
Muddy sand	9	113			

34 (supply well 1 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 728

	Thickness	Depth		Thickness	Depth
Peat	2	2	Sandy clay	5	127
Yellow clay	3	5	Clay	4	131
Blue clay	39	44	Sandy clay	3	134
Clay	15	59	Medium hardpan	3	137
Sand	17	76	Clay; gravel	4	141
Dirty sand	17	93	Clay	11	152
Hardpan	5	98	Fine water gravel	1½	153½
Clay; gravel	4½	102½	Gravel	3½	157
Clay	8	110½	Dirty gravel and sand	18	175
Sand; clay	11½	122			

35 (test well 10 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 728±

	Thickness	Depth		Thickness	Depth
Topsoil	2	2	Gravel	1	97
Yellow and blue clay	8	10	Hardpan	5	102
Blue clay	43	53	Clay hardpan	50	152
Soft sandy blue clay	20	73	Coarse gravel	19	171
Fine water sand	17	90	Fine gravel	6	177
Gravel hardpan	6	96	Hardpan	2	179

36 (supply well 2 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 732

	Thickness	Depth		Thickness	Depth
Medium hardpan	8	8	Dirty quicksand	27	77
Blue clay	32	40	Firm sand and clay	20	97
Quicksand	5	45	Gravel	22	119
Clay	5	50	Blue clay	Entered	-------

37 (test well 2 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 729

	Thickness	Depth		Thickness	Depth
Clay	3	3	Stony hardpan	11	75
Sand	2	5	Hardpan	32	107
Stiff clay	7	12	Coarse gravel	2	109
Medium clay	12	24	Fine sand	14	123
Quicksand	26	50	Fine gravel	4	127
Fine sand	1	51	Medium fine sand	15	142
Gravel	5	56	Sand	10	152
Fine sand	2	58	Coarse gravel	25	177
Hardpan	4	62	Hardpan	8	185
Sandy hardpan	2	64	Rock	5±	190±

38 (test well 1 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 728

	Thickness	Depth		Thickness	Depth
Stiff clay	5	5	Quicksand	10	105
Soft clay	3	8	Fine sand	5	110
Stiff clay	4	12	Wet sand	8	118
Medium clay	5	17	Stony clay	17	135
Soft clay	3	20	Sandy clay	7	142
Medium stiff clay	30	50	Hardpan (cemented gravel?); water	9	151
Soft clay	5	55	Coarse sand	3	154
Wet clay	4	59	Hardpan; water	8	162
Sandy clay	3	62	Coarse gravel	5	167
Clay	20	82	Shale	3±	170±
Wet clay	6	88			
Fine sand; some clay	7	95			

40 (test well 3 at Willow Run Townsite). Federal Public Housing Authority, owner. Altitude, 731

	Thickness	Depth		Thickness	Depth
Yellow sand	8	8	Clay	35	127
Quicksand	12	20	Fine gray sand	11	138
Clay	37	57	Clay	2	140
Quicksand	5	62	Sandy clay	8	148
Sandy hardpan	10	72	Shale	3	151
Quicksand	10	82	Rock	Entered	-------
Gravel	10	92			

41 (SDM well A-24-1). Floyd Parker, owner. Altitude not recorded

	Thickness	Depth		Thickness	Depth
Gravel	18	18	Coarse gravel	2	65
Blue clay	45	63			

43 (FWA 8). S½SW¼ sec. 25, Ann Arbor Township, on Geddes Road approximately 100 feet west of schoolhouse. Altitude, 810±

	Thickness	Depth
Brown medium sand	10	10
Brown sandy clay; some gravel	5	15
Clean fine to medium gravel	20	35
Gravel, somewhat coarser than above, water bearing near base	7	42
Gray stiff clay	13	55
Gray clay and silt; few small pebbles	10	65
Gray stiff clay	10	75
Gray clay; fine gravel	5	80
Medium to fine gravel; clay	10	90
Medium gravel; fragments of greenish-white sandstone	17	107
Medium gravel; some fine gravel	1	108
Medium to fine gravel	8	116
Fine, medium, coarse clean gravel	14	130
Fine, medium, coarse clean gravel; fragments of sandstone between 132 and 134 feet	12	142
Medium to fine gravel	8	150
Fine gravel; coarse sand; some large pebbles	14	164
Coarse clean gravel	2	166
Coarse to fine gravel; some fragments of sandstone at 168 feet	4	170
Clean medium gravel, well sorted	2	172
Fine to coarse gravel; some pebbles up to 2 inches in diameter	6	178
Fine gravel, sand, and silt; occasional large pebbles	5	183
Fine gravel, silt, and clay	5	188
Silt; fragments of sandstone; some very fine gravel (base of Pleistocene possibly at 190 feet)	11	197

44. Ann Arbor sewage-treatment plant, owner. Altitude, 739

	Thickness	Depth
Surface soil; gravel; boulders	5	5
Yellow clay; small stones	25	30
Hard blue clay	54	84
Fine gray sand; water	7	91
Sand and gravel up to 1½ inches in diameter	14	105
Sand and gravel, finer	9	114

45 (SDM well VB-5-1). Flowing well. Altitude, 694.5

	Thickness	Depth
Clay	40	40
Quicksand	10	50
Gravel	10	60

46 (SDM well Y-3-11). Hewitt Apartments, owner. Altitude, 753

	Thickness	Depth
Fine sand and gravel	27	27
Blue clay	65	92
Fine water sand and gravel (not completely penetrated)	35	127

47 (SDM well Y-3-10). Kirkshaven, owner. Altitude, 764

	Thickness	Depth
Yellow sand	12	12
Yellow clay	18	30
Quicksand	50	80
Water gravel	8	88

48 (FWA 3). NE¼SE¼ sec. 4, Ypsilanti Township, near southwest corner of Holmes and Prospect Roads, Ypsilanti. Altitude, 770±

	Thickness	Depth		Thickness	Depth
Brown medium sand, clean, loose	5	5	Fine gravel with clay (gravelly hardpan)	2	90
Coarse brown sand; medium gravel; some pebbles ¾ inch in diameter	10	15	Fine gray silty sand	10	100
Brown medium sand; fine gravel, fairly clean	10	25	Gray clay	20	120
Fine brown sand; medium gravel; clay	5	30	Gray clay; occasional small fragments of rock	15	135
Gray fluid clay; gravel	5	35	Fine gray gravel and clay	5	140
Firm gray sand and clay (hardpan)	5	40	Fine gravel, sand, and silt	10	150
Soft gray clay and silt	10	50	Gray silty clay; some gravel	10	160
Gray silty clay; few small pebbles	15	65	Gray silty clay; some fragments of greenish-white soft sandstone (Berea?). Top of sandstone probably at 161 feet	3	163
Gray silty clay	15	80			
Gray clay; small fragments of shale and limestone	8	88			

49 (SDM well Y-4-6). George Freeman, owner. Altitude, 787

	Thickness	Depth		Thickness	Depth
Clay	16	16	Putty clay	40	120
Sand; gravel	24	40	Blue clay	15	135
Blue clay	40	80	Water gravel [1]	5	140

[1] Thirty feet of water gravel reported in well about 800 feet to northeast.

50 (SDM well Y-5-31). Peninsular Paper Co., owner. Altitude not recorded

	Thickness	Depth		Thickness	Depth
Dry coarse gravel	13	13	Boulders	2	72
Clay; rock	42	55	Clay	34	106
Sand; gravel	15	70			

51 (SDM well Y-5-2). Peninsular Paper Co., owner. Altitude, 705

	Thickness		Depth			Thickness		Depth	
	Feet	Inches	Feet	Inches		Feet	Inches	Feet	Inches
Boulders; brick	5	10	5	10	Sandy blue clay	5	9	42	10
Clay; fine sand	8	8	14	6	Hard clay; stones	5	6	48	4
Clay; fine sand; boulders	6	7	21	1	Clay; gravel	4	8	53	0
Sand; clay; gravel	4	2	25	3	Clay; gravel; sand	11	2	64	2
Clay; stones	5	11	31	2	Clay; gravel	30	0	94	2
Fine sand	5	11	37	1	Sandstone	8	0	102	2

52 (test well 3). Peninsular Paper Co., owner. 600 feet south of office. Altitude not recorded

	Thickness	Depth		Thickness	Depth
Gravel; stones	13	13	Sand; gravel	7	103
Clay	24	37	Clay; sand; gravel	2	105
Quicksand	9	46	Sand; gravel	2	107
Gravel	8	54	Dirty fine sand	3	110
Clay; gravel	30	84	Sand	6	116
Gravel; sand	4	88	Clay; sand; gravel	3	119
Fine sand	6	94	Clay	8	127
Dirty sand; fine gravel	2	96			

53 ("Atlantis" well of USGS Geol. Atlas folio 155). T. C. Owen, owner (at former residence). Altitude, 785±

	Thickness	Depth		Thickness	Depth
Sand, clay, gravel, etc., unconsolidated	185	185	Limestone, pale, cherty	10	371
Shale, soft	4	189	Shale, sandy	5	376
Sandstone, fine, slightly calcareous; fresh water	10	199	Limestone	43	419
Limestone, fine	10	209	Shale, blue to dun-colored, some gritty	22	441
Shale, lower 74 feet black	84	293	Limestone, siliceous to pure	24	465
Shale, sandy, dun-colored	64	357	Shale	21	486
Sandstone, very fine, slightly calcareous; mineral water	4	361	Limestone, sulfurous (H_2S) water	138	624
			Unrecorded	184	808

54 (SDM well Y-5-1). E. Campbell, owner. Altitude, 777

	Thickness	Depth		Thickness	Depth
Clay	5	5	Clay; gravel	10	60
Yellow sand	10	15	Sand	15	75
Gravel	10	25	Clean sand	4	79
Blue clay	5	30	Water gravel	2	81
Dry gravel	20	50			

55 (SDM well Y-6-8). Lipke, owner. Altitude, 808

	Thickness	Depth		Thickness	Depth
Clay	40	40	Sandstone	½	207½
Sand	4	44	Slate rock (shale)	18	225½
Clay	163	207			

56 (SDM well Y-6-5). Harry Gilmore, owner. Altitude, 811

	Thickness	Depth		Thickness	Depth
Yellow sand	23	23	Medium gravel	8	93
Yellow sand and clay	62	85			

57 (SDM well Y-6-15). Paul Wolf, owner. Altitude, 815

	Thickness	Depth		Thickness	Depth
Yellow clay	32	32	Putty clay and sand	21	116
Yellow dry sand	46	78	Packed gravel	18	134
Gray sand	10	88	Medium gravel	1	135
Blue clay	7	95			

58 (SDM well Y-6-14). Schaefer Crane, owner. Altitude, 816

	Thickness	Depth		Thickness	Depth
Yellow clay	3	3	Yellow sand	39	74
Hardpan	5	8	Medium gravel; water	6	80
Yellow clay	27	35			

59 (SDM well Y-6-17). O. C. Beals, owner. Altitude, 809.5

	Thickness	Depth		Thickness	Depth
Yellow clay	16	16	Sand; gravel	37	98
Blue clay	45	61	Coarse gray sand	2	100

60 (SDM well Y-6-13). Altitude, 808

	Thickness	Depth		Thickness	Depth
Clay	18	18	Water gravel	3	43
Sand; gravel	22	40			

61 (SDM well Y-6-12). Grant Wilson, owner. Altitude, 818

	Thickness	Depth		Thickness	Depth
Yellow clay	5	5	Quicksand	13	83
Gravel; clay	10	15	Hard blue clay	167	250
Blue clay	7	22	Hardpan	3	253
Hardpan; stone	6	28	Water sand; fine gravel	12	265
Blue clay	42	70	Medium gravel	3	268

62 (SDM well Y-8-16). Walker, owner. Altitude, 792

	Thickness	Depth		Thickness	Depth
Sand; clay	70	70	Water gravel and sand	3	125
Water gravel and sand	5	75	Blue clay	73	198
Blue clay	47	122	Water gravel	2	200

63 (SDM well Y-8-13). Otto Lidke, owner. Altitude, 767

	Thickness	Depth		Thickness	Depth
Clay	10	10	Sand	2	42
Sand	2	12	Clay	26	68
Clay	13	25	Gravel (not completely penetrated	2	70
Sand	2	27			
Clay	13	40			

64 (SDM well Y-8-10). Oliver Houston, owner. Altitude, 792

	Thickness	Depth		Thickness	Depth
Clay	3	3	Sand; gravel	25	85
Sand	37	40	Fine gravel and sand	5	90
Clay; sand	10	50	Gravel; water	5	95
Yellow sand	10	60			

65 (SDM well Y-8-11). Harry Rominski, owner. Altitude, 766

	Thickness	Depth		Thickness	Depth
Topsoil	14	14	Blue clay	41	63
Quicksand	8	22	Gravel	4	67

66 (SDM well Y-8-26 [city of Ypsilanti test well 8]). Altitude, 767

	Thickness	Depth		Thickness	Depth
Yellow sand	15	15	Clay; stones	4	101
Gray sand	17	32	Hardpan; little coarse sand near top and bottom	25	126
Blue clay	8	40	Blue clay and stones	31	157
Gray sand	15	55	Sand and gravel	5	162
Quicksand	10	65	Sand; gravel; streaks of clay	4	166
Blue clay and stones	10	75	Fine sand	2	168
Hardpan	15	90	Sandy shale	6	174
Blue clay	6	96	Sandstone	3	177
Fine sand and clay	1	97			

67 (SDM well Y-8-1). Warner Dairy, owner. Altitude, 783

	Thickness	Depth		Thickness	Depth
Yellow clay	8	8	Gray sand	18	68
Yellow sand	32	40	Sand; gravel	6	74
Clay; gravel	10	50	Water gravel	29	103

68 (SDM well Y-9-27 [city of Ypsilanti test well 7]). Altitude, 700

	Thickness	Depth		Thickness	Depth
Topsoil; stones	5	5	Sand; clay	10	45
Dry gravel and clay	5	10	Blue clay	20	65
Hardpan	2	12	Fine sand and clay	22	87
Blue clay and stones	23	35			

71 (SDM well Y–9–24–25–26 [city of Ypsilanti test well T. D. 4–5–6]). Altitude, 695

	Thickness	Depth		Thickness	Depth
Topsoil; broken concrete	7	7	Blue clay	2	77
Hardpan	5	12	Hardpan	5	82
Blue clay and stones	33	45	Blue clay and stones	20	102
Blue clay and sand	30	75	Soft sandy shale	10	112

72 (FWA 10). NE¼ sec. 9, Ypsilanti Township, in center strip of River Street just south of intersection with North Street, Ypsilanti. Altitude, 710

	Thickness	Depth		Thickness	Depth
Medium gravel; brown sand	4	4	Medium gravel; some pebbles over 1½ inches in diameter	5	49
Medium gravel; considerable brown silty clay	5	9	Gray and brown silty clay	10	59
Coarse sand; fine gravel. Moderately permeable	5	14	Gray silty clay	10	69
Medium to fine gravel; some sand; some pebbles up to 1½ inches in diameter	20	34	Light-gray stiff clay; fragment of sandstone	5	74
Coarse sand, fairly well sorted	10	44	Gray clay (base of Pleistocene)	16	90
			Gray sandstone (Berea?)	5	95
			Hard dense sandstone	2	97

73 (FWA 14). SE¼NE¼ sec. 9, Ypsilanti Township, at south end of State Police building at southwest corner of Michigan Avenue and Park Street in Gilbert Park, Ypsilanti. Altitude, 710±

	Thickness	Depth		Thickness	Depth
Brown dirty gravel	5	5	Gray silty clay; some gravel	3	90
Brown medium gravel	20	25	Medium to coarse clean gravel	5	95
Gravel, finer than above	5	30	Gray silty clay, pebbly	20	115
Gray clay; some small pebbles	20	50	Gray silty clay, pebbly; fragments of Berea(?) sandstone (probably base of Pleistocene)	10	125
Fine brown sand	5	55	Gray-green sandstone. Sample contains clay and pebbles that may be cavings	5	130
Medium sand, fairly well sorted	10	65			
Medium to coarse sand, arkosic	10	75			
Fine gray silty sand	5	80			
Medium gravel; coarse sand	3	83			
Sand; gray clay; some gravel	4	87			

74 (SDM well Y–9–16). Trojan Laundry, owner. Altitude, 691

	Thickness	Depth		Thickness	Depth
Stony fill	4	4	Coarse clean gravel	4	33
Quicksand	6	10	Hardpan	3	36
Hardpan	19	29			

75 (city of Ypsilanti supply well 1). Altitude, 688

	Thickness	Depth		Thickness	Depth
Sand; gravel; clay	5	5	Dirty fine sand	8	65
Stones; clay; hardpan	15	20	Gravelly hardpan	9	74
Blue clay	10	30	Dirty coarse sand and gravel	2	76
Sandy blue clay	10	40	Coarse sand and gravel	12	88
Sandy hardpan	17	57	Very coarse gravel	14	102

76 (city of Ypsilanti supply well 2). Altitude, 687

	Thickness	Depth		Thickness	Depth
Soil	3	3	Coarse gravel; clay	2	63
Sand; gravel; clay	10	13	Gravel; sand	3	66
Hardpan	3	16	Sand; little gravel	1	67
Gravelly tough blue clay	10	26	Coarse gravel	7	74
Gravelly blue clay	10	36	Very coarse gravel	10	84
Soft blue clay	20	56	Coarse gravel	3	87
Hardpan; stones	5	61			

77 (city of Ypsilanti supply well 3). Altitude, 689

	Thickness	Depth		Thickness	Depth
Sandy fill	5	5	Coarse sand and gravel	11	48
Gravel	3	8	Tight gravel	2	50
Soft gravelly blue clay	7	15	Coarse clean gravel, loose	15	65
Hardpan	12	27	Tight coarse gravel	7	72
Soft sandy mud	8	35	Very coarse gravel and rocks	22	94
Coarse sand	2	37			

78 (SDM well Y-9-22 [city of Ypsilanti test well 1]). Near well 75. Altitude, 687

	Thickness	Depth		Thickness	Depth
Topsoil; sand; gravel	9	9	Blue clay; fine sand	9	65
Hardpan	1	10	Gray sand; some clay	1	66
Blue clay	26	36	Gravel; coarse sand	39	105
Sandy blue clay	9	45	Blue clay and stones	1	106
Quicksand	11	56			

79 (SDM well Y-9-23 [city of Ypsilanti test well 2]). Near well 76. Altitude, 688

	Thickness	Depth		Thickness	Depth
Topsoil; coarse gray sand	12	12	Coarse sand and gravel	2	66
Blue clay	44	56	Gravel; sand	17	83
Blue clay and stones	3	59	Blue clay and stones	7	90
Gravel; coarse sand	5	64			

80. Banner Oil and Gas Co., owner. N½NE¼ sec. 16, Ypsilanti Township, 300 feet from Cornwell well (well 81). Altitude, 682

	Thickness	Depth		Thickness	Depth
Unconsolidated material; water at 90 feet	90	90	White shale. Water and odorless gas reported at about 135 feet	51	141
			Unrecorded [1]	1,059+	1,200+

[1] Entire record of doubtful accuracy.

81 (Cornwell test well for mineral water). Altitude, 680±

	Thickness	Depth		Thickness	Depth
Earth, clay, gravel, sand, etc., unconsolidated	109	109	Sandstone	38	393
Slate (probably shale)	241	350	Soft slate or sandstone (sandy shale)	157	550
Flint	5	355	Bedrock (hard limestone)	200	750

82 (SDM well Y-9-17). Ypsilanti Dairy, owner. Altitude, 749

	Thickness	Depth		Thickness	Depth
Sand	4	4	Blue clay	108	183
Blue clay	68	72	Medium gravel	4	187
Water gravel	3	75			

85 (SDM well Y-10-6). H. A. Disbee, owner. Altitude, 735

	Thickness	Depth		Thickness	Depth
Clay	60	60	Gravel; clay	20	90
Gray sand	10	70	Gravel; water	10	100

86 (SDM well Y-10-2). Plank Road Farm, owner. Altitude, 756

	Thickness	Depth		Thickness	Depth
Fine gravel and sand	27	27	Water gravel	2	97
Blue clay	68	95			

88 (SDM well Y-11-6). Altitude, 731

	Thickness	Depth		Thickness	Depth
Topsoil	3	3	Quicksand	13	22
Gravel	5	8	Clay	78	100
Fine water gravel	1	9	Water gravel	2	102

89 (Ford Motor Co. test well for Willow Run Boys Camp). Altitude not recorded

	Thickness	Depth		Thickness	Depth
Sand; clay	38	38	Light shale	38½	225
Sand; hardpan	103	141	Sandy limestone [2]	3	228
Sand; gravel [1]	½	141½	Limestone [2]	37	265
Dark shale	45	186½	Light shale [2]	35	300

[1] Water level 105 feet below surface.
[2] Water level 35 feet below surface.

90 (Ford Motor Co. test well 44 [Wiard test well]). Altitude, 736

	Thickness	Depth		Thickness	Depth
Yellow sand and stones	5	5	Sand; gravel; clay	10	65
Clay; stones	5	10	Clay; stones	20	85
Clay; sand; stones	5	15	Fine sand	45	130
Sand; clay	5	20	Gravel	5	135
Blue clay and stones	25	45	Fine sand	5	140
Clay; stones	10	55			

91 (FWA 11). SE¼SE¼ sec. 15, Ypsilanti Township, about 15 feet north of edge of Ford Lake on point of land jutting into lake. Altitude, 687±

	Thickness	Depth		Thickness	Depth
Clean brown gravel, medium to fine	5	5	Gray silty clay and pebbles	15	75
Brown clay; large and small pebbles; fragments of wood	5	10	Fine gray sand and silt; gravel	10	85
Brown clay; gravel	5	15	Fine, well-sorted brown sand. Low permeability	15	100
Brown sandy silt, soft, fluid	10	25	Sand, slightly coarser than above	13	113
Gray sandy clay	10	35	Gray stiff clay; fragments of shale (base of Pleistocene)	12	125
Gray clay and gravel	20	55	Dark shale (Antrim?)	15	140
Stiff blue-gray clay; few fragments of rock	5	60			

92 (SDM well Y-16-2 [city of Ypsilanti test well 3]). Altitude, 690

	Thickness	Depth		Thickness	Depth
Sand; clay; stones	20	20	Quicksand	2	52
Blue clay and sand	4	24	Clay; sand	7	59
Blue clay	23	47	Blue clay and stones	21	80
Blue clay and sand	3	50			

94 (SDM well Y-18-4). Fred Persons, owner. Altitude, 833

	Thickness	Depth		Thickness	Depth
Red sand	50	50	Clay; sand; gravel; water	45	140
Gray sand	15	65	Blue clay	35	175
Hardpan	5	70	Clay; fine gravel	4	179
Packed sand	25	95	Medium gravel	2½	181½

95 (SDM well Y-20-4). Thorn School, owner. Altitude, 760

	Thickness	Depth		Thickness	Depth
Yellow clay	12	12	Putty clay	70	170
Blue clay	33	45	Blue clay	8	178
Clay; sand	15	60	Water gravel	3	181
Blue clay	40	100			

97 (SDM well Y-21-6). Hammond, owner. Altitude, 731

	Thickness	Depth
Sand	4	4
Clay	120	124
Coarse gravel	3	127

99 (FWA 12). NW¼SE¼ sec. 23, Ypsilanti Township, at extreme southwest end of point jutting into Ford Lake, about 0.5 mile west of Ford Rawsonville dam, power plant, and water-treatment plant. Altitude, 685±

	Thickness	Depth
Tan to buff silt and clay	15	15
Gray silty clay, soft, fluid	35	50
Fine to medium sand and clay	10	60
Fine to medium brownish-gray sand	5	65
Fine to medium brownish-gray sand; some fragments of pebbles	5	70
Fine to medium brownish-gray sand without pebbles	5	75
Gray clay; fragments of shale and pebbles	20	95
Gray stiff clay; rounded pebbles of shale (base of Pleistocene)	5	100
Gray clay and crushed shale	15	115

100 (SDM well Y-23-1). Campbell, owner. Altitude, 716

	Thickness	Depth
Clay	120	120
Gravel	2	122
Bedrock	Entered	

101 (Ford Motor Co. test well 46). Altitude, 715±

	Thickness	Depth
Sand; boulders	10	10
Sand; clay	5	15
Clay; boulders	90	105
Sand; boulders	5	110
Clay; boulders	10	120
Black shale	20	140

102 (Ford Motor Co. test well 47). Altitude, 695±

	Thickness	Depth
Sand; clay; boulders	10	10
Clay; boulders	40	50
Quicksand	20	70
Sand; clay	5	75
Sand	15	90
Boulders; clay	5	95
Black shale	4	99

103 (Ford Motor Co. observation well 7). Altitude, 692

	Thickness	Depth
Clay; gravel	6	6
Blue clay	39	45
Muddy sand	23	68
Sand; gravel	25	93
Shale	2	95

104 (Ford Motor Co. observation well 8). Altitude, 665

	Thickness	Depth		Thickness	Depth
Clay; gravel	3	3	Sand	55	85
Clay; sand	27	30	Shale	2	87

105 (Ford Motor Co. observation well 10). Altitude, 653

	Thickness	Depth		Thickness	Depth
Sand; gravel	15	15	Clay	1	68
Gravel; sand	52	67			

106 (Ford Motor Co. observation well 9). Altitude, 665

	Thickness	Depth		Thickness	Depth
Sand; fill	5	5	Gravel; sand	40	65
Clay; sand	10	15	Boulders; clay	3	68
Clay; gravel	10	25			

107 (Ford Motor Co. observation well 11). Altitude, 664

	Thickness	Depth		Thickness	Depth
Clay; boulders	5	5	Gravel; clay	3	63
Sand; gravel	15	20	Gravel; sand	14	77
Gravel; sand	35	55	Shale	1	78
Clay; boulders	5	60			

108 (Ford Motor Co. test well 3). Altitude, 663

	Thickness	Depth		Thickness	Depth
Sand; clay; gravel	5	5	Sand	5	30
Sand; gravel; clay	10	15	Sand; clay	10	40
Sand; gravel	10	25	Sand; gravel	10	50

109 (Ford Motor Co. observation well 12. Altitude, 665

	Thickness	Depth		Thickness	Depth
Fill; clay; gravel	5	5	Boulders; gravel	4	54
Sand; gravel	15	20	Gravel; sand	31	85
Gravel; sand	30	50			

110 (Ford Motor Co. dam test boring 5). Altitude, 652

	Thickness	Depth		Thickness	Depth
Sand; clay	4	4	Boulder	2	33
Sand; gravel; clay	8	12	Coarse blue sand and gravel; clay	7	40
Coarse blue sand and gravel; clay	19	31			

111 (Ford Motor Co. foundation test boring B-2). Altitude, 684

	Thickness	Depth		Thickness	Depth
Sand; clay	1	1	Clay	10	17
Sand	6	7	Sand	18	35

112 (Ford Motor Co. supply well 1). Altitude, 668

	Thickness	Depth		Thickness	Depth
Clay	3	3	Boulder; gravel	39	87
Gravel; sand	45	48			

113 (Ford Motor Co. supply well 2). Altitude, 661.5

	Thickness	Depth		Thickness	Depth
Sand; clay; stones	10	10	Boulders; clay	11	92
Coarse sand; gravel; boulders	71	81	Gravel	5	97

114 (Ford Motor Co. supply well 3). Altitude, 665±

	Thickness	Depth		Thickness	Depth
Topsoil	5	5	Clay; gravel	5	50
Coarse sand	10	15	Sand; gravel; clay	5	55
Fine gravel	5	20	Fine gravel; coarse sand; some boulders	25	80
Coarse sand	10	30	Shale	2	82
Medium sand	15	45			

115 (Ford Motor Co. dam test boring 4). Altitude, 650

	Thickness	Depth		Thickness	Depth
Sand; clay	3	3	Coarse blue sand and gravel	10	40
Coarse yellow sand and gravel; clay	27	30			

116 (Ford Motor Co. dam test boring 7). Altitude, 654

	Thickness	Depth
Sand; clay	3	3
Yellow sand and gravel	12	15
Coarse blue sand and gravel, clean	25	40

117 (FWA 13). E½SW¼ sec. 24, Ypsilanti Township, 50 feet south of Huron River, just below Ford Rawsonville dam opposite well field of Willow Run bomber plant. Altitude, 658.

	Thickness	Depth
Reddish-brown soil and pebbles	5	5
Red gravel; some red sandy clay	5	10
Brown gravel; silt	10	20
Gravel; gray mud and silt. Not so well sorted as material from 10 to 20 feet	10	30
Medium to fine gravel	5	35
Fine to coarse gravel; some pebbles up to 3 inches in diameter	15	50
Fine to medium gravel; pebbles up to 1 inch in diameter	10	60
Clean medium gravel; sand in lower part	10	70
Loose gravel; some pebbles up to 2 inches in diameter	8	78
Fine gravel; clay; sand (hardpan)	2	80
Gray angular gravel and sand, similar to hardpan	5	85
Gray angular gravel of cemented limestone and shale pebbles. Low permeability	5	90
Moderately loose gravel and sand. Probably equivalent to "salt water" bed between 92 and 97 feet in well 113	5	95
Brown limestone; some hard white chert (Traverse formation?)	2	97
Hard white chert	3	100

118 (Ford Motor Co. dam test boring 9). Altitude, 660

	Thickness	Depth
Sand; clay	3	3
Yellow sand and gravel	6	9
Coarse yellow sand and gravel; clay	20	29
Coarse blue sand and gravel	11	40

119 (Ford Motor Co. dam test boring 11). Altitude, 657

	Thickness	Depth
Sand; clay	3	3
Yellow sand and gravel	5	8
Yellow sand and gravel, clean	8	16
Coarse blue sand and gravel, clean	24	40

120 (Ford Motor Co. dam test boring 10). Altitude, 657

	Thickness	Depth
Sand; clay	3	3
Yellow sand and gravel, clean	6	9
Coarse blue sand and gravel, clean	31	40

121 (Ford Motor Co. dam test boring 1). Altitude, 654

	Thickness	Depth		Thickness	Depth
Sand; clay	5	5	Coarse blue sand and gravel, coarser than above	42	102
Coarse blue sand and gravel, clean	55	60	Bedrock (chert)	2	104

122 (Ford Motor Co. dam test boring 3). Altitude, 653

	Thickness	Depth		Thickness	Depth
Sand; gravel	5	5	Coarse blue sand and gravel; clay	12	40
Coarse yellow sand and gravel; clay	23	28			

123 (Ford Motor Co. dam test boring 6). Altitude, 660

	Thickness	Depth		Thickness	Depth
Sand; clay	3	3	Coarse blue sand and gravel	15	40
Yellow sand and gravel; clay	22	25			

124 (Ford Motor Co. test well 2 [unsuccessful supply well W2]).[1] Altitude, 686.5

	Thickness	Depth		Thickness	Depth
Sand and clay, gravelly	5	5	Sand; gravel	5	95
Clay	30	35	Sand	5	100
Sand; clay	5	40	Sand; gravel; clay	5	105
Coarse sand and gravel	45	85	Clay; stones	10	115
Sand	5	90	Rotten shale	18	133

[1] Unsuccessful supply well completed at 100 feet.

125 (Ford Motor Co. foundation test boring B-1). Altitude, 683

	Thickness	Depth		Thickness	Depth
Sand and clay	5	5	Sand	19	33
Clay	9	14			

129 (SDM well Y-27-2). James Moore, owner. Altitude, 721

	Thickness	Depth		Thickness	Depth
Clay	114	114	Gravel	6	121
Hardpan	1	115			

134 (SDM well Y-33-6). Claude Eaton, owner. Altitude, 708

	Thickness	Depth		Thickness	Depth
Sand	4	4	Hardpan	1½	26½
Blue clay	21	25	Gravel	3½	30

135 (SDM well Y-34-3. Gorton, owner. Altitude, 701

	Thickness	Depth		Thickness	Depth
Soil	6	6	Sand	25	107
Clay	76	82	Gravel	9	116

137 (SDM well P-1-3). MacDonald, owner. Altitude, 823.5

	Thickness	Depth		Thickness	Depth
Dry gravel and clay	112	112	Gravel	1	165
Blne clay	52	164			

138 (SDM well P-1-7 [E. La Pointe well 2]). Altitude, 835

	Thickness	Depth		Thickness	Depth
Clay	16	16	Sand; clay	218	236
Sand; gravel	2	18	Gravel	2	238

139 (SDM well P-1-8). Watts, owner. Altitude, 828

	Thickness	Depth		Thickness	Depth
Yellow clay	12	12	Blue clay	27	200
Clay; sand; gravel	18	30	Sand	3	203
Blue clay	25	55	Blue clay	25	228
Sand; clay	50	105	Sand; clay	10	238
Blue clay	65	170	Blue clay	18	256
Sand; some water	3	173	Clean sand and gravel	1	257

140 (SDM well P-14-1). Ypsilanti airport, owner. Altitude, 837

	Thickness	Depth		Thickness	Depth
Yellow clay	12	12	Gray sand	24	122
Yellow sand	1	13	Putty sand	37	159
Hardpan	31	44	Fair gravel and sand	3½	162½
Packed sand	20	64	Good coarse gravel	½	163
Blue clay	34	98			

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