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G. E. EDDY, State Geologist

GROUND-WATER RESOURCES OF THE GLACIAL DEPOSITS, BESSEMER AREA, MICHIGAN 1950

BY
E. A. BROWN AND W. T. STUART

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By E. A. Brown and W. T. Stuart

ABSTRACT

This report is based on an investigation of the ground-water resources in the vicinity of Bessemer in the western part of the northern peninsula of Michigan, made by the Geological Survey of the United States Department of the Interior in cooperation with the Geological Survey Division of the Michigan Department of Conservation. The area studied in detail covers about 60 square miles within a 4.5-mile radius of Bessemer, although an area of about 120 square miles was mapped. The map on figure 3 shows the surface geology and location of wells, test borings, and springs.

The area is included in the Laurentian Upland physiographic province of North America. The topography is variable, being hilly in the bedrock-outcrop areas and a rolling plain elsewhere. Altitudes range from about 1,150 to 1,800 feet above sea level. The drainage is northward toward Lake Superior.

The bedrock crops out in a discontinuous, hilly east-west band across the central part of the area, and also as isolated exposures in the southern part of the area. The Gogebic range, a major iron-mining district of the Lake Superior region, is in the central band.

During the periods of glaciation many of the low areas between the bedrock highs were filled with glacial deposits. Information about these glacial formations was gained by mapping the surficial deposits and examining excavations and logs of wells and test borings. The data collected in the inventory of wells, borings, and springs are tabulated in appendixes A and B.

Most of the glacial drift in this area is red stony, sandy clay to clayey sand, known as boulder till, or hardpan, which generally is not of uniform character in vertical section. However, widespread sand and gravel deposits occur west of Black River and north of Spring Creek, about 5 miles northwest of Bessemer and in an area just south and southwest of Bessemer in the vicinity of Powder Mill Creek.

The surficial glacial deposits, like the subsurface deposits, consist mainly of hardpan. This material is common in both the bedrock-outcrop and the till plain areas. Sand and gravel occur in several types of deposits, most of which have distinct topographic forms. These include terraces, eskers, kames and morainal knolls.

Precipitation, which is the primary source of ground water, amounts to a normal annual total of 34.63 inches according to the U. S. Weather Bureau records at Ironwood, 4 miles west of Bessemer. It is fairly evenly distributed by months, although the precipitation in the summer exceeds that in the winter.

Ground water exists under modified artesian conditions in most of the area. It is most easily obtained from the glacial sand and gravel, as the other glacial deposits and the bedrock do not yield water readily.

Limited ground-water storage capacity of the glacial materials, due both to the scarcity of thick sand and gravel deposits below the water table and to shallow depth to bedrock results in the rejection of much water from precipitation that otherwise would become ground water. The water level in most wells fluctuates several feet annually, reaching a peak usually about May, because of recharge from melting snow and spring rains, and a low either in the fall, because of high transpiration and a lack of rainfall, or in February from reduced recharge because of frozen ground.

Ground water is used principally for public, industrial, and railroad supplies and for domestic and stock purposes. The quality of ground water in this area is satisfactory for most uses and the water is only slightly to moderately hard. Its temperature varies from about 45° to 50° F. Springs are common around the rock-cored hills but their yields are small. The largest spring noted had a flow of 50 gallons per minute. Most of the wells are dug. In the immediate area there are only five well systems pumping regularly at a rate exceeding 25 gallons per minute.

Supplies of ground water for domestic and farm use are generally available throughout the area but supplies greater than about 10 gallons per minute are not easily obtained. The only aquifers suitable for the larger demands are sand and gravel.

Certain areas that appear to be favorable for greater development have been determined by this investigation. They are (1) south of Bessemer in the vicinity of and along the persistent but discontinuous sand and gravel ridge (esker) and associated deposits; (2) a few terraces along Black River, Jackson's Creek, and Spring Creek; (3) south of Wakefield along Little Black River; (4) northeast of Wakefield in the vicinity of the Duluth, South Shore and Atlantic Railway; (5) just north of town in Bessemer Gap; (6) north of Spring Creek and west of Black River; and (7) north and east of Black River, about 3 to 4 miles north of Bessemer.

The City of Bessemer drilled four test holes in the northern part of area (1) in a search for a supplemental water supply. The only suitable aquifers found were in the esker, so two production wells were drilled in it. Natural recharge to the esker appears to be limited, but the proximity of Powder Mill Creek to the wells indicates water from this stream might be induced to the aquifer when the water levels in the wells are lowered sufficiently. However, during continued dry periods the yield of the wells will probably decrease owing to lowered water levels, lack of ground-water storage, and reduction in flow of the creek.

Laboratory tests to determine the hydrologic properties of the glacial formations were made on samples from the test holes.

A 24-hour pumping test on the upper sand and gravel at the site of test well 2A revealed the field transmissibility of these water-bearing materials to be 16,000 gallons per day per foot and the storage coefficient to be 0.009.

Short pumping tests on the two new production wells showed the field transmissibility of the upper sand and gravel to be 42,400 gallons per day per foot at well 2 and 21,600 gallons per day per foot for two water-bearing formations at well 1. During these tests the specific capacity for well 2 was 48 gallons per minute per foot of drawdown, and 21.3 gallons per minute per foot for well 1.

INTRODUCTION

The Geological Survey Division of the Michigan Department of Conservation and the Geological Survey of the United States Department of the Interior have been investigating the water resources of Michigan on a cooperative basis since 1945. The investigation that forms the basis of this report was a part of a larger program of determining the ground-water conditions of the State in order that the most effective use of the water resources could be made for farm, public, and industrial supplies. This report covers the ground-water conditions in the vicinity of Bessemer, Mich. and will be incorporated in a general county-wide study of Gogebic County later.

The expansion of the iron-mining industry and the growth of population in Gogebic County have created a condition whereby the public water-supply systems in the area are no longer adequate. The three largest towns in the area, Ironwood, Bessemer, and Wakefield, have been forced to develop new and larger public-supply systems. Bessemer lies approximately in the center of this area.

The present water supply for Bessemer is obtained mainly from three dug wells, in a gravel deposit on the north side of town, at the sites of former springs. The natural recharge to the field was not sufficient to maintain the demand, so recharge by diversion and impoundment of a stream (Powder Mill Creek) was necessary to make up the deficiency. Mine-drainage water entering the creek upstream from the diversion polluted the artificial recharge, and the creek flow declined to practically nothing during the period of below normal precipitation in 1947 and 1948. These conditions, plus probable increasing demands in the future, created the need of an additional source of supply.

A reconnaissance of the area, consisting of a series of measurements of the flow of Powder Mill Creek and an appraisal of the scope of the necessary work, was made by W. T. Stuart in July 1947. E. A. Brown began field work in the summer of 1948 by mapping the surface geology, and inventorying the wells. Subsequently, the City of Bessemer drilled four test holes, in the spring of 1949, and two production wells, in October 1949.

ACKNOWLEDGMENTS

Appreciation is due the officials and employees of the towns, county, mines, railroads, and other industries, and residents of the area, who gave freely of their time and information. Especial thanks are due the members of the Bessemer Water Department, particularly James Boggio, Superintendent, Jay Tobin, and Fred Crenna; W. H. Byrne, O. E. Olson, and E. V. Jacobson, of Oliver Iron Mining Co.; H. W. Johnson of Pickands, Mather & Co.; and O. J. Husemeir of the Chicago & Northwestern Railway Co. Many of the well logs were obtained from H. O. Rice of Gurney, Wis. and John DaRonco of Hurley, Wis. The cooperation and assistance of H. J. Nystrom and his helpers of Mason, Wis. during the test drilling are gratefully appreciated.

PERSONNEL

The data were collected and interpreted and the report was prepared by E. A. Brown under the general supervision of W. T. Stuart, of the Ishpeming office, who worked on many phases of the project, including the hydrologic calculations and interpretations. Miss Betty Conradson and Harold C. Boback assisted in making laboratory tests of the water-bearing materials. G. E. Eddy, State Geologist, and A. N. Sayre, Geologist in charge of the Ground Water Branch of the U. S. Geological Survey, have criticized the report.

PREVIOUS WORK

No previous publications of investigations of ground-water conditions or detailed glacial geology in this area are known to the author. Several publications on the geology of the area are available, most of them dealing with bedrock formations. U. S. Geological Survey Monographs 19 (2, 1892) and 52 (6, 1911)1/ treat the bedrock geology in detail, but discuss the glacial deposits only regionally, with no detail in this area. Gordon (1, 1907) describes the bedrock geology of a narrow strip of land extending from Bessemer to Lake Superior, with little reference to the overburden. Leverett (3, 1917; 4, 1928) treats the glacial deposits of the northern peninsula of Michigan on a regional basis with no detail in this area. Thwaites' outline (5, 1948) contains maps that include this area in much larger areas, but he does not discuss the deposits in this vicinity.

GEOGRAPHY

LOCATION AND SIZE

Bessemer, the county seat of Gogebic County, is in the western end of the northern peninsula of Michigan, close to the Wisconsin state line, in the central part of T. 47 N., R. 46 W. (See fig. 1.) The intersection of longitude 90°00' and latitude 46°30' is about 2 miles northeast of town. The area covered in detail by this report is about 60 square miles although reconnaissance mapping of an area of about 120 square miles is shown on figure 3.

CULTURE

Bessemer is about 3 miles west of Wakefield and 4 miles east-northeast of Ironwood on U. S. Highway 2, which runs in a general east-west direction. (See fig. 2.) It is served by the Chicago & Northwestern Railway and the Soo Line, the tracks of which nearly parallel each other just south of U. S. Highway 2. The Duluth, South Shore & Atlantic Railway runs in an east-west direction about 2.5 miles north of Bessemer on the banks of an old stream channel in which Black River and Jackson Creek are now located.

1/ Numbers are bibliography reference number and year of publication.

The main industries of the area are iron mining and lumbering. The iron mines are in a belt that almost parallels U. S. Highway 2 about a mile to the south. Farming is important in the area, and cleared lands are common as far as 4 miles north and about 5 miles south of this highway. The populations of Bessemer, Ironwood, and Wakefield were 4,080, 13,369, and 3,591, respectively, according to the 1940 census. Present populations of each are probably from 1,000 to 3,000 greater.

TOPOGRAPHY

The topography is variable, conforming to the differential erosion of the various bedrock formations, their outcrop pattern, and structural attitude. (See figs. 2 and 3.) The surface altitudes range from about 1,150 to 1,800 feet above mean sea level. A large east-west ridge, Trap Range, lies just north of Bessemer. The south wall of this ridge forms the most prominent topographic feature of the area, a bold bluff 250 to 300 feet above the surrounding land surface. Four northward-flowing streams cut through this high ridge. The widest gap is just north of Bessemer. A lower east-trending ridge extends from the western to the central parts of this area about a mile south of U. S. Highway 2. North of Trap Range is a moderately level, but gently undulating, plain with some swampy tracts, and terraces along Black River. South of the southern ridge is a rolling lowland, which contains swamps and jutting outcrops. Also south of the ridge and east of Black River is a relatively level highland with a gently rolling surface.

DRAINAGE

The drainage of the Bessemer area is northward toward Lake Superior. (See fig. 3.) The main stream is Black River, which originates in Wisconsin, flows northeastward passing through a deep gap at Ramsay, drops about 60 feet in a fall 2.5 miles north of Ramsay to an older channel, which it follows for 4 miles westward and then abandons to turn northward again.

The main tributaries to Black River in the immediate area are Powder Mill Creek, City (or Sewer) Creek, Sunday Lake Outlet (Little Black River), and Jackson Creek. Powder Mill Creek originates in swamps and lowlands southwest of Bessemer, and flows northward, passing through a wide gap in the bedrock, where it is joined by Sellwood Creek from the east, and continues northward through Trap Range over falls to join Black River near North Bessemer.

Siemens Creek, which drains the western part of the area, flows northward to join Spring Creek which flows westward and empties into the Montreal River, northwest of Ironwood.

CLIMATE

The climate of the area is similar to that of the northern Midwestern States. The winters are cold, with much snow, the summers are cool, the humidity is rather high, and precipitation is moderate.

The mean annual air temperature is 40.8° F. Temperatures have ranged from about 98° to -33° F. and the time between killing frosts has varied from 3 to 4.5 months.

The normal yearly precipitation is 34.63 inches. The annual snowfall has ranged from about 80 to 150 inches in the last 4 years. February is normally the driest month, and July, the wettest.

GEOLOGY

Because the occurrence of ground water is controlled by the geologic and hydrologic properties of the different materials in an area, a knowledge of the geologic formations is essential for a ground-water study. The surface materials in this vicinity form an irregular pattern of consolidated rock (bedrock) and glacial drift. (See fig. 3.)

BEDROCK FORMATIONS

A generalized stratigraphic section of the bedrock formations is shown below in table 1. In this table the oldest formations are at the bottom of the list and the youngest, or latest, at the top. All of these units are very old rocks, some of the most ancient in the United States, formed about a billion years ago.

Igneous rocks (dikes) cutting through these formations in the form of "veins" are common, and some small exposures of eruptive (volcanic) rocks crop out in a few places.

A geologic map (fig. 2) shows the pattern of these formations. The area of this map is only a fraction of that on figure 3, but the formations on the north and south borders of the map continue north and south, respectively, over the additional areas included on figure 3. The iron-ore deposits are in the Ironwood iron-formation.

The bedrock structure, consisting of roughly parallel banded, metamorphosed sedimentary and igneous rocks resting upon older metamorphic and igneous rocks and dipping north at angles of 55° to 75°, was produced in a long period of complicated geologic history during which the formations were tilted, folded, faulted, intruded by igneous masses, metamorphosed and eroded. Faults, or zones of fracture along which movement has occurred, are common in the bedrock. They are responsible for many of the cliffs in the Trap Range.

Table 1.--Generalized section of bedrock formations in the Bessemer area

Era		Series	Group	Formation	Rock types
Proterozoic	Pre-Cambrian	Keweenawan	Middle	---	Trap (lava flows) and basal quartzite
		Huronian	Upper	Tyler slate	Slate
			Middle	Ironwood iron-formation	Dolomite, slate, and chert
				Palms quartzite	Quartzite, (slate, and conglomerate)
			Lower	Bad River dolomite	Dolomite
		Laurentian	---	---	Granite and gneiss
		Keewatin	---	---	Greenstone and green schist

UNCONSOLIDATED DEPOSITS

Glacial history

The "Ice Age", or Pleistocene epoch, followed a long period of geologic history of which little or no record in the way of deposits is present here. Prior to the Pleistocene epoch this region underwent long periods of erosion accompanied by uplift. Owing to climatic changes, large masses of snow and ice began to accumulate at certain localities in the northern part of North America. With continual addition to these masses by precipitation, their borders began to expand, forming continental glaciers. The direction of the greatest growth, or movement, was generally to the south. As these glaciers became larger their borders became irregular. In many places the movement and growth of the glacier into long lobes was controlled by topography. Changes in climate resulted in advances, retreats, and periods of stagnation of the glaciers. The continental glaciers and their accompanying depositional and erosional processes were extremely complicated and were controlled by so many different factors that the history of the events is difficult to determine from the evidence at hand. However, regional study in the northern Midwestern States by many glaciologists has indicated four major glacial stages or advances separated by interglacial substages (or retreats) during which vegetation returned and soil horizons were developed.

This area was probably overridden by the ice sheets in all these periods of glaciation. However, the glacial deposits of the last (Wisconsin) stage are the only ones that are evident. This stage had at least five substages of ice advance, but the deposits of only two of these are believed to be common to the area. The ice moved into this region from the northeast in the Chippewa Lobe of the Labradorian ice sheet or glacier. Striae and other markings on bedrock surfaces indicate a due-south movement of the ice in the area. In only one area were barely visible east-west striae found.

Subsurface glacial deposits

Information on materials below the ground surface was obtained by examination of road cuts and excavations, and from logs of wells and test borings. Data on the formations penetrated in wells and borings were obtained from well drillers, well owners, and railroad, mine, county, and town officials and employees. Most were taken from the memory of people interviewed, with only a part from written records. It is probable that the same formation may be called different names by different people. The records obtained in this inventory of water wells, drill holes, test borings, shaft excavations, and springs are shown in appendixes A and B. The location of these wells, other excavations, and springs is shown on figure 3. They are numbered and tabulated according to their location, as described in the explanation sheets preceding appendix A. The well number is composed of the township, range, section, and individual well numbers.

The major part of the glacial drift, according to these records, is a red stony, sandy clay to clayey sand, commonly known as hardpan or boulder till. It usually contains large rocks and boulders, clay beds, quicksand, sandy and gravelly clay layers, and sand and gravel lenses or pockets. These sand and gravel deposits transmit water more freely than the hardpan and, therefore, wells are dug to tap these deposits. Usually a well penetrates only the top of one of these zones, so the thickness of the deposit is not ascertained.

In some areas the logs of adjacent wells are similar, but in others the logs differ greatly. As explained above in the discussion on glacial history, the drift deposits are extremely irregular at places because of the complex processes of deposition.

In an area consisting of the southeastern part of T. 48 N., R. 47 W. and the southwestern part of T. 48 N., R. 46 W., west of Black River, the upper part of the drift is fairly regular in character and thickness. There are two zones of sand and/or gravel, each 2 to 5 feet thick according to most well logs, that are separated by red hardpan about 25 feet thick. The uppermost material is in most places red hardpan, the thickness of which varies with the altitude of the well. However, the two sand and gravel zones are at depths of 22 and 48 feet in most places. The hole with the greatest amount of drift above bedrock recorded in the area is in this vicinity (240 feet in hole 48.47.25.2-1), but no log of it could be obtained.

The logs of wells in T. 48 N., R. 26 W., north and east of Black River indicate a lack of uniformity in the drift, with the exception of a great amount of red boulder till. However, there are many wells between 30 and 40 feet deep, and two are about 90 feet deep, indicating that sand and gravel zones may be found at this depth. The second greatest thickness, or cover, of glacial drift recorded was in a well in this area (196 feet in well 48.46.28.7). The well was bottomed in coarse sand.

Records of the few existing wells in an area just north of Bessemer, in sec. 4, indicate that the subsurface materials consist mainly of sand and hardpan. One well there shows sand and gravel zones about 10 feet thick at depths of 8 and 22 feet. These are probably sandy and gravelly layers of hardpan.

The east-west lowland in which Bessemer is located is almost completely covered by glacial drift. However, this cover is generally not very thick, being 20 to 30 feet in most wells, but as much as 47 feet in one well. The material is mainly hardpan, but gravelly phases are common at or near the bedrock surface.

Just southwest of Bessemer, in secs. 20, 21, 28, and 29, the glacial drift is moderately regular in vertical sequence. In most shallow wells in areas of sandy or clayey till, a layer of sand about 0.5 to 4 feet thick overlies gravel several feet thick. The till cover ranges in thickness from about 8 to 33 feet, depending on the surface altitude of the well. The thickest drift cover is 90 feet, according to the record of well 47.46.20.5-1. Several wells in the W½ sec. 20 penetrated surface sand and gravel to a depth of 20 feet, gravel to a depth of 25 feet, and gravelly hardpan to a depth of 34 feet. The Bessemer exploration test holes, all of which reached bedrock, were drilled in this area. Test hole 1 (47.46.20.1) was drilled to a depth of 71.3 feet in the gravel pit at the center of the sand and gravel ridge in the NE¼ sec. 20. Test hole 2A (47.46.20.1-2A) was drilled to a depth of 68.9 feet in the center of this ridge about 900 feet southwest of test hole 1. Test hole 2A was drilled at the site of original test hole 2 which had been abandoned at a depth of 32.5 feet because of difficulties in drilling. Sand and gravel extends to a depth of 36.5 feet in test hole 1 and to a depth of

32.3 feet in test hole 2A. Beneath this is a sandy and gravelly clay with boulders (hardpan or glacial till). Layers of sand and clayey gravel are just above bedrock in test hole 1, and 3 feet of clean uniform gravel overlies the bedrock in test hole 2A.

Test hole 3 (47.46.21.1-3) was drilled to a depth of 33.3 feet in the NW$\frac{1}{4}$ sec. 21, several hundred feet south of Sellwood Creek, a tributary of Powder Mill Creek. Most of the material encountered in this hole is hardpan but 4.5 feet of clayey sand and gravel was penetrated at a depth of 20 feet. This sand and gravel horizon corresponds with that reported in the many surrounding dug wells. Test hole 4 (47.46.21.1-4) was drilled 1 foot into bedrock to a depth of 72.5 feet on the west end of a sand ridge in the NW$\frac{1}{4}$ sec. 21. In this hole 35 feet of silt, sand, and clay overlies 36.5 feet of hardpan resting on bedrock.

These test holes indicate that the bedrock topography in the immediate area is a broad valley about a mile wide, with the deepest part 70 feet below Powder Mill Creek level, trending northeastward through the NE$\frac{1}{4}$ sec. 20. In vertical section they show (1) the greater part of the subsurface glacial deposits to be sandy and stony hardpan with interbedded sand and gravel layers, (2) thin sand and gravel beds just above or on the granite bedrock, and (3) the extension of surface sand and gravel deposits to a depth of about 35 feet. Logs of these holes are shown in appendix B.

The logs of wells east of Bessemer, in the area around Sunday Lake Outlet and farther south, indicate lack of uniformity in the drift except for the preponderance of hardpan, usually sandy and stony. The greatest thickness of drift recorded here is 100 feet in a drill hole in sec. 8.

The hardpan, or till, generally is red or reddish brown. However, in the northwestern part of the area, two wells (48.46.32.5 and 48.47.25.1) penetrated about 40 feet of bluish-tinged till under red till. This "blue till" evidently is the deposit of an earlier glacial stage. No sand or gravel zones were reported in this till.

Surficial deposits

The surficial glacial deposits, like the subsurface drift, consist mainly of sandy and stony hardpan (boulder till). They are mapped on figure 3. Glacial deposits generally have certain types of land forms indicative of the materials in the deposits, except where this form is modified by the bedrock topography (bedrock control).

In general, except in areas where bedrock exposures are numerous and in areas of bedrock control, which compose the greater part of the immediate vicinity of Bessemer, most of the district is a moderately level but gently undulating plain, dissected by streams. On this till plain, or ground moraine, are irregularly shaped forms of till. An example of a characteristic till form is the drumlin, an oval-shaped mound with the long axis parallel to the direction of the ice movement. Several of these hills are in the Bessemer Gap area near the center of sec. 4, T. 47 N., R. 46 W.

Two kinds of till, the hardpan and the sandy type, are present here. (See fig. 3.) The sandy type is common to the area south of Trap Range. The hardpan is present in most areas; generally it is the cover where the bedrock is near the land surface. However, in the southeastern part of the area the sandy till is the main cover over bedrock, and south of Bessemer it is generally just a veneer over the hardpan. A large, high hill, or moraine, in the NW¼ sec. 27, T. 47 N., R. 46 W., is covered with this sandy till.

Boulders are very common in the till. Their distribution is not regular, but they are generally more common at the surface in areas where the bedrock is near the surface. They are also very common along streams and former stream channels ("sluiceways") where they are residual concentrates from the till after the finer materials have been eroded. They are not as abundant in the sandy till, as in the hardpan.

In the till areas muck and peat are common. They are organic soils containing a large percentage of plant matter in various stages of decomposition, ranging from the black finely divided type (muck) to the brown coarse and fibrous type (peat). These are not true glacial deposits. They are found in the swamps, bogs, and "bedrock basins." Usually they indicate a water table close to the surface, such as in the large flat swampy areas and along some streams, but they also occur on slopes where seeps flowing across materials that do not transmit water rapidly keep the ground wet enough to maintain swamp-type vegetation. Minor muck and peat areas are not shown on figure 3.

Flood-plain deposits of silt, sand, and muck occur in the outlet channel of glacial Lake Ontonagon (ancient Lake Gogebic) along Black River, Jackson's Creek, and Spring Creek; and they are present also in small areas along the upstream course of Black River. They are not glacial deposits.

Sand and gravel occur in this area in several types of deposits with characteristic topographic forms. One is the terrace or flat-topped long and narrow type along major stream channels. It is a glacio-fluvial, or clean sand and gravel, deposit laid down by escaping meltwaters of the glaciers. Deposits of this type are remnants of valley trains, or sand and gravel that filled the valleys in the early stages of the melting of the glacier. They are common in the channel of the outlet of glacial Lake Ontonagon, which drained westward through the valleys of Jackson's Creek, Black River, and Spring Creek. Several of them have been buried by till. The base of some of these deposits as exposed in gravel pits is about 25 feet above the present streams. Sorting, stratification, and cross bedding of the sand and gravel are pronounced in these exposures.

Another type of deposit is the esker, which is a long, narrow, and usually persistent but discontinuous, low, winding ridge with an irregular or wavy top. Eskers are formed by deposition from streams in the ice draining toward the ice front. The materials of this deposit usually show some stratification but are poorly sorted; they contain some fine sand and silt. When the glacier retreated, the material was laid on the ground surface and the sides slumped. A long esker in this area has its most prominent expression in the NE¼ sec. 20, T. 47 N., R. 46 W. It may be traced somewhat discontinuously from its possible point of origin on the north side of Black River, in secs. 27 and 34, T. 48 N., R. 46 W. southward into secs. 3 and 4, T. 47 N., R. 46 W. through its area of prominent expression in sec. 20

southward into secs. 29 and 32, T. 47 N., R. 46 W. From the northern part of sec. 20, a branch of this esker extends eastward into the northern part of sec. 16, T. 47 N., R. 46 W. From the eastern part of sec. 9 to the southwestern part of sec. 16, T. 47 N., R. 46 W., the course of this esker is shown on the map by a wide band of sand and gravel. In this band the details of the natural features and deposits have been partially obliterated by cultural developments. Another type of sand and gravel deposit, the kame, is associated with the esker in this area.

Kames are irregularly shaped hills or knolls of various sizes formed in or in front of the glacial ice where the meltwaters of the streams in the ice were allowed to spread out and deposit their load. Kames and kame-like deposits are common in the area. They are present also in the central part of the W½ sec. 20, and at the corner of secs. 3, 4, 9, and 10, and between these two locations. Kames are plentiful also in secs. 5 and 6, T. 46 N., R. 46 W., and along the west side of Black River in the SW¼ sec. 13, T. 47 N., R. 46 W. The kames show varying degrees of sorting, stratification, and cross bedding.

Morainal knolls of sand and gravel are generally large, irregularly rounded hills or mounds dumped in front of the glacial ice. They commonly contain clay in varying percentages. They might possibly come under the classification of kames. Examples of these are the large, comparatively high mounds in the NW¼NE¼ sec. 20, and north central part of sec. 24, T. 47 N., R. 46 W., and in the N½ sec. 20, T. 48 N., R. 46 W. Sorting and stratification of these deposits is generally poor except where the material was dumped into standing water.

These sand and gravel deposits generally are only surficial deposits except for the eskers, which extend to greater depths.

In many places a thin layer, not more than 4 feet thick, of clayey sand till containing some boulders covers these deposits.

HYDROLOGY

Water in and on the earth's crust is generally in one of the stages of the hydrologic cycle. Meteoric water, or precipitation on the earth, may pursue various courses in the cycle. Water that falls on the open and porous formations seeps beneath the surface, where it is only loosely held, and quickly flows out through the rocks and soils into the streams. In other places the water seeps into tighter formations, is held longer, and furnishes a steady source of flow for dry periods - the so-called base flow. Under favorable geologic conditions, some of the water seeps downward to the ground-water reservoirs where it is available to wells or is discharged by springs into surface streams.

Precipitation records are not kept at Bessemer but the record of the nearest station maintained by the U. S. Weather Bureau at Ironwood, Mich., is shown in tables 2 and 3.

Table 2.--Annual precipitation for the years 1940 to 1949,

Ironwood, Michigan

Year	Precipitation, in inches	Year	Precipitation, in inches
1940	36.37	1945	40.51
1941	43.10	1946	36.15
1942	51.88	1947	27.10
1943	38.57	1948	24.47
1944	41.98	1949	35.38

Table 3.--Monthly normal precipitation and mean temperatures,

Ironwood, Michigan

Month	Precipitation, in inches	Temperature, ° F.
January	1.93	12.7
February	1.86	14.3
March	2.47	25.7
April	2.49	39.9
May	3.13	52.5
June	4.09	62.1
July	4.12	67.3
August	3.44	64.7
September	3.59	57.1
October	2.75	45.5
November	2.78	30.5
December	1.98	17.4

Considerable variation of the annual precipitation is apparent from the above records, but in general this area receives an amount comparable to that in adjacent parts of the north central United States.

Water is added to the ground-water reservoirs when the accumulated precipitation is in excess of the amount needed to saturate the soil and provide for the needs of the vegetative cover. As the precipitation is fairly well distributed on a monthly basis throughout the year it is possible for this recharge to take place during most of the year. However, from November to April when the precipitation is in the form of snow and the ground is partly frozen the recharging process is hindered. In April and May, when the air temperatures rise sufficiently to thaw the snow cover, much of the meltwater runs off to the surface streams because of the slow thawing of the frozen ground and the general inability of the land surface to accept recharge at a high rate. In some places the bedrock outcrops constitute a considerable part of the area and in other places the drift cover is thin, so that a considerable part of the meltwater is rejected owing to lack of storage.

The Bessemer area has a well-developed drainage system so that the runoff is fairly rapid, especially in the bedrock, or hilly, areas. However, the headwaters of many of the creeks have low gradients, and drain swampy areas. The area is well covered with vegetation. About 40 percent of the land within 3 miles of Bessemer is cleared land, and about a third of this is devoted to crops. The outlying areas, especially to the north and south, are mainly forest and swamp lands. Transpiration by plants probably accounts for a large percentage of ground-water discharge during the growing season.

Surface streams receive a large part of their water from ground-water discharge of springs and seeps, and from "invisible inflow" where the water table, or surface of the ground water, meets the stream bed. The streams are effluent throughout the entire area except in times of high runoff and in unusual local conditions.

GROUND WATER

General conditions

Ground water is the water that occurs in the zone of saturation in the earth's crust. In places where the water-bearing formations are not overlain by impermeable materials the upper surface of the zone of saturation is called the water table. The water table usually is similar to the land surface configuration in that it rises under hills and sinks under valleys, but its slope is everywhere less than that of the land. The water levels in wells represent an expression of the water table. The banks of many streams, lakes, and ditches, seeps and springs are the points of discharge of ground water in its movement from points of recharge.

In places where saturated permeable formations are overlain by impermeable formations, the ground water is under hydrostatic (artesian) pressure. The water levels in wells tapping the permeable formations represent the pressure-indicating or piezometric surface, which does not necessarily conform to the land surface. Here also, the movement of ground water is from points of higher to points of lower pressure.

In the Bessemer area the greater part of ground water is under "modified artesian conditions" - that is, the aquifers are overlain in most places by confining beds of relatively low permeability.

In this area the beds of sand and gravel are the most permeable of the glacial formations and, therefore, they allow recharge, storage, and transmission of water to wells. The remainder of the unconsolidated deposits generally contain many fine materials which retard the movement of water through them. Quantitative measurements of the rate of flow through these formations are discussed in the section on hydrologic properties of water-bearing materials, in which the results of tests of samples of these materials are shown.

The bedrock in the Bessemer area is generally too impermeable to yield water to a well. The amount of water pumped from the iron mines in the district substantiates this observation; it is generally less than 500 gallons per minute even though subsidence has fractured the bedrock around many of the mines. The rate of pumping at the Ironton mine in sec. 17, T. 47 N., R. 46 W., ranged from 409 to 572 gallons per minute during the period 1934 to 1948.

Recharge

The original source of ground water is precipitation. Recharge is that water from all sources which is added by percolation to the main ground-water body. In the Bessemer area the precipitation is about 600 million gallons per square mile per year. However, the salvageable recharge is a very small percentage of this. In places the recharge may be large but the storage is temporary because much of the recharge is lost by plant use and by ground-water discharge to streams. The net increment retained in storage is small, and only this portion can be salvaged by wells. This net accretion may be as low as 5 percent of the normal precipitation.

An effort to determine the net accretion of ground water that could be salvaged by wells was made in 1947 in a basin of Powder Mill Creek by comparing the stream flow at two selected points. Measurements of the flow at the bridge a quarter of a mile east of the SW cor. sec. 20, T. 47 N., R. 46 W., and about a mile downstream in the NE¼ of the section indicate a gain from the ground-water inflow along this reach of about 35 gallons per minute on June 24 and 17 gallons per minute on July 22, 1947. Inasmuch as the downstream measuring point is south of the northern edge of the basin and is above the mouth of Sellwood Creek, the observed increase in discharge does not measure the total accretion of Powder Mill Creek from the northern part of the basin in secs. 16, 17, 20, and 21. Mine drainage water entering the creek in several unmeasurable places near the northern edge of the basin made it impractical to determine the total accretion for the basin. It is probable that the basin contributes more surface flow to the discharge of Powder Mill Creek than is shown by the above figures. In addition to the surface flow there is drainage from the basin by underflow. On June 24, the surface flow at the lower measuring point was 1.49 second-feet, or 670 gallons per minute, but on July 22, it was only 0.14 second-feet, or 62.8 gallons per minute. During periods of severe drought, Powder Mill Creek is dry.

No long-term hydrologic studies have been made in this area but a continuous record of water levels in well 47.46.20.3-2 from May 22 to July 15, 1949 was obtained by means of an automatic water-stage recorder. This well taps alluvial sand and gravel in the Powder Mill Creek valley. In this well the levels rise rapidly after a rainfall, with little or no time lag, indicating quick recharge to the aquifer. In several instances the levels declined to the same altitude as that prior to the rainfall in about 9 to 10 times the interval required for the peak level to be reached. Usually the peak was reached between 10 and 15 hours after the levels started to rise, although the time ranged from 3 to 30 hours in the records studied. The 24-hour rainfall totals ranged from a trace to 2.35 inches during the time the recorder was on the well. The quantitative effect of rainfall on the water level was determined by comparing the rise of the water level, in feet, with the rainfall, in inches. The ratio varied from no effect to a 0.75-foot rise per inch of rainfall. The mean was approximately a 0.3-foot rise in water level for each inch of rainfall.

Water-level fluctuations

The water levels in wells are continuously fluctuating owing to several causes, such as changes in barometric pressure, recharge, stage of the rivers and creeks, and discharge. The fluctuations cause minor changes in the configuration of the piezometric surface and the water table. The major features of these surfaces change noticeably only after some period of time. The ground-water levels rise when the recharge exceeds the discharge and decline when the discharge exceeds the recharge. Seasonal fluctuations indicate that the levels reach a peak usually some time in May and a low usually in either October or February in this region. Owing to differences in annual rainfall the peaks and lows vary in magnitude. In general the peaks are in the spring and early summer because of recharge from melting snow or heavy rainfall, and the lows are reached in the fall due to transpiration, evaporation, and other methods of ground-water discharge, and in February because of lack of recharge.

Although no regular measurements of water levels were made by the writer in wells in the Bessemer area through an entire year, this yearly cycle is reported by well owners. The cycle is evident in the water-level fluctuations as shown by the weekly measurements of levels in the well of the Oliver Iron Mining Co. In this well (47.46.20.6-8), the yearly fluctuation is about 9 feet. (See fig. 4.) The normal yearly fluctuation in most wells tapping sand and gravel lenses in the hardpan is about 3 feet, according to most reports. However, annual changes as great as 9 feet were reported in several wells during 1948. The water levels and fluctuations, if available, are shown in the well records in appendix A.

Utilization of ground water

Because ground water is obtained more economically and is of better quality, it is utilized more than surface water. Ground water is used principally for public, industrial, railroad, domestic, and stock supplies.

Springs

Ground water is obtained generally from springs and wells. Springs, some of which have been improved to the extent of piping of water to dwellings, barns, and other points of use, are the only source of water for many farms. They supply many residents on the flanks and periphery of the bedrock hills and hills having a thin cover of till overlying the bedrock, where wells are difficult to develop, and along the valley of Black River and some of its tributaries. Records of springs shown on figure 3 are listed in appendix A.

The spring with the largest observed flow, about 50 gallons per minute in the fall of 1948, is about a mile north of Black River on the banks of one of its tributary streams draining a swampy area. It is numbered 48.46.28.8. It consists of two openings about 50 feet apart. Seeps and other springs yielding as much as 5 gallons per minute each are common on both sides of this stream.

Another spring (48.46.34.3) with a large flow (20 gallons per minute in the fall of 1948) is on the south side of Black River valley. It is diverted into a storage tank for railroad use. Just across the valley is a spring (48.46.34.4) which flowed at the rate of 15 gallons per minute in the fall of 1948. Many seeps and springs are evident at the same altitude. They are the natural points of discharge of the shallow sand and gravel zones in the hardpan, which are tapped by wells.

Except for Cox's Springs (47.46.4.2-1 to 3), the remainder of the springs south of Black River yield little water. Most, however, continue to flow slightly, even in continued dry spells. Cox's Springs consists of three springs which have been improved to provide a supplemental source of water for the Bessemer water system. They have stone sheds with roofs and drain through pipes into one sump, from which the water is pumped into the city system. Only two springs are used now. The maximum rate of yield from these springs is about 20 gallons per minute. Normally their flow ceases in the fall or winter, but in 1948, owing to the continued deficiency in precipitation their flow stopped in the summer. They discharge from a surficial aquifer.

Wells

Most ground water is obtained by wells. The wells in this area are dug, drilled, and driven. The most common type is the dug well, which is usually lined with cement pipe, rocks, tile, or bricks, or is cribbed with timber, to prevent caving. The dug well is generally the most economical and satisfactory at shallow depths as it yields sufficient water at low cost. It is desirable also because many of the aquifers transmit water slowly. The large diameter affords a larger storage. Driven or drilled wells are constructed in those areas where it is not feasible to dig wells; only a few such wells are in the Bessemer area. Many of the farm wells are equipped with pitcher or cylinder pumps; a few have power-driven jet or cylinder pumps combined with a storage-tank system. These wells normally yield 10 gallons per minute or less. A few better-constructed wells are equipped with centrifugal or deep-well turbine pumps.

Wells in the Bessemer area that produce large quantities of water are described below.

The Underwood Veneer Co. well (47.46.9.6) is 45 feet deep and taps a sand and gravel aquifer at a depth of 35 to 45 feet. It is a drilled well with a 10-inch casing; the static water level was 7.5 feet below ground level in July 1948. No record is kept of the amount of water pumped, but a 10-horsepower turbine pump operates half the time during an 8-hour work day to supply the sawmill. The company has had no shortage of water from this well.

The Ironton, or Bessemer Township, well (47.46.20.2) is a dug well 36 inches in diameter, lined with tile. It is reported to have a depth of 31 feet but its depth when measured was 20 feet. It is an open-end well tapping a sand aquifer. It is equipped both with a centrifugal pump with a 35-horsepower motor for general use and a centrifugal pump with an 85-horsepower motor for emergency use. The amount of water pumped from this well averages 35,000 gallons per day. The water is stored in a reservoir with a capacity of about 47,000 gallons, and serves the Ironton mine and surrounding residences, although at one time it served many company houses. The static water level was about 9 feet below ground level during July 1949. It is reported that test holes 20 to 40 feet north and south of this location did not encounter aquifers as good as at this location. The well has never failed to furnish an adequate supply of water.

The Oliver Iron Mining Co. well (47.46.20.6-8) is a drilled gravel-packed well about 16 inches in diameter and 25 feet deep. It has an iron casing with a 10-foot slotted screen in the bottom. It taps a sand and gravel formation, and is equipped with a large cylinder pump which operates an average of about 6 hours a day at a rate of 70 gallons per minute, pumping about

25,000 gallons a day. It is reported to have been pumped at 105 gallons per minute for 7 days when it was completed in 1928. Since then, sand which came in through the screen has been cleaned out of the well three times. Otherwise, no trouble has been experienced in the operation of the well. However, the level dropped so low in October 1948 that only 2 feet of water was in the well when the pump was operating. The pumping level normally ranges from about 15 to 20 feet below ground level and the static level is generally 3 or 4 feet higher than the pumping level. (See fig. 4.) This well serves the Geneva mine and some residences in the Puritan location. The well was constructed at the site of one of a series of 15 test holes the company drilled in a search for a water supply. Records of the test holes indicate that the subsurface materials differed greatly in short distances, necessitating the location of the production well at the exact site of the most successful test hole.

The Chicago & Northwestern Railway Co. well (47.46.18.1-1) was drilled in 1947. It is 32 feet deep, has a 36-inch-diameter casing, and taps a 4-foot gravel aquifer. It is equipped with a centrifugal pump and is reported to yield 50,000 to 60,000 gallons of water per day, which is stored in a large tank for railroad use. The static level is reported to be 5 feet below ground level and the drawdown is 7.2 feet. Out of seven test holes in this area, only one tapped water-bearing materials. This condition is similar to that described above in the Oliver Iron Mining Co.'s search for a water supply.

Bessemer municipal water-supply system

The major part of the water supply for Bessemer was obtained from three wells which are described below. The remainder was furnished by Cox's Springs.

Well 47.46.9.1-1 is a stone-lined dug well 20 feet in depth and about 15 feet in diameter. It is at the site of a former spring and is known as the Finnegan well. It was Bessemer's first source of a municipal water supply, constructed in 1906. Water from the well flows by gravity to the concrete-lined sump in the municipal waterworks building at the city pond several hundred feet west of it.

Well 47.46.9.1-2 was dug to a depth of 16 feet in 1913 as an additional supply to the system. It taps a gravel aquifer underlain by hardpan and the water is pumped to the city sump.

Well 47.46.9.1-3 was dug about 1920, 7 years after the supply of Cox's Springs was developed and added to the system. It is about 10 feet in diameter and 12 feet deep, and taps a gravel aquifer. The site was known as Massies Spring, and water from the well now flows by gravity to the city sump.

The natural recharge to this field was insufficient to meet the demand; therefore artificial recharge was induced by constructing a dam near the waterworks building to impound surface waters which were supplemented by diversion from Powder Mill Creek in the NW¼ sec. 16, T. 47 N., R. 46 W. Recharge to the field is regulated by a valve on a pipe line through which water flows to the aquifer by gravity from the city pond.

The only treatment the water receives is injection chlorination, but sediment in the diverted water settles and is filtered during ponding and transfer to the gravel aquifer of the well system.

The average rate of pumping during the last 2 years, including the maximum supplement of 30,000 gallons per day from Cox's Springs, was approximately 215 gallons per minute. A tabulation of the quantity of water pumped annually at the Bessemer municipal water plant for the last 10 years is listed in table 4 below.

Table 4.--Annual pumpage for Bessemer municipal supply

Year	Gallons	Year	Gallons
1940	68,300,000	1945	73,250,000
1941	59,905,000	1946	98,395,000
1942	62,135,000	1947	98,365,000
1943	67,220,000	1948	115,055,000
1944	65,220,000	1949	112,945,000

These figures show a fluctuating but general upward trend in pumpage.

During the last several years the Ironton iron mine, in sec. 17, T. 47 N., R. 46 W., was deepened considerably. When the more highly mineralized waters encountered at depth in the mine were discharged into Powder Mill Creek, the discoloration and mineral matter became objectionable for diversion into the Bessemer water system. The analyses of the Bessemer water showed increases in hardness from 155 parts per million in May 1947 to 551 parts per million in October 1948. Analyses of Powder Mill Creek water above the mine water discharge point, the mine water discharge, and Bessemer's diversion water at U. S. Highway 2 showed 85, 1,474, and 1,395 parts per million of hardness, respectively, in October 1948.

On October 30, 1948, the mine water was diverted and discharged into Powder Mill Creek several hundred feet downstream from Bessemer's diversion intake by means of a combined tile and open ditch drainage system installed by Pickands, Mather & Co. Subsequently there was a gradual decrease in the hardness of Bessemer tap water, the hardness being 276 parts per million on November 29, 1948, 188 parts per million on December 13, 1948, 157 parts per million on January 31, 1949, 111 parts per million on March 8, 1949, and 104 parts per million on April 19, 1949. The natural discoloration of Powder Mill Creek water in its upper reaches by organic material in the swamps is carried into the Bessemer water by the diversion of this creek. This condition is slightly objectionable.

In order to obtain a supplemental supply of water of good quality or a substitute supply, the City of Bessemer began an exploration program in the spring of 1949. Four test holes were drilled in a favorable area in Powder Mill Creek valley southwest of Bessemer. As a result of the exploration drilling a ground-water supply was located in this area. In October 1949 two production wells were drilled and added to the municipal system.

HYDROLOGIC PROPERTIES OF WATER-BEARING MATERIALS

By W. T. Stuart

Laboratory determinations

Laboratory tests to determine the capacity of the glacial materials to transmit water under pressure were made on the samples from the test holes drilled during the exploration program of the City of Bessemer. These tests were made with a variable-head discharging type of permeameter. The results of these determinations were expressed in a unit, known as the coefficient of permeability, which is defined by Meinzer (5, 1923) as the rate of flow of water, in gallons a day, through a cross-sectional area of 1 square foot under a unit hydraulic gradient at a temperature of 60° F. The highly permeable materials have a high numerical coefficient, and the less permeable materials a low one.

In test well 1, (47.46.20.1-1) the coefficients of permeability of the sand and gravel to a depth of 35 feet ranged from about 350 to 3,700; of the hardpan to a depth of 59 feet, from 28 to 378; of the sand and gravel to a depth of 64.5 feet, from 100 to 248; and of the lower hardpan to a depth of 70.5 feet, from 133 to 594.

In test wells 2 and 2A, (47.46.20.1-2A) the coefficients of permeability of the sand and gravel to a depth of 32 feet ranged from 190 to 5,395; of the hardpan to a depth of 65 feet, from 25 to 685; and of the basal gravel to a depth of 68 feet, from 1,870 to 2,420.

The coefficient of permeability as determined in the laboratory may be converted mathematically to a comparable field coefficient, which can be determined by pumping-test methods, by multiplying the average weighted coefficient of permeability by the thickness of the water-bearing materials and applying a temperature adjustment from the standard laboratory water temperature of 60° F. to the prevailing ground-water temperature, which in this case is 45° F.

The field coefficient, or coefficient of transmissibility, as determined by pumping-test methods is defined as the number of gallons of water that will move in 1 day through a vertical strip of the water-bearing materials 1-foot wide under a unit hydraulic gradient.

In test well 1, the coefficient of transmissibility for 31 feet of the upper sand and gravel was determined to be about 20,100 gallons per day per foot. In test wells 2 and 2A it is 43,900 gallons per day per foot for 20 feet of upper sand and gravel, and about 5,920 gallons per day per foot for the basal gravel from 65.5 to 68.5 feet.

Field determinations

Exploratory drilling

After the completion of the first four test wells, another test well with a 6-inch casing (test well 2A) was drilled at the site of test well 2 in order that a pumping test could be made, to determine the quality of water and the hydraulic properties of the aquifers. When completed, the well was pumped at the rate of 30 gallons per minute for 1 hour from the deep gravel bed after the 6-inch casing was raised about 1.5 feet above the bedrock. Later the casing was raised to the bottom of the shallow water-bearing materials and an 18-foot section of slotted 5-inch pipe was inserted through the 6-inch casing to serve as a well screen. The slotted pipe was exposed and the well was developed by surging, pumping, and bailing. Eleven sand-point observation wells were driven on lines in the form of a cross at distances of 10, 25, and 50 feet from test well 2A. Another was driven 150 feet from test well 2A on the west line. (See fig. 5.) None of these sand-point wells are included in the well tables in appendix A, since they were only temporary observation wells for this pumping test. The observation well on the east line 10 feet from test well 2A was a drilled well with a 6-inch casing, and it was equipped with an automatic water-stage recorder.

Measurements were made of the rate and extent of growth of the cone of depression in the water level developed around the pumped well for the 1-day period during which the pumping rate averaged 77 gallons per minute.

Similar measurements of the recovery of the water levels and the collapse of the cone were made for 1 day after the pumping ceased. Typical graphs of the drawdown and recovery in the various observation wells and profiles of the cone after specific periods of pumping are shown in figures 6, 7, and 8. Profiles of water levels in observation wells around a pumped well in an isotropic or homogeneous aquifer differ from those shown in figures 6 and 7 in that the profile of the cone of the former is symmetrical and has steep slopes next to the pumped well, which taper off or ascend more gradually with increasing distance from the pumped well. In other words, the idealized profile is a simple deep V-notched form instead of a small V-notched form surrounded by a broader U-shaped cone as shown in figures 6 and 7. The irregular profiles of the cones are exaggerated by the 25-to-1 scale ratio of the figures and are caused by the arrangement or position of the materials of different permeabilities in which this well is located. Some of the irregularities in the shape of the profiles on figures 6 and 7 may be due to the lenses of materials of varying permeabilities causing more or less perched water levels. The levels in wells N-10 and E-50 show these obvious irregularities. The hydraulic effect of the change in materials from the pumped well outward in the line of wells across the esker is apparent, in figure 7, between wells S-25 and S-50 and wells N-25 and N-50. The longitudinal profiles on figure 6 indicate a rather uniformly permeable formation along this line, although a less permeable material is indicated to the west by the profiles between wells W-50 and W-150. The eastern segment of the profiles is apparently influenced by lenses of different materials or perched water levels but generally it simulates the western segment and indicates less permeable materials. Had test well 2A been about 20 feet farther west, it would have penetrated a more permeable part of the esker and many of the irregularities of the profiles would have been eliminated.

The hydrographs of three wells are shown in figure 8. The boundary effect of the sides of the esker are not evident on curves of drawdown or recovery because they occurred too soon after the start and cessation of pumping.

Analysis of the field test data indicates that the average coefficient of transmissibility of the water-bearing materials in the immediate area of the well is about 16,000 gallons per day per foot. It was expected that all the field coefficients determined directly through application of pumping-test methods would be lower than the corresponding coefficients derived from laboratory methods inasmuch as the laboratory determinations required utilization of samples obtained during the drilling process, in which the materials were greatly disturbed and many of the fine particles were lost.

The coefficient of storage, which is the volume of water released from storage in a vertical prism of the aquifer of a unit cross section when the head is lowered one unit, was determined to be 0.009 for the period of the test. This figure indicates that the water in the formations is under modified artesian pressure as the figure is of the magnitude of coefficients of storage of artesian aquifers.

The specific capacity of a well is an expression of the yield in relation to the drawdown of the water level. The specific capacity of test well 2A was a little over 13 gallons per minute per foot of drawdown after 22.75 hours of pumping during this test.

Production wells

On the basis of the exploration work and the pumping tests of well 2A, the Bessemer Water Department Superintendent, James Boggio, and the Board of Public Works decided to construct two production wells at the sites of test wells 1 and 2A, without test drilling other favorable areas. The Dunbar Drilling Co. of Delta, Ohio, drilled the wells in the early part of October 1949.

Production well 1 is about 12 feet west of test well 2A. It has a 10-inch casing to a depth of 25 feet, a 10-inch screen to a depth of 35 feet, an 8-inch casing to 67 feet, and an 8-inch screen to 70 feet. The screens are red brass and have a slot 0.10-inch wide.

The materials encountered were similar to those in test wells 2 and 2A, but the formations extended to slightly greater depths. A pumping test was made on this well by pumping it 4 hours at a rate of 320 gallons per minute. The drawdown was 15.0 feet; therefore, the specific capacity was 21.3 gallons per minute per foot of drawdown for this period. The coefficient of transmissibility of the upper and lower water-bearing formations was determined to be 21,600 gallons per day per foot on the basis of the drawdown and recovery curves of the water levels in this well.

Production well 2 was drilled about 12 feet northeast of test well 1. It has a 10-inch casing to 25 feet and a 10-inch red brass screen with a 0.10-inch slot opening to 35 feet. This well was pumped 4 hours at a rate of 350 gallons per minute, with a 7.3-foot drawdown, giving it a specific capacity of 48 gallons per minute per foot for this period of pumping, 2.27

times that of the first production well. The coefficient of transmissibility of the water-bearing formation was calculated to be 42,400 gallons per day per foot on the basis of curves showing the water-level drawdown and recovery in this well.

The coefficient of transmissibility determined by the laboratory method and the pumping-test method in well 2A are not on a comparable basis with the tests on production well 1 as the production well was drilled in an area of greater permeability in the esker. A comparison of the values of the coefficient of transmissibility by the laboratory and field methods for well 2A was expected to show a large difference as the samples used in the laboratory were both washed and disturbed.

QUALITY OF WATER

The quality of ground water in the Bessemer area is satisfactory for most uses. The waters are generally low in mineral content, though several owners have reported hard water from their wells. A complete chemical analysis of water from Bessemer's new production well 2 is shown in table 5. Analyses of water from the old wells of the City of Bessemer in the northern part of town and private wells southwest of town, including exploration test wells 1 and 2 and the two new production wells, are listed below in table 6. These indicate a water of low to moderate hardness. The hardness tends to increase slightly with depth. During pumping tests on test well 2A, several samples of water were taken and their analyses indicate that the quality remained essentially the same during pumping.

The temperature of the ground water as determined by measurements of spring and well water during the summer and fall of 1948 ranges from 45° to 53° F. Most of the measurements were less than 50° F. One spring (47.46.16.1) yielded water at 48° F. in August 1948 and water at 45° F. in January 1949. The measured temperatures are shown in the well records, appendix A.

Table 5.--Complete chemical analysis of water from Bessemer's new production well 2*

(Parts per million)

Calcium (Ca)	25
Magnesium (Mg)	6.8
Sodium and potassium (Na and K)	2.0
Total metallic ions	33.8
Bicarbonate (HCO_3)	98
Carbonate (CO_3)	None
Sulfate (SO_4)	10
Nitrate (NO_3)	None
Chloride (Cl)	3
Fluoride (F)	None
Total non-metallic ions	111
Silica (SiO_2)	4
Iron (as Fe)	None
Total solids	120
Total hardness (as $CaCO_3$)	90

*Sample collected October 19, 1950, and analyzed by the Michigan Department of Health.

Table 6.--Partial chemical analyses of ground water in the Bessemer area

(Parts per million)

Well no.	Owner	Well depth (feet)	Date of collection	Bicarbonate[a] (HCO_3)	Chloride (Cl)	Hardness (as $CaCO_3$)
47.46.9.1-1 to 3[b]	City of Bessemer	12 to 20	4/19/49	118	67	104
47.46.20.1-1	do.	23.8	5/26/49	104	14	58
47.46.20.1-1	do.	64.5	6/2/49	104	24	63
Production 2	do.	70[c]	10/12/49	(d)	3	90
Production 2	do.	70[c]	do.	77	38	65
47.46.20.1-2A	do.	67.0	7/13/49	99	22	72
47.46.20.1-2A	do.	32[e]	7/18/49	87	15	55
Production 1	do.	35[f]	10/17/49	(d)	4	105
47.46.20.2	Bessemer Township	20	1/13/49	80	14	92
47.46.20.3-1	Ivah Wirpio	15	do.	120	14	104
47.46.20.6-8	Oliver Iron Mining Co.	25	do.	72	14	72
47.46.21.12	Emil Erickson	20.5	do.	133	27	132
47.46.28.1	Anton Marander	24	do.	135	20	140
47.46.29.2	Victor Niemi	30	do.	185	14	156
47.46.29.3	Matt Hill	16	do.	142	19	130
47.46.29.7	Reino Niemi	15	do.	145	14	121
47.46.30.3	Charles Sipola	45	do.	142	14	120

a No carbonate (CO_3) present.
b Composite sample, taken from city water system.
c Tapping two aquifers, with screens from 25 to 35 feet and from 67 to 70 feet.
d Analyzed by the Michigan Department of Health; no iron present.
Remainder of samples were analyzed by Pickands, Mather & Co. at the Anvil mine laboratory.
e With screen from 16 to 32 feet.
f With screen from 25 to 35 feet.

AREAS FOR DEVELOPMENT

An area favorable for the development of a ground-water supply must have adequate recharge and must be underlain by materials sufficiently permeable and thick to transmit adequate water to wells and to store sufficient water to maintain the yield of the wells between periods of recharge. The materials in this area most suitable for yielding a large quantity of water are large, continuous, saturated deposits of sand and gravel. These are not too common in the immediate vicinity of Bessemer. Bedrock crops out and is near the surface over a large part of the area, and the dominant glacial cover is relatively impermeable sandy and stony boulder clay.

Water supplies adequate for domestic and farm use are generally prevalent throughout the region, some sections having more favorable conditions for their development than others. These supplies are obtained easily by wells in the sand and gravel and in the sandy-till areas where the water table is close to the surface, but in the hardpan areas they are more difficult to obtain, except in those places where sandy and gravelly layers or pockets are common. However, the development of a public or industrial supply for which the demand is in excess of about 10 gallons per minute limits the areas in which adequate quantities of water can be found.

This investigation has located areas where the hydrologic conditions appear to be suitable for the development of larger supplies of ground water. They are (1) south of Bessemer, in secs. 20, 21, 28, 29, and 32, T. 47 N., R. 46 W., and sec. 5, T. 46 N., R. 46 W., (2) along Black River, Jackson's Creek, and Spring Creek in some sand and gravel terraces, (3) south of Wakefield, along Little Black River, (4) northeast of Wakefield in the vicinity of the Duluth, South Shore & Atlantic Railway, (5) north of Bessemer in parts of secs. 3 and 4, T. 47 N., R. 46 W., (6) north of Spring Creek and west of Black River, and (7) north and east of Black River, about 3 to 4 miles north of Bessemer. These areas should be proved or disproved by test drilling before any large development is undertaken.

In this discussion small supplies are amounts up to about 50 gallons per minute; moderate supplies, approximately 50 to 200 gallons per minute; and large supplies, more than 200 gallons per minute.

(1) Area south of Bessemer.-The northern part of this area, in secs. 20, 21, 28, and 29, is part of a large drainage basin from which Powder Mill Creek flows northward through a drift-filled bedrock gap. The drainage area of Powder Mill Creek up to the base of the Ironwood iron-formation is about 11.5 square miles. The data collected in the well inventory for this basin indicate a uniform succession of glacial deposits over a broad area, with gravel of unknown thickness at the bottom of most of the shallow wells. The test holes drilled by the City of Bessemer show that most of the subsurface drift is hardpan with sand and gravel zones several feet thick. Test hole 3, although it encountered bedrock at a shallow depth, penetrated materials similar to those penetrated by the farm wells in this area. It encountered 4.5 feet of clayey sand and gravel, which is underlain by hardpan on bedrock, indicating that the area is suitable for the development of only small supplies. However, further test drilling throughout the entire area may possibly prove otherwise. Surface indications of gravel are found in the rather persistent, but discontinuous, sand and

gravel ridge (esker) that trends northward and passes through the bedrock gap. Kames and morainal knolls and ridges in this area also contain coarse materials. Logs of wells in these deposits show that these materials extend below the surface and indicate that moderate to large yield wells can be developed in them.

Natural recharge to the water-bearing sand and gravel is of a small magnitude. However, the proximity of the sand and gravel ridge to Powder Mill Creek provides a situation whereby water may be induced to flow from the creek into the gravel when the ground-water levels are lowered below the creek level. Bessemer's two new production wells are in the esker in the NE¼ sec. 20. The distance from Powder Mill Creek to Bessemer's new production well 1 (at the site of test well 2A) is about 250 feet, and to Bessemer's new production well 2 (at the site of test well 1), about 200 feet.

Assuming the drainage area of Powder Mill Creek above the production well sites to be 10 square miles and the average annual rainfall as 34 inches, the amount of rainfall falling on this area per year is computed to be about 6 billion gallons. The part of this water that enters the ground-water reservoir is small. Only a portion of this part can be salvaged by a well system in this location, as the shallow aquifers do not allow the cone of influence of a well system to spread outward sufficiently to intercept a large quantity of water. If the City of Bessemer withdraws 250 gallons per minute, or about 132 million gallons a year, and the Oliver and Ironton wells continue to withdraw 22 million gallons a year from this area the total withdrawals will amount to about 3 percent of the total rainfall. This will be satisfactory if the precipitation is evenly distributed during the year. However, if deficiencies in precipitation result in lowered ground-water levels and consequently low base flow in Powder Mill Creek, the yield of the well fields will necessarily decrease at a fast rate because of the small storage facilities in this ground-water reservoir. Further well development should be sufficiently far south of the base of the Ironwood iron-formation to prevent the possible dewatering of the glacial deposits by future subsidence caused by mining. As the bedrock about 400 feet south of the base of the Ironwood iron-formation is granite, a competent formation, subsidence probably will not take place more than about 500 to 800 feet south of the base of the Ironwood iron-formation.

In secs. 32 and 5 there are many areas of sand and gravel deposits. These are similar to those in sec. 20 to the north, and it is likely that they too would support moderate to large water supplies. The areas of sandy till in this vicinity might also contain gravel layers capable of supplying small to moderate amounts of water.

(2) Area along Black River, Jackson's Creek, and Spring Creek.- Low-level sand and gravel terraces along these streams in the old outlet channel of glacial Lake Ontonagon are likely areas for water-supply developments. (See fig. 3.) The terraces most favorable for the development of ground water are in sec. 35, T. 48 N., R. 47 W., secs. 20 and 29, T. 48 N., R. 46 W., and secs. 22, 31, and 32, T. 48 N., R. 45 W. These appear to be capable of large-supply development providing they have sufficient thickness below the water table and a connection with the nearby streams whereby recharge could be induced.

(3) Area south of Wakefield.-Along Little Black River in this vicinity there are some sand and gravel deposits. They appear to be capable of yielding moderate supplies providing they extend to a considerable depth below the ground-water table. The sandy-till area along this stream also warrants test drilling for supplies.

(4) Area northeast of Wakefield.-This area of several square miles overlain by sandy till appears promising for a water-supply development. The glacial drift is apparently thick as no bedrock crops out in the area and well 48.45.34.1 penetrated bedrock at a depth of 125 feet. It is probable that buried gravel layers capable of furnishing at least moderate supplies of water can be found here.

(5) Area north of Bessemer.-This area just north of Bessemer, in secs. 3 and 4, is small and it is doubtful if anything but a small water supply could be obtained. The small size of the area where recharge can take place, the absence of suitable aquifers according to the meager subsurface data available, and the location of Bessemer's sewage disposal plant within the area detract from its desirability as a well field. However, a supply for a small industry or housing development could probably be located here.

(6) Area north of Spring Creek and west of Black River.-This area contains no bedrock outcrops and has a thick cover of unconsolidated deposits. Bedrock was reported at a depth of 90 feet in one well and 240 feet in another. Well logs indicate gravel zones, at least 2 to 5 feet thick, separated by about 25 feet of hardpan. The possibility of developing small or moderate supplies from these and perhaps other deep aquifers seems fairly good. However, no attempts to develop anything other than farm and domestic supplies have been made here.

(7) Area 3 to 4 miles north of Bessemer.-Although both surface and subsurface indications of aquifers are common in this area, no developments have been made to substantiate the evidence that a large supply of water could be obtained from these aquifers. Most of the aquifers tapped by farm wells are not very thick, but no wells were reported to reach bedrock, and therefore more deeply buried highly productive aquifers may be here. The deepest well, 196 feet, did not reach bedrock. The information on wells and springs implies that the shallow aquifers are more productive than the deeper ones.

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APPENDIX A

RECORDS OF WELLS, TEST BORINGS, AND SPRINGS IN BESSEMER AREA, GOGEBIC COUNTY, MICHIGAN

Explanation of symbols used in records

Well number

The well number is composed of four main units separated by periods. The first three units have a geographic significance, indicating the location of the well within 1 square mile (a conventional section).

The first unit is the number of tier of townships north of the Michigan base line; the second unit is the number of range of townships west of the Michigan meridian. These two numbers designate the township within which the well is located. The third unit is the number of the section within the township. The fourth unit is composed either of one number or of two separated by a dash. The single number is that assigned to the well; the first of the two numbers is that assigned to the owner of the well, and the number following the dash is that of the well. The latter "dual numbers" are used where an owner has more than one well in a section.

Example: 46.46.3.1-1.--This is the number of a well in sec. 3, T. 46 N., R. 46 W., one of two or more wells (for which records are presented) in this section owned by one person.

Note: The test holes belonging to the City of Bessemer are included in this system but are commonly referred to only by their last number when discussed frequently in the text. The two new production wells drilled by Bessemer in October 1949 are not listed, but they are discussed in the text and their logs are similar to those of the test holes near which they were drilled. Production well 1 is about 12 feet northwest of test hole 2A and production well 2 is about 12 feet northeast of test hole 1.

Location

The location of the well within the section designated in the well number is listed as close as practicable with standard division units of the General Land Office system of the subdivision of sections into quarters or other fractional pieces of land. The location of all the wells in the tables is shown on fig. 3.

Depth

Depths enclosed in parentheses indicate former greater depth to which well was drilled.

Water level

All water levels are in feet below land surface except where preceded by a "+", which indicates the water level is in feet above the land surface.

A "+" without a figure indicates a flowing spring.

Figures shown in tenths or hundredths of feet indicate measured water levels; others are reported.

Two figures showing a range of water level, as "11 to 14", indicate a reported yearly range.

A figure followed by "est." is an estimated water level.

Use

D, domestic; S, stock; PS, public supply; RR, railroad; I, industrial.

Parentheses enclosing a use symbol indicates only occasional use.

Remarks

The temperature of the water was determined in the summer or fall of 1948.

"See log" refers to log of well in appendix B.

"See analysis" refers to analysis of water sample from well, in table 6.

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
46.46.3.1-1	SW¼SE¼SW¼	Andrew Keranen	20	48	Gravel	--
46.46.3.1-2	SW¼SE¼SW¼	do.	10	36	Muck and peat	--
46.46.5.1	SE¼SE¼NW¼	Unknown	--	24	Sand and gravel	--
47.45.7.1	E½SW¼SE¼	State Highway Dept.	34	--	--	--
47.45.7.2	SE¼SE¼	Pickands, Mather & Co.	--	--	--	80
47.45.8.1	SW¼SE¼SW¼	State Highway Dept.	38	--	--	--
47.45.8.2	SW¼SW¼SW¼	Pickands, Mather & Co.	--	--	--	100
47.45.8.3	E½NE¼SE¼	M. A. Hanna Co.	--	--	--	58
47.45.9.1	NW¼NW¼SW¼	do.	--	--	--	43
47.45.17.1	NE¼NE¼NE¼	State Highway Dept.	43.5	2	--	--
47.45.17.2-1	NE¼NE¼NE¼	Pickands, Mather & Co.	--	--	--	45
47.45.17.2-2	N½SW¼	do.	--	--	--	55
47.45.18.1-1	N½SE¼	do.	--	--	--	55
47.45.18.1-2	SW¼NW¼	do.	--	--	--	40
47.45.19.1	NW¼NE¼SW¼	Andrew Petkie	11	48	Sand	--
47.46.3.1	SW¼NW¼NW¼	Ted Johnson	14	40	--	--
47.46.4.1	NE¼SE¼NW¼	A. Pollari	32	36	Gravel	--

Water Level Feet from land surface	Water Level Date	Use	Remarks	Well no.
11 to 14	1948	D,S	Section consists of 19 feet of gravel overlain by 1 foot of topsoil.	46.46.3.1-1
5 to 8	1948	S	Section is all muck and peat.	46.46.3.1-2
.5	10/29/48	(PS)	Spring. Slight discharge on Oct. 29, 1948.	46.46.5.1
--	--	--	Bridge foundation boring. See log.	47.45.7.1
--	--	--	Mining company drill hole.	47.45.7.2
--	--	--	Bridge foundation boring. See log.	47.45.8.1
--	--	--	Mining company drill hole.	47.45.8.2
--	--	--	Mining company drill hole. Section is black muck, sand, gravel, and boulders.	47.45.8.3
--	--	--	do.	47.45.9.1
+2	--	--	Bridge foundation boring. See log.	47.45.17.1
--	--	--	Mining company drill hole.	47.45.17.2-1
--	--	--	Mining company overburden record. Overburden ranges from 30 to 100 feet in area.	47.45.17.2-2
--	--	--	do.	47.45.18.1-1
--	--	--	Mining company drill hole.	47.45.18.1-2
7.5 to 10.5	1948	D,S	See log.	47.45.19.1
13.3	8/20/48	D	--	47.46.3.1
28.5	8/20/48	D,S	See log.	47.46.4.1

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
47.46.4.2-1 to -3	NE¼NW¼SE¼	City of Bessemer	--	100	Sand	--
47.46.4.3	SW¼SW¼SE¼	Geo. Beaudette	26	40	Bedrock	14
47.46.4.4	E½SW¼SE¼	Joseph Meyers	17	24	Sand and gravel	--
47.46.4.5	S½SE¼NE¼	Joseph Tower	8	60	Sand	--
47.46.6.1	SW¼SW¼NW¼	Louis Mollar	14	30	Sand and gravel	14
47.46.8.1	SW¼SW¼SW¼	Mrs. Gayan	10	48	Sand	--
47.46.8.2	SW¼SW¼	Mr. Gayan	20	48	Bedrock	20
47.46.8.3	SW¼SW¼SE¼	A. Kiomento	100	4½	Black slate	25
47.46.8.4	SW¼SE¼	Frank Gheller	42	5	do.	18
47.46.8.5	SE¼SE¼SE¼	Joe Marshallek	42	4	do.	35
47.46.8.6	SE¼NW¼SE¼	State Highway Dept.	7	--	--	5
47.46.9.1-1	SE¼SE¼NE¼	City of Bessemer	20	180	Bedrock	--
47.46.9.1-2	N½NE¼SE¼	do.	16	144	Gravel	--
47.46.9.1-3	NE¼SE¼	do.	12	120	--	--
47.46.9.2	NW¼SW¼SW¼	Mrs. Marshallek	32	36	Sand	--

Water Level: Feet from land surface	Water Level: Date	Use	Remarks	Well no.
+ to 2+	1948	PS	Cox's Springs. Used occasionally. Maximum yield in 1948 was about 20 gallons per minute (g.p.m.); no flow in dry periods.	47.46.4.2-1 to -3
--	--	--	Abandoned. Bedrock is overlain by 14 feet of hardpan and sand.	47.46.4.3
13	Aug. 1948	--	Abandoned. See log.	47.46.4.4
1.4	9/10/48	D,S	Well has failed at times. Red hardpan is overlain by 8 feet of sand.	47.46.4.5
7.8	7/19/48	D,S	--	47.46.6.1
6.7	8/4/48	D	--	47.46.8.1
--	--	D	--	47.46.8.2
5	1938	D,S	Drilled by H. O. Rice. Not a "strong" well. See log.	47.46.8.3
5	1938	D	Drilled by H. O. Rice. Yield 20 g.p.m. in 1938.	47.46.8.4
7 to 21	1940-48	D,S	Drilled by H. O. Rice. Not a "strong" well. See log.	47.46.8.5
--	--	--	Bridge foundation boring. See log.	47.46.8.6
--	--	PS	Recharged by impounded water diverted from Powder Mill Creek. Yield of 3 wells about 225 g.p.m. in 1947-48. "Finnegan well." See analysis.	47.46.9.1-1
--	--	PS	Recharged by impounded water diverted from Powder Mill Creek. Yield of 3 wells about 225 g.p.m. in 1947-48. See analysis.	47.46.9.1-2
--	--	PS	Recharged by impounded water diverted from Powder Mill Creek. Yield of 3 wells about 225 g.p.m. in 1947-48. "Massie's Spring." See analysis.	47.46.9.1-3
--	--	D,S	--	47.46.9.2

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
47.46.9.3	SW¼NE¼SW¼	Michael Gall	--	--	Sand	--
47.46.9.4	NW¼SE¼SW¼	Mr. Lompart	10	24	do.	--
47.46.9.5	SE¼SW¼	Frank Lompart	23	5	Black slate	18
47.46.9.6	N½SW¼SE¼	Underwood Veneer Co.	45	10	Gravel	--
47.46.9.7-1	NW¼NE¼NE¼	Louis Nelson	14	36	None	14
47.46.9.7-2	NW¼NE¼NE¼	do.	40	48	do.	--
47.46.9.7-3	NW¼NE¼NE¼	do.	22	5	do.	22
47.46.9.7-4	NW¼NE¼NE¼	do.	22	5	do.	22
47.46.9.7-5	NW¼NE¼NE¼	do.	24	5	do.	24
47.46.10.1	SE¼NW¼SW¼	E. J. Nystrom	30	6	do.	30
47.46.11.1	N½SW¼SW¼	State Highway Dept.	--	--	Sand and gravel	--
47.46.12.1	SE¼SW¼NW¼	Mr. Bravado, Sr.	42	48	Sand	42
47.46.12.2	NW¼NE¼SW¼	Mr. Bravado, Jr.	46	48	Gravel	--
47.46.12.3	W½NW¼SE¼	John Erickson	42	5	do.	--
47.46.12.4	W½NW¼SE¼	State Highway Dept.	12.5	--	--	12.5(?)
47.46.13.1-1	N½NW¼SE¼	Pickands, Mather & Co.	--	--	--	40
47.46.13.1-2	N½NE¼SE¼	do.	--	--	--	25
47.46.15.1-1	W½SW¼NE¼	Oliver Iron Mining Co.	--	--	--	10
47.46.15.1-2	SW¼NE¼NW¼	do.	--	--	--	9
47.46.15.1-3	NW¼SW¼NE¼	do.	--	--	--	25

Water Level		Use	Remarks	Well no.
Feet from land surface	Date			
+	1948	D	Spring. Discharge 2 g.p.m. in 1948.	47.46.9.3
8.2	8/17/48	D	--	47.46.9.4
--	--	D	Drilled by H. O. Rice. See log.	47.46.9.5
7.5	7/27/48	I	Section is 10 feet of gravel, overlain by sand.	47.46.9.6
Dry	--	--	Test boring.	47.46.9.7-1
do.	--	--	Test boring. Dry gravel at 38 feet.	47.46.9.7-2
do.	--	--	Test boring. Drilled by H. O. Rice. Section is mostly hardpan and boulders.	47.46.9.7-3
do.	--	--	do.	47.46.9.7-4
do.	--	--	do.	47.46.9.7-5
do.	--	--	Test boring. Drilled by H. J. Nystrom.	47.46.10.1
--	--	--	Spring. Discharge 0.75 g.p.m. on Aug. 10, 1948. Temperature 53° F.	47.46.11.1
38	1948	D,S	Well goes dry in dry weather.	47.46.12.1
40 dry	1945 1948	D,S	See log.	47.46.12.2
18.4	10/29/48	D,S	Drilled by H. O. Rice. Abandoned.	47.46.12.3
--	--	--	Bridge foundation boring. See log.	47.46.12.4
--	--	--	Mining company drill hole.	47.46.13.1-1
--	--	--	do.	47.46.13.1-2
--	--	--	do.	47.46.15.1-1
--	--	--	do.	47.46.15.1-2
--	--	--	do.	47.46.15.1-3

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
47.46.15.1-4	SW¼NE¼NE¼	Oliver Iron Mining Co.	--	--	--	20
47.46.15.1-5	E½NE¼NE¼	do.	--	--	--	35
47.46.15.1-6	NW¼SW¼NW¼	do.	--	--	--	5
47.46.15.1-7	SE¼NW¼NW¼	do.	--	--	--	4
47.46.15.1-8	E½NW¼NE¼	do.	--	--	--	18
47.46.15.1-9	NE¼NE¼NE¼	do.	--	--	--	38
47.46.15.1-10	SW¼NW¼NE¼	do.	--	--	--	47
47.46.15.1-11	NE¼NE¼NW¼	do.	--	--	--	35
47.46.15.1-12	S½NE¼NW¼	do.	--	--	--	20
47.46.16.1	NW¼NE¼NE¼	Unknown	--	--	Bedrock	--
47.46.17.1	SE¼SE¼	do.	8	6	--	--
47.46.17.2-1	SW¼NE¼SE¼	Pickands, Mather & Co.	--	--	--	65
47.46.17.2-2	SW¼	do.	--	--	--	50
47.46.17.2-3	W½SE¼SW¼	do.	--	--	--	30
47.46.18.1-1	W½NE¼NE¼	Chicago & Northwestern Ry. Co.	32	36	Gravel	32
47.46.18.1-2	W½NE¼NE¼	do.	32	6	do.	32
47.46.18.1-3	W½NE¼NE¼	do.	39	6	None	32
47.46.18.1-4	W½NE¼NE¼	do.	27	1¼	do.	27
47.46.18.1-5	W½NE¼NE¼	do.	18	1¼	None	18

Water Level				
Feet from land surface	Date	Use	Remarks	Well no.
--	--	--	Mining company drill hole.	47.46.15.1-4
--	--	--	do.	47.46.15.1-5
--	--	--	do.	47.46.15.1-6
--	--	--	do.	47.46.15.1-7
--	--	--	do.	47.46.15.1-8
--	--	--	do.	47.46.15.1-9
--	--	--	do.	47.46.15.1-10
--	--	--	do.	47.46.15.1-11
--	--	--	do.	47.46.15.1-12
+	--	(D)	Spring. Discharge 2.15 g.p.m. on Aug. 17, 1948. Temperature 48° F.	47.46.16.1
4.0	7/29/47	--	Auger hole. See log.	47.46.17.1
--	--	--	Corrigan mine shaft.	47.46.17.2-1
--	--	--	Puritan mine no. 4 shaft.	47.46.17.2-2
--	--	--	Puritan mine no. 1 shaft.	47.46.17.2-3
5	1947	RR	Drilled by Layne-Northwest Co. Yield 40 g.p.m. in 1948. Drawdown 7 feet in 1948 when pumping 40 g.p.m. Water hardness-130 parts per million (p.p.m.). Well has never failed. Temperature 46° F. See log.	47.46.18.1-1
5	1947	--	Test hole. See log.	47.46.18.1-2
Dry	--	--	do.	47.46.18.1-3
do.	--	--	Test hole.	47.46.18.1-4
do.	--	--	do.	47.46.18.1-5

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
47.46.18.1-6	W½NE¼NE¼	Chicago & Northwestern Ry. Co.	12	1¼	None	12
47.46.18.1-7	W½NE¼NE¼	do.	12	1¼	do.	12
47.46.18.1-8	NW¼SE¼NW¼	do.	32	6	do.	32
47.46.18.2	NW¼NW¼NE¼	Sue Labradi	30	5	Gravel and bedrock	30
47.46.18.3	S½SW¼SE¼	Oliver Iron Mining Co.	--	--	--	17
47.46.19.1	SE¼SE¼NE¼	Oscar Korpi	11	36	Gravel	--
47.46.19.2	SE¼NW¼SE¼	Victor Nygart	13	36	Sand	--
47.46.19.3	SW¼SE¼SE¼	Eric Anderson	24	48	do.	--
47.46.20.1-1	SW¼NE¼NE¼	City of Bessemer	71.3	4	Sand and gravel	70.5
47.46.20.1-2A	SE¼NW¼NE¼	do.	68.9	6	do.	68.5
47.46.20.2	SE¼SE¼NW¼	Bessemer Township	20	36	Sand	--
47.46.20.3-1	NW¼SW¼	Ivah Wirpio	15	36	--	--
47.46.20.3-2	NW¼SW¼	do.	10	36	--	--
47.46.20.4	NE¼NE¼	Unknown	6	4	--	--
47.46.20.5-1	NE¼NE¼	do.	90	4	None	--
47.46.20.5-2	NE¼NE¼	do.	45	4	Hardpan	--
47.46.20.5-3	SE¼NE¼	do.	60	4	None	--
47.46.20.5-4	SW¼NE¼	do.	50	4	do.	--
47.46.20.6-1	SW¼SE¼NW¼	Oliver Iron Mining Co.	16	--	Sand and gravel	14
47.46.20.6-2	SW¼SE¼NW¼	do.	19	--	Gravel and boulders	17

Water Level: Feet from land surface	Water Level: Date	Use	Remarks	Well no.
Dry	--	--	Test hole.	47.46.18.1-6
do.	--	--	do.	47.46.18.1-7
do.	--	--	Test hole. Muck and silt above bedrock.	47.46.18.1-8
5	1937	D	Drilled by H. O. Rice. Well has never failed. See log.	47.46.18.2
--	--	--	Mining company drill hole.	47.46.18.3
8.7	8/19/48	D,S	Well has never failed.	47.46.19.1
10.3	8/19/48	D	do.	47.46.19.2
22	1948	D,S	See log.	47.46.19.3
4.36	7/21/49	--	Bessemer test well 1. See log. See analyses.	47.46.20.1-1
6.50	7/21/49	--	Bessemer test well 2A. See log. See analyses.	47.46.20.1-2A
13.0	7/22/47	PS	See analysis.	47.46.20.2
12.4	8/19/48	D,S	do.	47.46.20.3-1
3.18	1948	(S)	--	47.46.20.3-2
4.5	7/29/47	--	Auger test hole. See log.	47.46.20.4
Dry	--	--	Test hole. Stopped in hardpan under muck.	47.46.20.5-1
--	--	--	Test hole. Stopped in hardpan. Water supply limited, bad taste and smell.	47.46.20.5-2
Dry	--	--	Test hole. Stopped in hardpan under muck.	47.46.20.5-3
do.	--	--	do.	47.46.20.5-4
--	--	--	Test hole. Water supply limited. See log.	47.46.20.6-1
--	--	--	Test hole. Water. See log.	47.46.20.6-2

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
47.46.20.6-3	SW¼SE¼NW¼	Oliver Iron Mining Co.	15	--	None	15
47.46.20.6-4	SW¼SE¼NW¼	do.	29	--	do.	--
47.46.20.6-5	SE¼SE¼NW¼	do.	36	--	do.	36
47.46.20.6-6	SE¼SE¼NW¼	do.	37	--	do.	37
47.46.20.6-7	NE¼SE¼NW¼	do.	25	--	do.	18
47.46.20.6-8	SE¼SE¼NW¼	do.	25	--	Gravel	--
47.46.20.6-8A	SE¼SE¼NW¼	do.	34	--	do.	34
47.46.20.6-8B	SE¼SE¼NW¼	do.	34	--	do.	34
47.46.20.6-9	SE¼SE¼NW¼	do.	29	--	None	--
47.46.20.6-10	SE¼SE¼NW¼	do.	32	--	do.	32
47.46.20.6-11	SE¼SE¼NW¼	do.	26	--	Gravel	--
47.46.20.6-12	SW¼SE¼NW¼	do.	26	--	do.	--
47.46.20.6-13	SW¼SE¼NW¼	do.	25	--	None	--
47.46.20.6-14	SW¼SW¼SE¼NW¼	do.	25	--	Gravel	25
47.46.20.6-15	SW¼SW¼SE¼NW¼	do.	33	--	do.	33
47.46.21.1-1	NW¼NW¼	City of Bessemer	5	4	None	--
47.46.21.1-2	Near center N½NW¼	do.	17	36 to 6	do.	--
47.46.21.1-3	NW¼SW¼NW¼	do.	33.3	6	Sand and gravel	32
47.46.21.1-4	NW¼NW¼NW¼	do.	72.5	6	do.	71.5

Water Level		Use	Remarks	Well no.
Feet from land surface	Date			
Dry	--	--	Test hole. Section is 15 feet of sand and boulders.	47.46.20.6-3
do.	--	--	Test hole. Section is 29 feet of sand.	47.46.20.6-4
do.	--	--	Test hole. See log.	47.46.20.6-5
do.	--	--	Test hole. Section is 37 feet of sand and gravel.	47.46.20.6-6
do.	--	--	Test hole. See log.	47.46.20.6-7
12.5 2.0	5/20/49 10/ 1/48	D,I	Capacity yield 107 g.p.m. in 1928. Pumped at 70 g.p.m. in recent years. See log. See analysis.	47.46.20.6-8
--	--	--	Test hole. Water. See log.	47.46.20.6-8A
--	--	--	do.	47.46.20.6-8B
Dry	--	--	Test hole. Section is 29 feet of clay and gravel.	47.46.20.6-9
do.	--	--	Test hole. Section is 32 feet of clay and gravel.	47.46.20.6-10
--	--	--	Test hole. Water. See log.	47.46.20.6-11
--	--	--	do.	47.46.20.6-12
Dry	--	--	Test hole. Section is 25 feet of clay and gravel.	47.46.20.6-13
--	--	--	Test hole. Water. See log.	47.46.20.6-14
--	--	--	Test hole. Section is 33 feet of clay and gravel. Water supply limited.	47.46.20.6-15
Dry	7/29/47	--	Auger test hole. See log.	47.46.21.1-1
do.	--	--	Test hole. See log.	47.46.21.1-2
6	6/14/49	--	Bessemer test well 3. Water supply limited. See log.	47.46.21.1-3
29	6/20/49	--	Bessemer test well 4. Water supply limited. See log.	47.46.21.1-4

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bed-rock (ft.)
47.46.21.2	NW¼NE¼NE¼	A. Spagnoletti	12	48	--	12
47.46.21.3	N½NW¼SW¼	Nesto Erickson	33	86	Sand and gravel	--
47.46.21.4	NE¼NE¼SW¼	Chas. Anderson	32	48	Gravel	--
47.46.21.5	SW¼SW¼SE¼	DX Service Sta.	10	48	--	--
47.46.21.6	SW¼SW¼SE¼	Unknown	13	48	--	--
47.46.21.7	SW¼SE¼SE¼	Harding Athletic Club	29	48	--	--
47.46.21.8	SE¼SE¼SE¼	E. Erickson	18	72	Sand	--
47.46.21.9	N½NE¼NW¼	John E. Mattson	18.5	36	Gravel	--
47.46.21.10	SW¼NE¼	George Aijalla	15	36	--	--
47.46.21.11	SW¼SE¼NW¼	Arne Suomi	13	36	Sand and gravel	--
47.46.21.12	NE¼NW¼SW¼	Emil Erickson	20.5	36	Sand	--
47.46.22.1	NW¼NW¼NW¼	E. G. Johnson	--	36	do.	--
47.46.24.1	SE¼NE¼NW¼	Frank Morviua	94	5	Gravel	--
47.46.27.1	NW¼NW¼NW¼	Victor Jacobson	68	2	Sand	--
47.46.27.2-1	SW¼NW¼NW¼	Floyd Jacobson	39	4	None	--
47.46.27.2-2	SW¼NW¼NW¼	do.	16	36	--	--
47.46.27.3	NW¼SW¼SW¼	Weino Jacobson	18	32	Sand and gravel	--
47.46.27.4-1	SW¼SW¼SE¼	Wayne Salonen	18	36	Sand ?	18
47.46.27.4-2	SW¼SW¼SE¼	do.	18	36	--	18
47.46.27.5	SE¼SE¼SE¼	L. and J. Mattson	17	96 to 72	Sand	--
47.46.28.1	NE¼NW¼NW¼	Anton Marander	24	40	Gravel	--

Water Level: Feet from land surface	Water Level: Date	Use	Remarks	Well no.
7 est.	8/19/48	D	--	47.46.21.2
14.1	6/24/47	D,S	Aquifer is overlain entirely by hardpan. Temperature 44° F.	47.46.21.3
23.0	8/18/48	D,S	See log.	47.46.21.4
6.48	7/23/47	--	Abandoned. Temperature 49° F.	47.46.21.5
2.80	6/20/47	--	do.	47.46.21.6
26.7	7/28/48	(D)	Temperature 45° F.	47.46.21.7
11	1948	D,S	--	47.46.21.8
16.1	9/9/48	D,S	See log.	47.46.21.9
10.0	9/9/48	D,S	--	47.46.21.10
11	1948	D	See log.	47.46.21.11
10.7	9/9/48	D	See log. See analysis.	47.46.21.12
+	7/21/48	D,S	Spring. Discharge 2 g.p.m. on July 21, 1948. Temperature 49° F.	47.46.22.1
60	1948	D,S	Drilled by H. O. Rice. See log.	47.46.24.1
--	--	D,S	Well has never failed. See log.	47.46.27.1
Dry	--	--	Test boring. Sand and clay for 39 feet.	47.46.27.2-1
3.0	8/17/48	--	--	47.46.27.2-2
4 to 13	--	D,S	Well has never failed. See log.	47.46.27.3
13	1948	D	Water is reported to be hard.	47.46.27.4-1
13	1948	S	Water is reported to be soft.	47.46.27.4-2
13	7/28/48	D,S	--	47.46.27.5
18.7	8/19/48	D,S	Well has never failed. See log. See analysis.	47.46.28.1

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
47.46.28.2	E½NE¼NE¼	Johmillar Erickson	14.4	--	Gravel	--
47.46.28.3	NW¼SW¼NE¼	Bert Pelto	15	48	do.	--
47.46.28.4	NW¼NW¼SE¼	John Erickson	14	36	Sand and gravel	--
47.46.28.5	S½SW¼SE¼	do.	18	48	Gravel	--
47.46.29.1	NW¼NW¼NW¼	Roy Iverson	46	6	do.	46 ?
47.46.29.2	N½SW¼NW¼	Victor Niemi	30	48	--	--
47.46.29.3	NW¼SE¼NW¼	Matt Hill	16	112	--	--
47.46.29.4	NE¼NE¼SW¼	Raynor Usadell	18	48	--	18
47.46.29.5	NW¼SE¼	Unknown	10	24	--	--
47.46.29.6	N½NW¼NE¼	John Morris	18.3	48	Gravel	--
47.46.29.7	N½NE¼NE¼	Reino Niemi	15	48	Sand	--
47.46.30.1-1	SW¼SW¼NW¼	Bill Korpi	84	6	None	84
47.46.30.1-2	SW¼SW¼NW¼	do.	34	48	Sand and gravel	--
47.46.30.2	NW¼NE¼NW¼	Gust Korpi	16	48	Sand	--
47.46.30.3	N½NE¼NE¼	Chas. Sipola	55	6	Sand and gravel	--
47.46.31.1	SW¼SW¼	Mr. Kato	32	48	Granite	32
47.46.33.1	W½NW¼NW¼	Unknown	11	24	--	11
47.46.33.2	NW¼SW¼NE¼	Nick Pumula	14	48	--	--
47.46.34.1	NE¼NE¼NW¼	R. T. Salonen	18	--	Gravel	--
47.46.34.2	NE¼SW¼SW¼	Matti Erikainen	14	60	--	--
47.47.12.1	SW¼SW¼SE¼	Mr. Clamella	28	48	Sand	--

Water Level				
Feet from land surface	Date	Use	Remarks	Well no.
3.9	6/24/47	D	Gravel aquifer is overlain by hardpan. Temperature 47° F.	47.46.28.2
12.0	8/19/48	D	See log. Temperature 49° F.	47.46.28.3
10	1948	D,S	do.	47.46.28.4
6 to 12	1948	D,S	Well has never failed. See log.	47.46.28.5
20	1946-48	D,S	Drilled by H. O. Rice. See log.	47.46.29.1
22.7	8/18/48	D,S	See analysis.	47.46.29.2
10.22	7/29/48	D,S	do.	47.46.29.3
9 to 16	1948	D,S	--	47.46.29.4
7.1	8/17/48	--	--	47.46.29.5
11.6	8/17/48	D,S	Well has never failed.	47.46.29.6
9.3	8/19/48	D,S	Well has never failed. See analysis.	47.46.29.7
Dry	--	--	Test boring. Drilled by H. O. Rice. See log.	47.46.30.1-1
28.7	8/18/48	D,S	Temperature 48° F.	47.46.30.1-2
10 to 12	1948	D	--	47.46.30.2
17	1946	D,S	Drilled by H. O. Rice. Well has never failed. See log. See analysis.	47.46.30.3
29	1948	D,S	--	47.46.31.1
10	Aug. 1948	D,S	Clay, sand, and gravel overlies granite. Well has failed many times.	47.46.33.1
5.0	8/19/48	D,S	--	47.46.33.2
10 to 13	1948	D	See log.	47.46.34.1
9.1	8/19/48	D,S	Well has never failed.	47.46.34.2
21	1948	D,S	Aquifer is 3 feet of sand.	47.47.12.1

Well no.	Location	Owner	Depth (ft.)	Diam-eter (in.)	Aquifer	Depth to bed-rock (ft.)
47.47.13.1	NW¼SW¼NE¼	Unknown	8	48	Sand	--
47.47.13.2	SE¼SE¼SE¼	Oliver Iron Mining Co.	--	--	--	10
47.47.24.1	N½SW¼SE¼	Michael Miskovich	46	4	Sand and gravel	--
47.47.24.2	N¼SE¼SE¼	Paul Suzik	52	5	do.	52 ?
47.47.36.1	NW¼NE¼NE¼	Mrs. Liponen	27	36	do.	27
47.47.36.2	NE¼SE¼NE¼	Elmer Nickelson	11	18	Sand	--
47.47.36.3	SW¼SW¼SE¼	John Mattson	11	48	Sand ?	--
48.45.34.1	N½N½NW¼	Wakefield Township	300	240 to 6	--	125 or 125+
48.46.21.1	SW¼SW¼SE¼	Fred Hedberg	18	48	Sand and gravel	--
48.46.21.2	SE¼NE¼SE¼	Oona Hedberg	60	4	Sand	--
48.46.27.1	SW¼SW¼SE¼	Andrew Maki	38	48	Gravel	--
48.46.27.2	SW¼SE¼SE¼	Carl Johnson	20	36	--	--
48.46.27.3	SW¼NW¼SE¼	John Heikkala	60	36	Gravel	--
48.46.27.4	W½SW¼NW¼	David Aho	30	36	Sand and gravel	--
48.46.27.5	SE¼SE¼NW¼	Mr. Runta	36.5	48	--	--
48.46.28.1	NE¼NE¼NE¼	Andrew Runta	32	36	Sand and gravel	--
48.46.28.2	S[illegible]¼NE¼NW¼	John Blomberg	14	36	Sand	--
48.46.28.3	SE¼SE¼NW¼	Mr. Salo	33	36	Sand and gravel	--

Water Level				
Feet from land surface	Date	Use	Remarks	Well no.
6	8/17/48	D	Aquifer is 2 feet of sand under 6 feet of red sandy clay.	47.47.13.1
--	--	--	Mining company drill hole.	47.47.13.2
7	1933	D,S	Drilled by H. O. Rice. Very "strong" well. See log.	47.47.24.1
--	--	D	Drilled by H. O. Rice. See log.	47.47.24.2
19.1	8/18/48	D,S	Bedrock is granite.	47.47.36.1
9.0	8/18/48	D	Section is mostly sand with clay.	47.47.36.2
7	7/29/48	D	--	47.47.36.3
115	1/12/49	PS	Dug to 125 feet; drilled and cased with 6-inch casing from 125 to 300 feet. Original yield was 17 g.p.m. in 1930.	48.45.34.1
4	1948	D,S	Temperature 50° F.	48.46.21.1
50	1948	D,S	--	48.46.21.2
30.8	8/4/48	D	Section consists of 3 feet of gravel overlain by 35 feet of sand. Temperature 46° F.	48.46.27.1
17	1948	D	Not a "strong" well.	48.46.27.2
45	1948	D	Not a "strong" well. See log.	48.46.27.3
28	1948	D,S	do.	48.46.27.4
31.9	9/10/48	D	--	48.46.27.5
29.5	Oct. 1948	D	See log.	48.46.28.1
--	--	D,S	Well has never failed.	48.46.28.2
--	--	D	See log.	48.46.28.3

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
48.46.28.4	NW¼NW¼SE¼	M. Lepislo	--	--	Sand and gravel	--
48.46.28.5	SW¼SW¼SE¼	Mr. Salmi	40	--	Hardpan	--
48.46.28.6	SW¼SW¼SW¼	Andrew Hedberg	93	4	Sand	--
48.46.28.7	SW¼SW¼SW¼	North Bessemer School	196	5 to 4	Coarse sand	--
48.46.28.8	E½NE¼SE¼	Szigmund Popko	--	--	Sand and gravel	--
48.46.28.9	NE¼SW¼	Unknown	--	--	do.	--
48.46.29.1	SE¼NE¼NE¼	Arthur Blomberg	16	24 to 30	Fine sand	--
48.46.29.2	W½NW¼SE¼	Oona Rundell	21	36	Sand and gravel	--
48.46.30.1	SW¼SW¼SE¼	Wester Lahti	26	48	Sand	--
48.46.30.2	SW¼NW¼SE¼	Arvo Suvanto	20	36	Fine sand	--
48.46.30.3-1	NE¼NE¼SE¼	John Koski	32	48	Gravel	--
48.46.30.3-2	E½NE¼SE¼	do.	--	--	Sand and gravel	--
48.46.30.4-1	SE¼NE¼SE¼	Albert Lagrew	49	48	None	--
48.46.30.4-2	SE¼NE¼SE¼	do.	85	6	Gravel	--
48.46.30.5	SE¼SE¼SE¼	Chas. Auvinen	(101) 63	5	Sandy hardpan	90
48.46.30.6	SE¼NE¼NE¼	William Koski	28	42	Hardpan	--
48.46.31.1	SE¼SE¼NW¼	Martin Lakvold	44	5	Gravel	--
48.46.31.2	SW¼NW¼NE¼	Wm. Backman	32	36	do.	--

Water Level: Feet from land surface	Water Level: Date	Use	Remarks	Well no.
+	1948	D,S	Spring.	48.46.28.4
35	--	D,S	Section consists of 40 feet of hardpan. Well has failed at times.	48.46.28.5
80 ?	1940	D,S	Well has never failed. See log.	48.46.28.6
--	--	D	Drilled by Carl Gustafson. Well has never failed.	48.46.28.7
+	--	D,S	Spring. Discharge 50 g.p.m. on Sept. 8, 1948. Temperature 45° F.	48.46.28.8
+	--	S	Spring. Discharge 5 g.p.m. on Sept. 8, 1948. Temperature 45° F.	48.46.28.9
12	1948	D	See log.	48.46.29.1
20	9/8/48	D,S	Not a "strong" well. See log.	48.46.29.2
23.5	Sept. 1948	D,S	Section consists of 24 feet of hardpan overlying 2 feet of sand.	48.46.30.1
16	do.	S	Very "strong" well. See log.	48.46.30.2
22	1948	D,S	do.	48.46.30.3-1
+	--	S	Spring. Discharge 10 g.p.m. on Sept. 11, 1948. Temperature 48° F.	48.46.30.3-2
Dry	--	--	Test boring. See log.	48.46.30.4-1
30	1942	D,S	Drilled by Don Johnson. Section is mainly hardpan.	48.46.30.4-2
20	About 1946	D,S	Drilled by H. O. Rice. See log.	48.46.30.5
24	9/1/48	D,S	Section is mainly hardpan, with gravel layers.	48.46.30.6
24	1948	D,S	Drilled by H. O. Rice. See log.	48.46.31.1
21 to 30	1948	D,S	Very "strong" well. Section is 2 feet of gravel overlain by 30 feet of red hardpan.	48.46.31.2

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
48.46.31.3	SE¼NE¼NE¼	Matti Weino	80	--	Gravel	--
48.46.31.4(?)	NE¼(?)	Unknown	108	4	do.	--
48.46.32.1-1	NW¼SW¼NW¼	Matti Pieronen	90	36	None	--
48.46.32.1-2	NW¼SW¼NW¼	do.	60	36	Sand and clay	--
48.46.32.2-1	E½SW¼NW¼	Albin Matiskola	70	48	None	--
48.46.32.2-2	E½SW¼NW¼	do.	40	48	Sand and gravel	--
48.46.32.3	W½NE¼NW¼	John Berg	25	?	Gravel	--
48.46.32.4	NW¼NW¼NE¼	Weino Runi	48	36	do.	--
48.46.32.5	SE¼NW¼SE¼	Henry Sikkenen	83	48	None	--
48.46.32.6	SE¼SE¼NW¼	A. Finn	--	--	Sand	--
48.46.33.1	NW¼NE¼NW¼	Mr. Sandene	90	24	Hardpan	--
48.46.33.2	NW¼NW¼SW¼	John Berg	30	36	Sand and gravel	--
48.46.33.3	W½NW¼SW¼	Pete Giacherio	25	--	None	--
48.46.34.1	NW¼NE¼NW¼	John Waitela	40	36	Sand and gravel	--
48.46.34.2-1	W½SE¼NW¼	K. Sakkanen	12	36	Red sand	--
48.46.34.2-2	W½SE¼NW¼	do.	--	--	Sand and gravel	--
48.46.34.3	N½NW¼SE¼	Duluth, South Shore & Atlantic Ry. Co.	--	72	do.	--
48.46.34.4	SW¼NE¼	Weino Runi	--	--	do.	--

Water Level: Feet from land surface	Water Level: Date	Use	Remarks	Well no.
76	About 1946	D	--	48.46.31.3
--	--	D,S	Drilled by John DaRonco. See log.	48.46.31.4(?)
Dry	--	--	Test boring. See log.	48.46.32.1-1
53	1948	D,S	See log.	48.46.32.1-2
Dry	--	--	Test boring.	48.46.32.2-1
37	1948	D,S	Section is mainly hardpan.	48.46.32.2-2
23	About 1945	(D,S)	Abandoned. Well had never failed.	48.46.32.3
36.3	9/8/48	D,S	See log.	48.46.32.4
Dry	--	--	Test boring. See log.	48.46.32.5
--	--	D	Spring. Temperature 45° F. No flow on Sept. 13, 1948.	48.46.32.6
84	Spring 1948	D,S	Entire section is reported to be hardpan.	48.46.33.1
12.9	9/8/48	D,S	Not a "strong" well.	48.46.33.2
Dry	--	--	Test boring. Entire section is reported to be red hardpan.	48.46.33.3
38	--	D,S	Section is mainly sand and gravel with little hardpan.	48.46.34.1
7.3	9/10/48	D,S	Well has never failed. Water level fluctuation reported to be very small. Temperature 53° F.	48.46.34.2-1
+	--	S	Spring. Two others nearby. Discharge 1 gpm on Sept. 10, 1948. Temperature 53° F.	48.46.34.2-2
+	--	RR	Spring. Flows into storage tank (capacity-5,000 gallons). Discharge 20 g.p.m. on Sept. 13, 1948. Temperature 45° F.	48.46.34.3
+	--	(D)	Spring. Discharge 15 g.p.m. on Sept. 8, 1948.	48.46.34.4

Well no.	Location	Owner	Depth (ft.)	Diameter (in.)	Aquifer	Depth to bedrock (ft.)
48.47.23.1	SE¼	Tom Kangas	33	4	Sand	--
48.47.25.1	SW¼NW¼NW¼	Matt Lainen	58+	4	--	--
48.47.25.2-1	NW¼NE¼SE¼	Nante Peelala	(247) 47	4	Sand	240
48.47.25.2-2	NW¼NE¼SE¼	do.	47	36 to 4	Gravel	--
48.47.25.3	SE¼SE¼SE¼	Matt Jarvi	80	5	Gravel and bedrock	78
48.47.26.1	NE¼SE¼NE¼	Reuben Kinnunen	48	5	Coarse sand	--
48.47.35.1	SW¼SE¼NW¼	Ernest Hannu	65	36	Gravel	--

Water Level		Use	Remarks	Well no.
Feet from land surface	Date			
--	--	D,S	Drilled by J. DaRonco. Section is 30 feet of hardpan underlain by 3 feet of sand.	48.47.23.1
--	--	--	Drilled by J. DaRonco. Well not completed. See log.	48.47.25.1
9	Summer 1948	(D)	Drilled by Matt Lampi. Casing dynamited at 47 feet. Not a "strong" well. See log.	48.47.25.2-1
15	Summer 1948	D,S	Dug to 21 feet; drilled and cased with 4-inch casing from 21 to 47 feet by John DaRonco. See log.	48.47.25.2-2
25	1940	D,S	Drilled by H. O. Rice. Yield 20 g.p.m. See log.	48.47.25.3
10	Sept. 1948	D,S	Drilled by John DaRonco. See log.	48.47.26.1
63.5	Sept. 1948	D,S	Section is mainly hardpan, with gravel at base. During times of normal precipitation the water level is about 59 feet below the land surface.	48.47.35.1

APPENDIX B

LOGS OF WELLS AND BORINGS

IN

BESSEMER AREA, GOGEBIC COUNTY, MICHIGAN

	Thickness (feet)	Depth (feet)
47.45.7.1 State Highway Dept., owner. Average log of 4 test borings.		
Clay, soft, sandy, gravelly, red	2	2
Sand and gravel, medium-red	29	31
Gravel, coarse, or rock or boulder	3	34
47.45.8.1 State Highway Dept., owner. Average log of 5 test borings.		
Loam	2	2
Sand, medium-red, and twigs	3	5
Clay to sand, soft, silty, red	2	7
Sand and gravel, medium-red	14 to 27	21 to 34
Gravel, coarse, and boulders	4	25 to 38
47.45.17.1 State Highway Dept., owner. Average log of 5 test borings.		
Sand, loamy	0.5	0.5
Peat, sandy, woody, aquatic	6.5	7
Peat, soft, slightly sandy, aquatic	3	10
Peat, soft, aquatic	1	11
Clay, very soft, silty, red	7	18
Sand, medium-red	1	19
Clay, gravelly, stony, red	1	20
Gravel, medium to coarse, red clay, and sand	4	24
Clay, medium, firm, gravelly, stony, sandy, red	4	28
Sand, loamy, medium-red	1.5	29.5
Gravel, compact, fine	1	30.5
Sand, medium, red	.5	31
Gravel, fine	1	32
Sand, very loamy, gravelly	2	34
Gravel, fine	1	35
Sand, very loamy, gravelly, red	3	38
Gravel, loamy, sandy, medium	3	41
Clay, firm, red, and medium to coarse gravel	2.5	43.5
Stones and coarse gravel	--	--

"Test boring no. 2 produced a slow flow with a 2-foot head in a 2-inch pipe, which sealed itself when casing was pulled."

	Thickness (feet)	Depth (feet)
47.45.19.1 Andrew Petkie, owner.		
Silt and sand, fine	8	8
Quicksand	3	11
Hardpan		
47.46.4.1 A. Pollari, owner.		
Soil	8	8
Gravel	10	18
Sand	4	22
Gravel	10	32
47.46.4.4 Joe Myers, owner.		
Sand	12	12
Boulder	2	14
Sand and gravel	3	17
47.46.8.3 A. Kiomento, owner.		
Sand and gravel	25	25
Slate, black	75	100
47.46.8.5 Joe Marshallek, owner.		
Topsoil	2	2
Clay, sand, and rock	10	12
Gravel	4	16
Hardpan, red and yellow	2	18
Sand, fine	23	41
Slate, black	1	42
47.46.8.6 State Highway Dept., owner. Average log of 5 test borings.		
Sand, red	3	3
Gravel, fine, sandy	2	5
Rock	2	7
47.46.9.5 Frank Lompart, owner.		
Topsoil	3	3
Quicksand and hardpan	15	18
Slate, black	5	23

	Thickness (feet)	Depth (feet)
47.46.12.2 Mr. Bravado, Jr., owner.		
Topsoil	-	-
Sand and clay	-	-
Hardpan	-	-
Sand and clay	-	-
Gravel	-	46
47.46.12.4 State Highway Dept., owner. Average log of 9 test borings.		
Topsoil, sandy loam	0.5	0.5
Loam, red, sandy	1.5	2
Gravel, slightly sandy	3.5	5.5
Sand, loamy, and fine gravel	2.5	8
Clay, hard, red, with hard rock fragments	4.5	12.5
Bedrock or boulder		
47.46.17.1 Hole augered by W. T. Stuart.		
Topsoil	2	2
Sand, fine	1	3
Gravel, fine	1	4
Sand and fine gravel	4	8
47.46.18.1-1 and -2 Chicago & Northwestern Ry. Co., owner.		
Muck and silt	28	28
Gravel (water)	4	32
Bedrock		
47.46.18.1-3 Chicago & Northwestern Ry. Co., owner.		
Muck and silt	32	32
Granite	7	39
47.46.18.2 Sue Labradi, owner.		
Muck and topsoil	7	7
Quicksand	-	-
Gravel	-	30
"Black granite"		

	Thickness (feet)	Depth (feet)
47.46.19.3 Eric Anderson, owner.		
Sand	10	10
Hardpan	5	15
Clay	2	17
Hardpan	5	22
Quicksand	2	24
47.46.20.1-1 Test well 1. City of Bessemer, owner.		
Sand and gravel, coarse, with cobbles (dry)	4.5	4.5
Sand and gravel, coarse, with fine to medium sand from 15 to 16.5 feet, and from 27 to 27.5 feet; boulders at 22, 31, and 33.5 feet	30.5	35
Sand, medium to fine, uniform	1.5	36.5
Clay, sandy and gravelly, red to reddish-brown; clayey sand and gravel (hardpan); fine sand and gravel from 51.5 to 52 feet; boulder at 56.5 feet	22.5	59
Sand, medium to fine, with some gravel	5.5	64.5
Sand and gravel, clayey to slightly clayey (hardpan) boulders at 65 and 69 feet	5.5	70
Sand and gravel, medium, clean, uniform	.5	70.5
Granite	.8	71.3
47.46.20-1-2A Test wells 2 and 2A. City of Bessemer, owner.		
Sand and gravel, yellow to brown, with some clayey layers and a few large cobbles	3	3
Sand and gravel, with some cobbles	1	4
Sand and gravel, clayey to slightly clayey, yellow	7	11
Sand, coarse, and gravel, very slightly silty and clayey to 20 feet, clean material below 20 feet	17.5	28.5
Sand and gravel, slightly clayey, with uniform sand from 30 to 30.5 feet; boulder at 28.5 feet	3	31.5
Sand and gravel, clayey	1	32.5
Clay, sandy and gravelly, red to reddish-brown to clayey sand and gravel (hardpan); very slightly clayey sand and gravel layers, one-half to one foot thick, at 33.5, 36.5, 41.5, and 56.5 feet, which "feed water freely"; boulders at 32.5 and 44 feet	27	59.5
Clay, sandy, to red, uniform, clayey, medium to fine sand (hardpan)	6	65.5
Gravel, fine to medium, clean, uniform, slightly clayey at base	3	68.5
Granite	.4	68.9

	Thickness (feet)	Depth (feet)
47.46.20.4 Hole augered by W. T. Stuart.		
Topsoil	2	2
Sand and gravel, dirty	1.5	3.5
Sand, dirty	2.5	6
Gravel		
47.46.20.6-1 Oliver Iron Mining Co., owner.		
Quicksand	12	12
Gravel	2	14
Rock	2	16
47.46.20.6-2 Oliver Iron Mining Co., owner.		
Surface	10	10
Gravel and boulders (water)	7	17
Rock	2	19
47.46.20.6-5 Oliver Iron Mining Co., owner.		
Surface gravel	10	10
Sand	15	25
Gravel and clay (mixed)	11	36
Rock		
47.46.20.6-7 Oliver Iron Mining Co., owner.		
Surface	18	18
Rock	7	25
47.46.20.6-8 (25 feet deep), 8A, and 8B, Oliver Iron Mining Co., owner.		
Sand and gravel	20	20
Gravel (water)	5	25
Gravel and clay	9	34
Rock		
47.46.20.6-11 Oliver Iron Mining Co., owner.		
Surface gravel	20	20
Gravel (water)	6	26
47.46.20.6-12 Oliver Iron Mining Co., owner.		
Surface gravel	15	15
Gravel (water)	11	26

	Thickness (feet)	Depth (feet)
47.46.20.6-14 Oliver Iron Mining Co., owner.		
Surface gravel	19	19
Gravel (water)	6	25
Rock		
47.46.21.1-1 Hole augered by James Boggio.		
Topsoil	1	1
Clay, hardpan, and gravel	4	5
Boulder or bedrock		
47.46.21.1-2 Hole dug and bored by James Boggio.		
Sand and gravel	7	7
Sand, fine	.5	7.5
Quicksand, dry	9.5	17
47.46.21.1-3 Test well 3. City of Bessemer, owner.		
Sand, clayey, reddish-brown, with cobbles	7	7
Clay, sandy and gravelly, reddish-brown (hardpan), with medium to fine sand from 13 to 13.5 feet; boulder at 15 feet	12.5	19.5
Sand, medium, clayey (hardpan?)	.5	20
Sand and gravel, clayey (hardpan?)	4	24
Clay, sandy and gravelly, reddish-brown (hardpan)	2	26
Clay, sandy and gravelly, grayish-brown to brownish-gray (hardpan)	3.5	29.5
Sand, fine, and gravel, clayey	.5	30
Clay, sandy and gravelly, reddish-brown, with cobbles (hardpan)	2	32
Granite	1.3	33.3
47.46.21.1-4 Test well 4. City of Bessemer, owner.		
Silt and fine sand, yellowish-brown	6	6
Silt and sand, clayey, to clay, silty and sandy, brown, with some gravel	29	35
Clay, sandy and gravelly, reddish-brown (hardpan), with sand and fine gravel from 38 to 40 feet, and thin sand layers at 44, 47, and 58 feet; boulders at 38, 52, and 58 feet	36.5	71.5
Granite	1	72.5

	Thickness (feet)	Depth (feet)
47.46.21.4 Charles Anderson, owner.		
Topsoil	2	2
Hardpan	7	9
Sand and clay	17	26
Quicksand	4	30
Gravel	2	32
47.46.21.9 John Emil Mattson, owner.		
Loam	-	-
Sand and clay	-	-
Gravel	-	18.5
47.46.21.11 Arne Suomi, owner.		
Clay with rocks	9	9
Quicksand	3	12
Gravel	1	13
47.46.21.12 Emil Erikson, owner.		
Clay and sand with rocks	10	10
Clay and sand with boulders	8	18
Quicksand or silt	1	19
Boulders	1.5	20.5
47.46.24.1 Frank Morviua, owner.		
Clay	20	20
Quicksand	70	90
Gravel	4	94
47.46.27.1 Victor Jacobson, owner.		
Clay, red	-	-
Gravel	-	-
Hardpan, red	-	-
Quicksand (water)	-	68

	Thickness (feet)	Depth (feet)
47.46.27.3 Weino Jacobson, owner.		
Topsoil	1	1
Sand, silt, and clay	5	6
Quicksand	3	9
Sand, clay, and rocks	3	12
Quicksand	1	13
Clay	1	14
Sand	1	15
Gravel	3	18
47.46.28.1 Anton Marander, owner.		
Surface	3	3
Hardpan	10	13
Sand and clay	6	19
Sand	4	23
Gravel	1	24
47.46.28.3 Bert Pelto, owner.		
Surface	3	3
Hardpan, red	4	7
Hardpan, red, with rocks, wet	5	12
Gravel	3	15
47.46.28.4 John Erickson, owner.		
Topsoil	2	2
Hardpan, red	8	10
Clay, sandy	3	13
Sand and gravel	1	14
47.46.28.5 John Erickson, owner.		
Clay, sandy, to sand, clayey	14.5	14.5
Quicksand	3	17.5
Gravel	.5	18
47.46.29.1 Roy Iverson, owner.		
Topsoil	4	4
Sand and boulders	38	42
Gravel	4	46
Bedrock		

	Thickness (feet)	Depth (feet)
47.46.30.1-1 Bill Korpi, owner.		
No record (dug well)	50	50
Clay with boulders (hardpan)	34	84
Granite		
47.46.30.3 Charles Sipola, owner.		
No record (dug well)	27	27
Clay and boulders	11	38
Sand	10	48
Gravel	7	55
47.46.34.1 R. T. Salonen, owner.		
No record	10	10
Quicksand	3	13
No record	2	15
Gravel	3	18
47.47.24.1 Michael Miskovich, owner.		
Soil	[illegible]	3
Quicksand	[illegible]	15
Hardpan and boulders	-	-
Quicksand and gravel	-	46
47.47.24.2 Paul Suzik, owner.		
Sand	48	48
Gravel	4	52
Bedrock	-	-
48.46.27.3 John Heikkala, owner.		
Hardpan, red	15	15
Gravel (dry)	8	23
Hardpan, sandy	12	35
Hardpan, red, dry	10	45
Hardpan, red, wet	10	55
Hardpan, red, very wet	4.5	59.5
Gravel	0.5	60
48.46.27.4 David Aho, owner.		
Hardpan, red, with boulders	10	10
Sand and gravel	20	30

	Thickness (feet)	Depth (feet)
48.46.28.1 Andrew Runta, owner.		
Sand	6	6
Hardpan, red	7	13
Sand, gravel, and boulders	19	32
48.46.28.3 M. Salo, owner.		
Hardpan	12	12
--	--	--
Sand and gravel	--	33
48.46.29.1 Arthur Blomberg, owner.		
Gravel, coarse	8	8
Sand and gravel, fine	8	16
48.46.29.2 Oona Rundell, owner.		
Hardpan	9	9
--	-	-
Sand and gravel	-	21
48.46.30.2 Arvo Suvanto, owner.		
Hardpan and stones	14	14
Sand	6	20
48.46.30.3-1 John Koski, owner.		
Surface	2	2
Gravel	3	5
Hardpan	26	31
Gravel	1	32
48.46.30.4-1 Albert Lagrew, owner.		
Surface	2	2
Hardpan	5	7
Gravel (dry)	12	19
Hardpan	30	49

	Thickness (feet)	Depth (feet)
48.46.30.5 Charles Auvinen, owner.		
Topsoil	5	5
Hardpan, clayey	55	60
Hardpan, sandy	5	65
Hardpan, clayey	25	90
Bedrock, soft, red	11	101
48.46.31.1 Martin Lakvold, owner.		
Hardpan, clayey, with boulders	26	26
Quicksand	10	36
Gravel	8	44
48.46.31.4 Owner unknown.		
Gravel, coarse	18	18
Hardpan	20	38
Gravel, very coarse	4	42
Clay, red	20	62
Sand, very fine	38	100
Gravel	8	108
48.46.32.1-1 (90 feet deep) and -2 (60 feet deep) Matti Pieronen, owner.		
Hardpan	20	20
Gravel, dry	2	22
Hardpan	18	40
Gravel, dry	3	43
Hardpan	16	59
Sand and clay (water-bearing in well 1-2)	1	60
Hardpan	25	85
Sand (water-bearing)	5	90
48.46.32.4 Weino Runi, owner.		
Hardpan, red	36	36
Gravel	4	40
Boulders, sand, and clay	8	48
Clay, hard		
48.46.32.5 Henry Sikkenen, owner.		
Clay, red, with sand layers	40	40
Clay, blue	43	83

	Thickness (feet)	Depth (feet)

48.47.25.1 Mat Lainen, owner. Well not completed.

	Thickness (feet)	Depth (feet)
Hardpan, red	22	22
Hardpan, green to blue	36+	58+

48.47.25.2-1 Nante Peelala, owner.

	Thickness (feet)	Depth (feet)
Glacial drift, unclassified; slightly water-bearing at 47 feet	240	240
Sandstone	7	247

48.47.25.2-2 Nante Peelala, owner.

	Thickness (feet)	Depth (feet)
Hardpan, red, with boulders at 21 feet	40	40
Gravel	7	47

48.47.25.3 Matt Jarvi, owner.

	Thickness (feet)	Depth (feet)
Topsoil	5	5
Clay with sandy layers (hardpan)	71	76
Gravel	2	78
Rock, red	2	80

48.47.26.1 Rueben Kinnunen, owner.

	Thickness (feet)	Depth (feet)
Hardpan, red	21	21
Quicksand	2	23
Hardpan, red	23	46
Sand, coarse	2	48

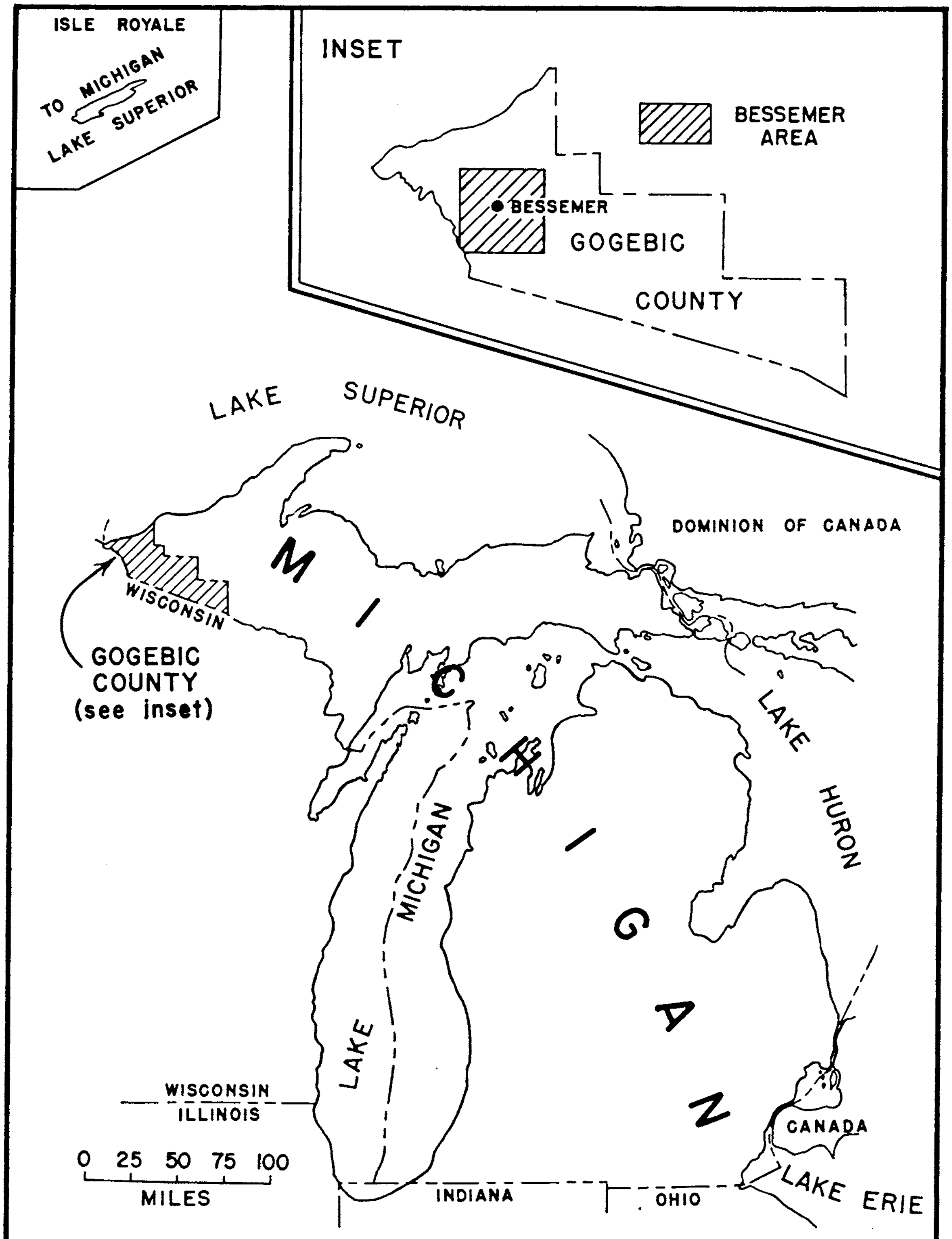

FIGURE 1

INDEX MAP OF MICHIGAN SHOWING LOCATION OF BESSEMER AREA IN GOGEBIC COUNTY

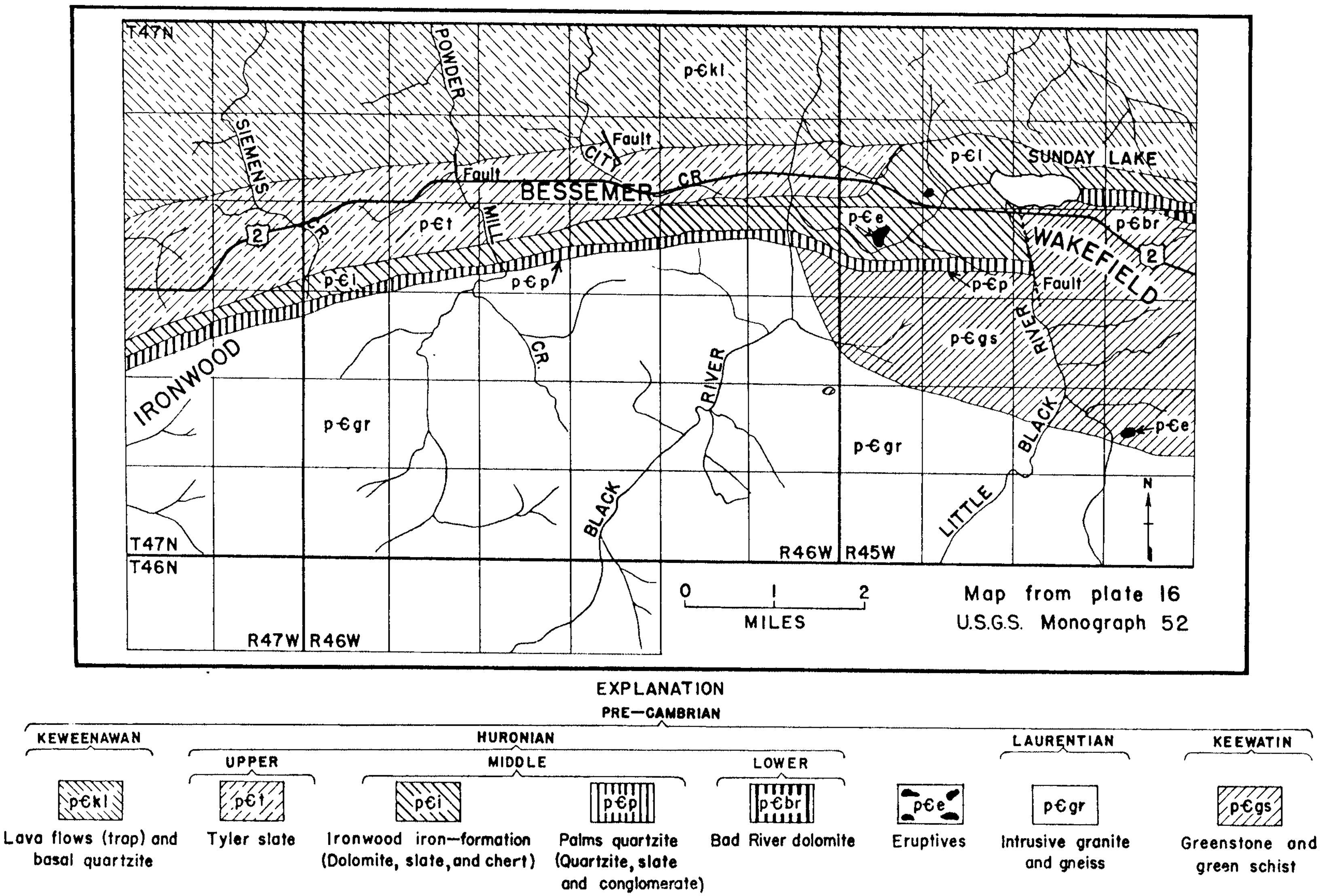

FIGURE 2

BEDROCK GEOLOGY IN THE BESSEMER AREA, GOGEBIC COUNTY, MICHIGAN

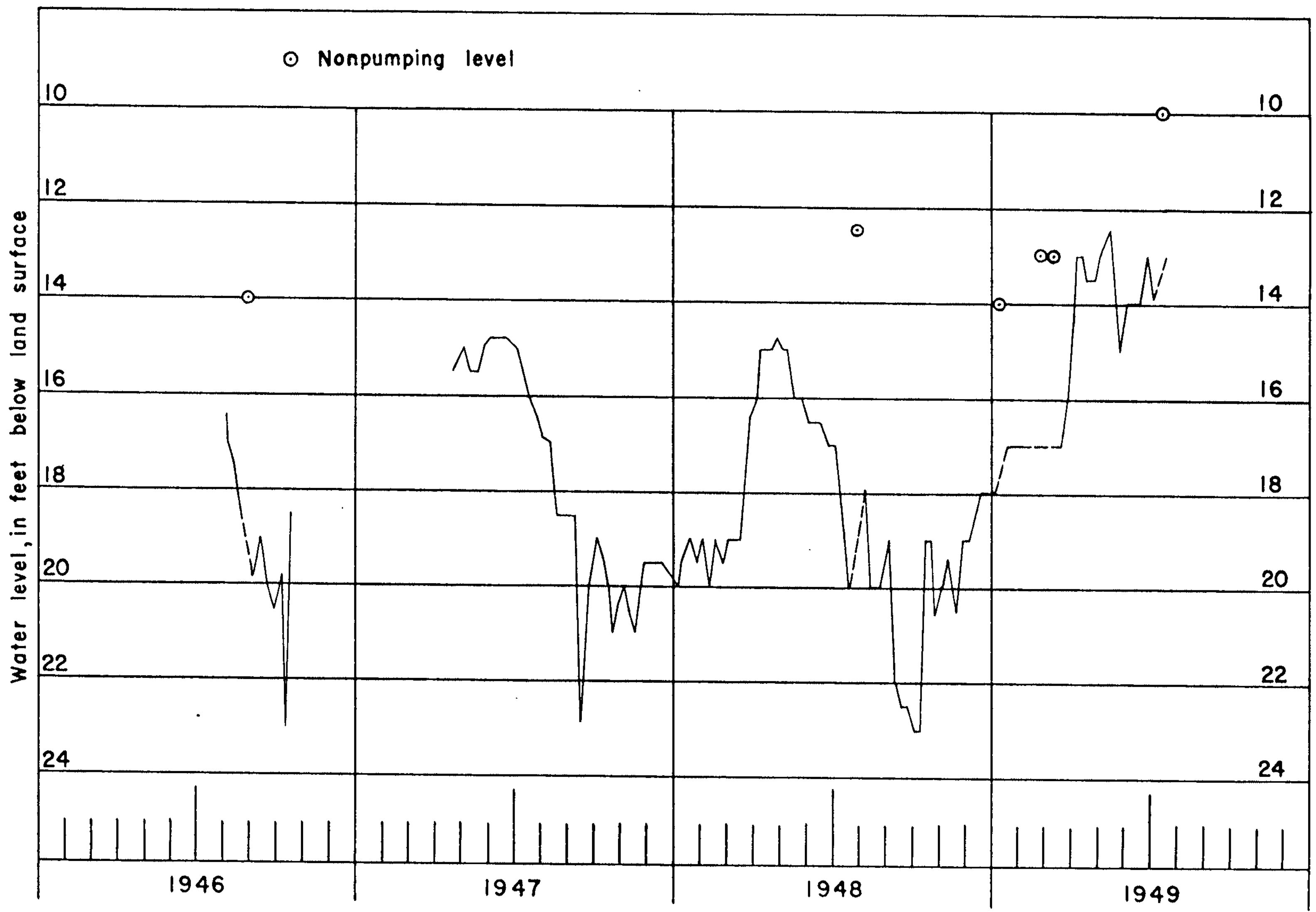

FIGURE 4

GRAPH OF PUMPING LEVELS IN OLIVER IRON MINING CO. WELL (47.46.20.6-8)

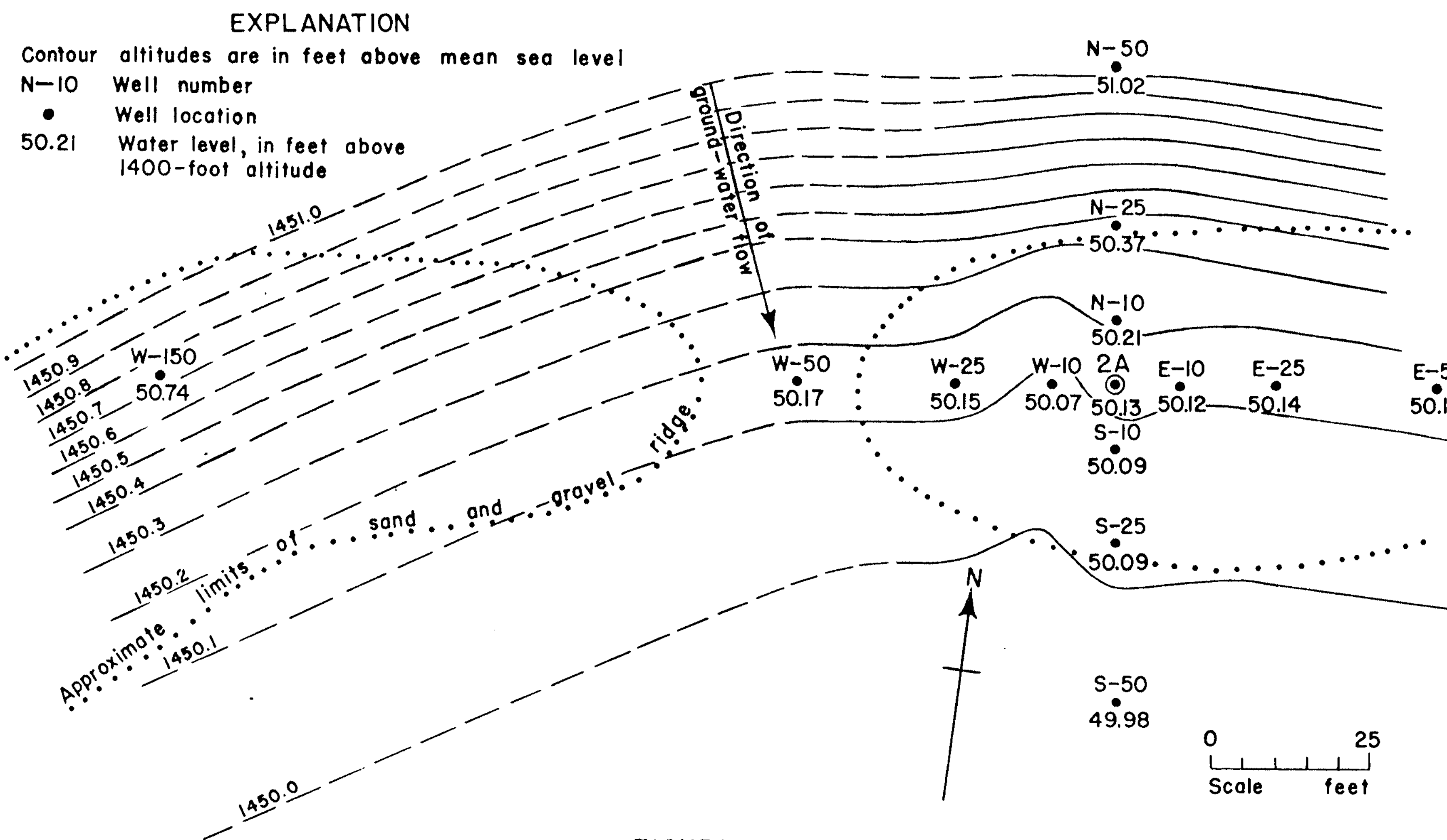

FIGURE 5

MAP SHOWING LOCATION OF CITY OF BESSEMER TEST WELL 2A(47.46.20.1-2A) AND OBSERVATION WELLS, AND CONTOURS OF STATIC WATER LEVELS
JULY 17, 1949

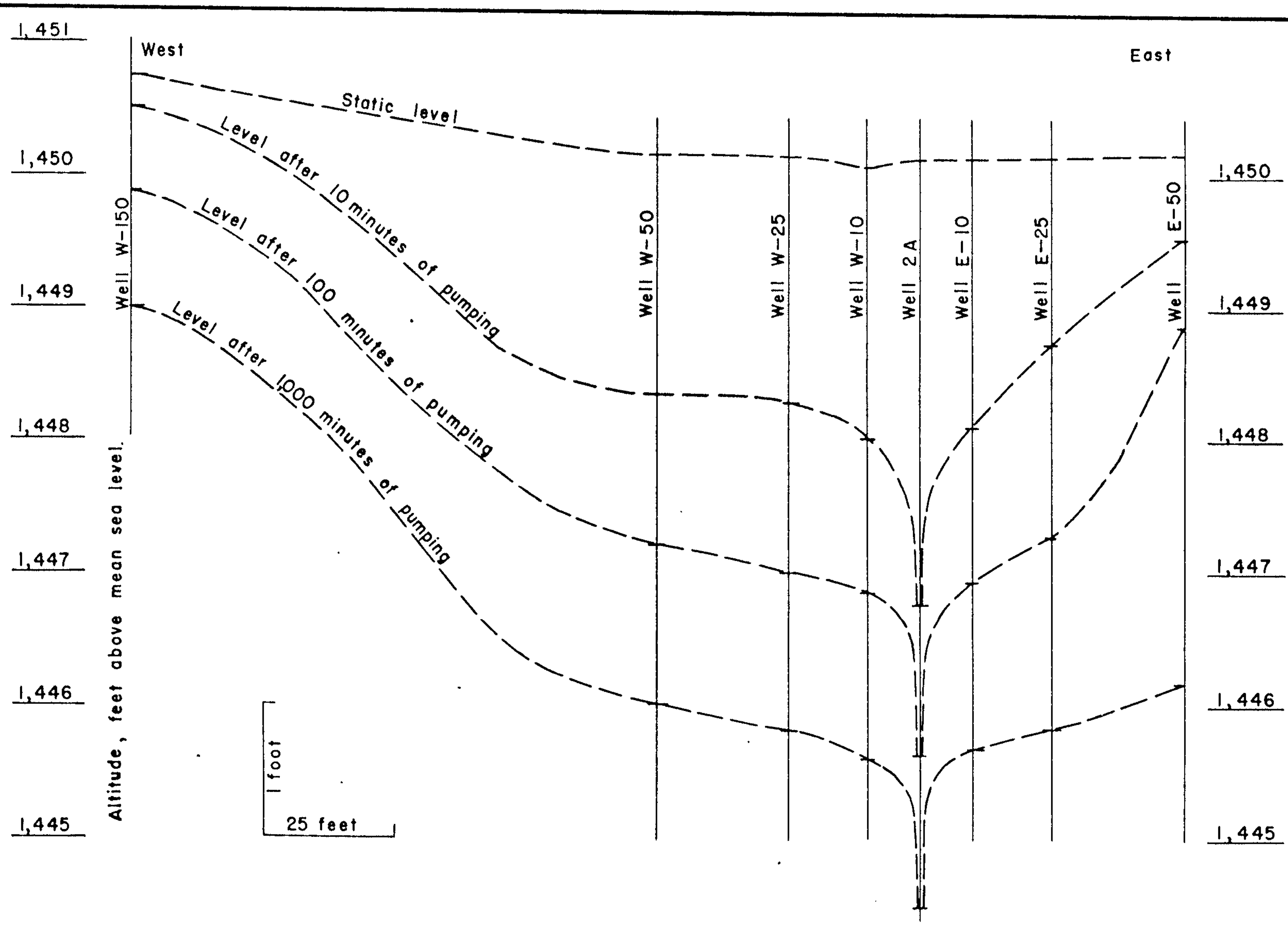

FIGURE 6

PROFILES OF WATER LEVELS IN EAST—WEST LINE OF OBSERVATION WELLS DURING PUMPING TEST ON WELL 2A (47.46.20.1–2A)

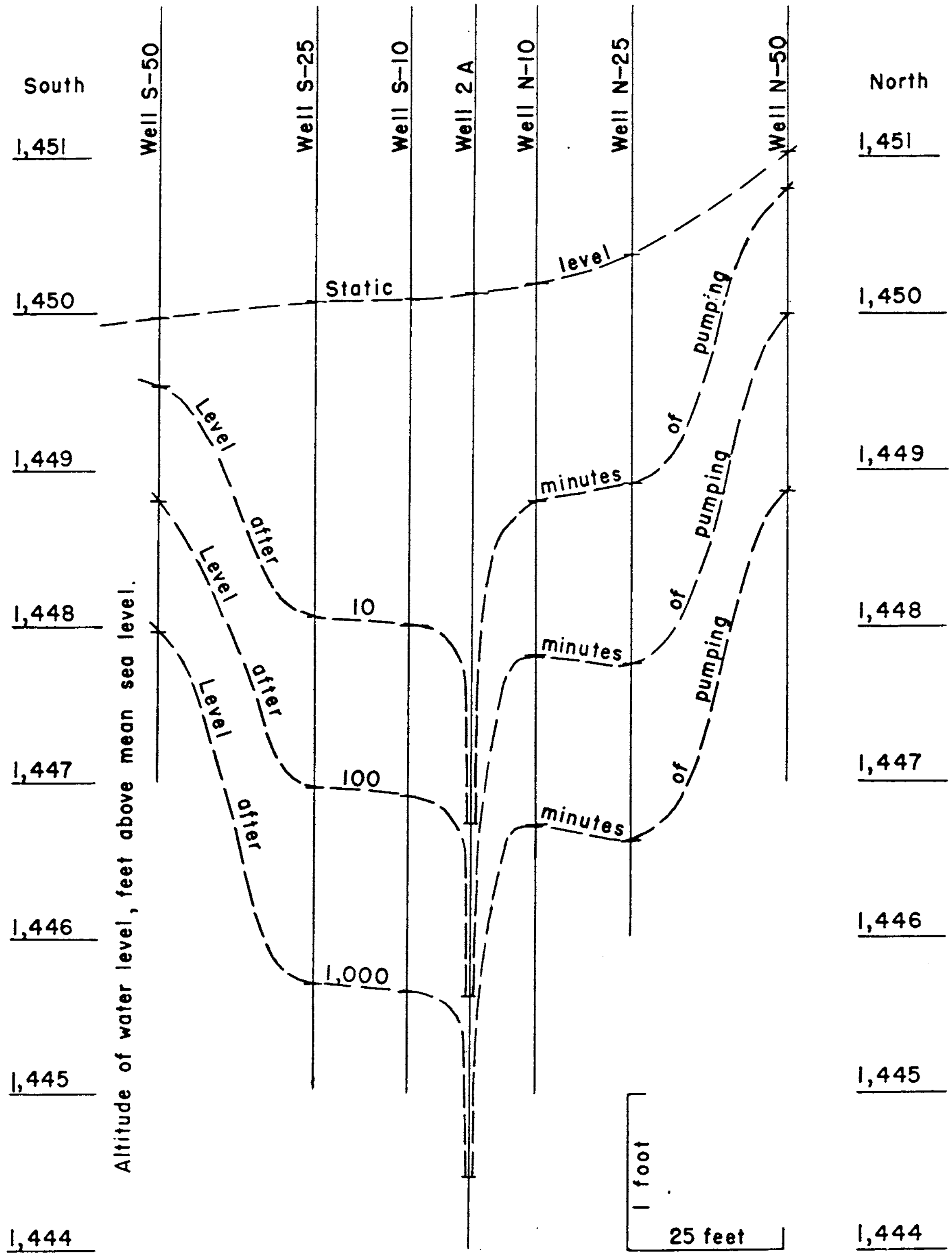

FIGURE 7

PROFILES OF WATER LEVELS IN NORTH-SOUTH LINE OF OBSERVATION WELLS DURING PUMPING TEST ON WELL 2A (47.46.20.1-2A)

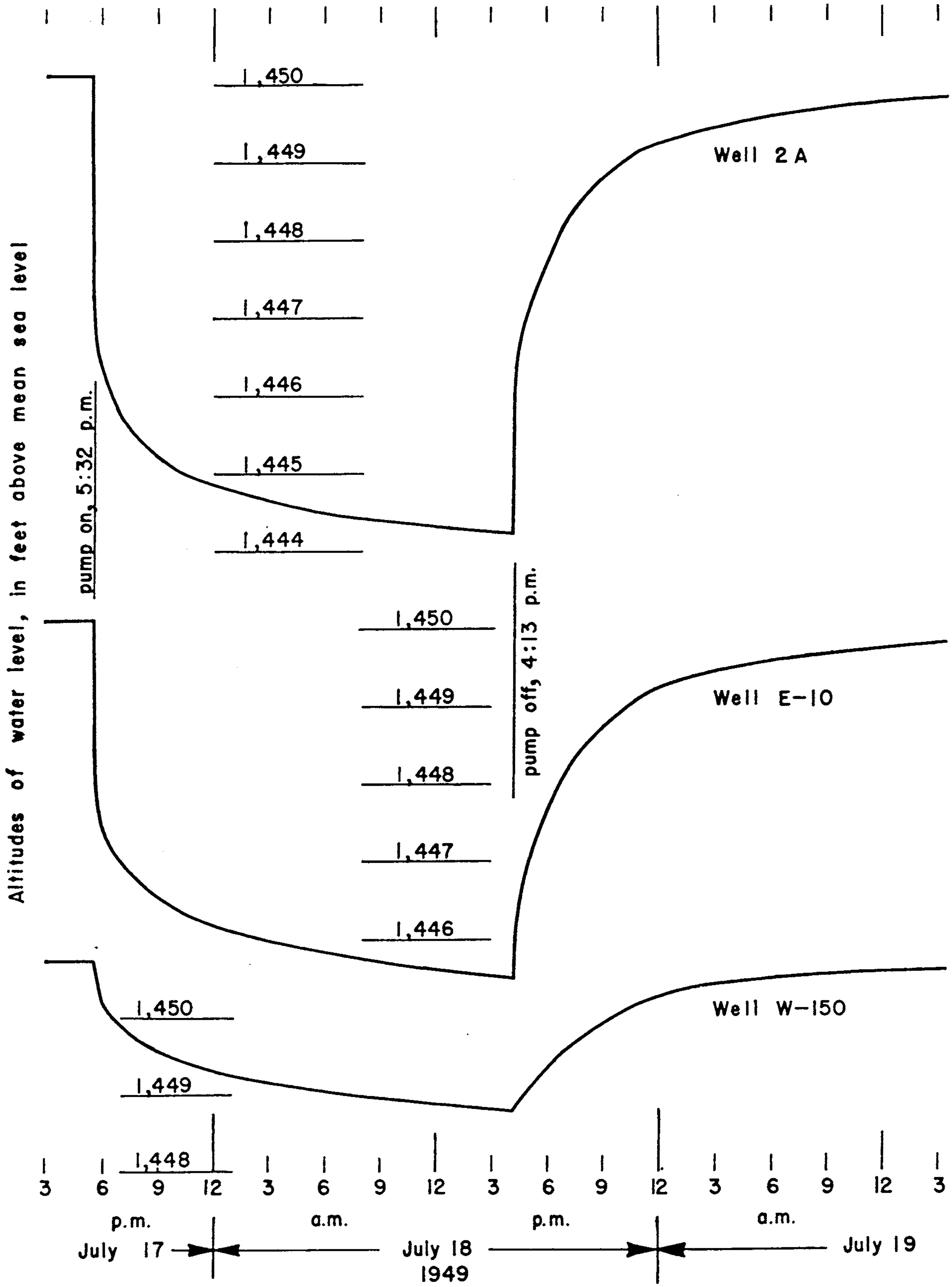

FIGURE 8

HYDROGRAPHS OF WELL 2A(47.46.20.1-2A) AND OBSERVATION WELLS E-10 AND W-150, SHOWING DRAWDOWN AND RECOVERY CAUSED BY PUMPING WELL 2A