STATE OF INDIANA
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

BULLETIN NO. 3

GROUND-WATER RESOURCES

OF

ST. JOSEPH COUNTY, INDIANA

PART 1. SOUTH BEND AREA

PREPARED IN COOPERATION WITH
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

INDIANAPOLIS, INDIANA
1948

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GROUND WATER RESOURCES

OF

SAINT JOSEPH COUNTY, INDIANA

PART 1. SOUTH BEND AREA

By

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Prepared in cooperation with

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

STATE OF INDIANA

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INTRODUCTION

The Indiana Department of Conservation and the United States Geological Survey began an expanded cooperative investigation of the water resources of Indiana, including stream flow, lakes, and ground-water supplies, in July 1943. One of the main objectives of the ground-water phase of the work is to determine the quantity and quality of the available ground-water supplies of the State and the relations between ground-water supplies and other sources of water such as precipitation and stream flow. The basic information pertaining to the ground-water resources of the State is essential to the wise development and economical use of one of Indiana's most important natural resources.

This report is one of the first of a series of bulletins to be released by the Indiana Department of Conservation describing the results of the State-wide water-resources investigation. It was originally planned to release a report on St. Joseph County, but inasmuch as the City of South Bend is one of the largest industrial areas in Indiana, where ground-water supplies are especially important, the report on St. Joseph County will be released in two parts. The present report, Part 1, discusses the results of a detailed study of the ground-water resources of the South Bend area; Part 2, to be released at a later date, will discuss the ground-water resources of the remainder of the county. The work discussed in Part 1 was done in cooperation with the City of South Bend during the period from September 1944 through March 1947.

The work was carried on under the general supervision of C. H. Bechert, Director, Division of Water Resources, Indiana Department of Conservation and O. E. Meinzer and A. N. Sayre, successive Chiefs, Division of Ground Water, United States Geological Survey. The detailed field work was done by the authors, and by J. G. Ferris, B. W. Swartz, H. L. Ballard, and others during the period September 1944 through March 1947, and observations of water level are being continued.

The City of South Bend has been dependent on wells as a source of public water supply for about 60 years. Favorably situated in the valley of the St. Joseph River, which is underlain by extensive deposits of sand and gravel, the city and its many industries have pumped many millions of gallons of water from wells since about 1886. The original public water-supply system, established in 1873, used water from the St. Joseph River until the first wells were drilled at Central Station in 1886. The use of river water was then abandoned and, although its use for public supply has been reconsidered several times by city officials and consulting engineers, high treatment costs, pollution of the river, and an adequate ground-water supply have made the further use of river water impractical up to the present time.

In addition to the large quantities of ground water pumped for the municipal supply, many of the local industries are dependent on private wells for water supply and for cooling and air-conditioning purposes. It is believed that the position of South Bend as one of Indiana's leading industrial centers is due at least in part to the large supplies of underground water which have been available for industrial use at a relatively low cost.

During recent years, it has been generally believed that the water levels in wells in the South Bend area have declined and that at some time in the future the present ground-water supplies may become insufficient to meet the needs of the city and the industries in the area. In looking ahead to the postwar years and future municipal and industrial expansion, the question of the adequacy and future of the ground-water resources of the

South Bend area as a whole should be considered. The future of the individual well fields of the city is closely allied to future industrial expansion within the area.

Purpose and Scope

The purpose of the investigation was to determine insofar as possible the safe yield of the water-bearing formations in the South Bend area of St. Joseph County, or the rates at which water may be drawn from them indefinitely within economic limits and without impairing the quality of the supply. The determination of the safe yield required the study of records of existing wells, the determination of the quantities of water pumped in the past and at the present time, a determination of the hydraulic characteristics of the water-bearing formations and of their extent and thickness, and correlation of ground-water levels, precipitation, and pumpage.

Although the present investigation was concerned chiefly with the ground-water conditions in the industrial area of South Bend, within the corporate limits of the city, information on ground water in the surrounding area of St. Joseph County was necessarily collected during the investigation. The work will be continued and Part 2 of this report, to be prepared in the future, will discuss the ground-water resources of the remainder of the county.

The municipal water-supply system is by far the largest user of ground water in the area, taking its supply of water from wells at five pumping stations widely spaced throughout the city. Information on the wells and well fields of the municipal supply system is given in more detail than that for many of the industrial well supplies, because it was possible to make more detailed pumping tests on the municipal wells and because better records of well construction and operation were available. The values of the hydraulic characteristics of the water-bearing sands and gravels obtained at the municipal well fields are utilized to great advantage in the quantitive estimates of ground-water supply of the entire South Bend area.

This report presents a summary of the work done in the investigation, including a discussion of the geology of the county and its relation to the ground-water supply of the South Bend area; the relation of precipitation and of the St. Joseph River to ground-water supply; a discussion of the present well facilities and the estimated future yields of these sources; and a discussion of the chemical quality of ground water in the South Bend area. The information included in this report is presented for the use of city and industrial officials and consulting engineers for future planning and wise development of ground-water supply in the South Bend area.

Acknowledgments

This investigation would not have been possible without the helpful assistance of C. E. Williams, former City Engineer; and G. L. Cain, Superintendent, and P. M. Shea, Chief Engineer, of the South Bend Water Department. Many data on wells, water supply, and surface elevations were provided by G. Malone of the South Bend Water Department and E. Fleming of the City Engineer's office. Water levels in observation wells were measured by Mr. Fleming and others in the City Engineer's office.

The information included in the tables of well records was provided largely by O. C. Schwier and N. E. Gunderson, of the Layne-Northern Company, Inc., and L. E. Smith and John Toyne, of the Smith-Monroe Company, who have been extremely helpful in making these records available. Chemical analyses of water were made by the Indiana State Board of Health. The assistance and help of the many plant engineers and well owners in the South Bend area in providing information is gratefully acknowledged.

Previous work

Considerable information on the geography, geology, and ground-water supplies of St. Joseph County is available in the reports of many writers. A number of these are listed in the bibliography in Appendix D, and only brief mention of the more important reports will be made here.

Detailed information on the glacial geology of St. Joseph County is given by Frank Leverett in his discussions of the Illinoian (15) 1/ and Wisconsin (16) stages of the Pleistocene epoch. One of the most detailed descriptions of the geology of St. Joseph County, including a discussion of the important changes in drainage, is that by Montgomery (19, 20, 21), and much of the glacial history given in this report is taken from these reports.

Data on wells and ground-water supplies are given by Leverett (13, 14, 16) and by Capps (4) in his discussion of the geology and ground-water resources of northern Indiana. Much valuable information, especially well logs and records of water levels and artesian head, has been taken from these reports. Additional general data on ground-water supplies are given by Harrell (8).

The municipal water supply of South Bend was described by Hammond in 1910 (7), including a detailed description of geology and ground-water conditions in the area. Charles Burdick (2), in an unpublished report in 1911, presented additional information on the ground-water hydrology of the area and gave many records of wells and test borings. Burdick outlined the area which supplied water to the wells of the South Bend area and estimated the yield of the area to be 20 to 30 million gallons of water a day.

In 1921 William Artingstall (1), a consulting engineer of Chicago, again discussed the geology and hydrology of the area and included in his report the results of much additional test drilling, done mainly in the

1/ See references in Appendix D.

southwestern and western parts of the city.

An investigation of ground-water conditions in 1928 by the Burns and McDonnell Engineering Company, consulting engineers of Kansas City, Mo. (3), resulted in additional test drilling, mainly in the eastern and southern parts of the city. The records of about 32 test wells and a pumping test on one of the original wells at the South pumping station of the municipal supply system are included in their report.

In 1945 the report of a recent investigation of the municipal water-supply system by Consoer, Townsend, and Associates (5), consulting engineers of Chicago, Ill., presented recent data on wells, pumpage, and quality of water.

In addition to the reports described above, much information was obtained from the files of the municipal Water Department, the Layne-Northern Company, Inc., and the Smith-Monroe Company and from the files of the many well owners in the South Bend area.

Well records

Records of about 200 wells, located primarily within the corporate limits of South Bend and Mishawaka, are included in tables in Appendix A of this report. The locations of these wells are shown in plate 1. Most of these records were provided by the Smith-Monroe Company of South Bend and by the Layne-Northern Company of Mishawaka. Many additional records were obtained from the files of the City Water Department and by visits to the larger industrial and commercial well owners. Many of the records provided by the well drillers were checked and brought up to date by visiting the wells and talking with the well owners, but it was not possible to visit all the wells for which information is included.

In order to facilitate the location of wells on a key map and the tabulation of well records, a well-numbering system has been adopted for the cooperative water-resources investigation. Under this system the well number has a geographic significance and indicates the location of the well within 1 square mile.

St. Joseph County includes all or parts of 20 townships of the General Land Office system of land subdivision. Each township or part of a township was assigned a letter, beginning in the northwest corner of the county and going eastward along the top tier of townships, as shown in the diagram on plate 2.

The well number consists of a two-letter prefix, Sj, designating St. Joseph County, a letter designating the Federal township, and a number corresponding to the Federal land-survey section number, designating the section within the township. Within a given section, the wells or well fields are numbered consecutively in the order in which information on the wells is obtained. A well field consisting of two or more wells is given a single number and each individual well is given an additional number either the owner's number or an arbitrary number based on the age of the well. Test wells are designated by the letter T preceding the owner's number. Oil and gas wells, the logs of which give important geologic information, are designated by the letter G, preceding the entire well number.

The present system of numbering wells described above had not been established at the time the wells in South Bend were numbered, and within the corporate limits of South Bend the wells were numbered consecutively as information on them was obtained. Rather than to assign new numbers to these wells, causing possible confusion and duplication, the original numbers are retained and a map location symbol is given in the last column of the well tables. The map location symbol corresponds to that described above and will show the square-mile section in which the well is located.

In the tables, the altitude of the land surface at the well is given in feet above city datum (CD) and also above mean sea level (MSL). Altitude above city datum may be corrected to altitude above mean sea level by adding 657.82 feet. The altitudes where given to the nearest foot are estimated from bench marks established by the City Engineer's office and kindly provided to the writers.

GENERAL DESCRIPTION

Location

The City of South Bend is located in St. Joseph County in northern Indiana, about 6 miles south of the Indiana-Michigan State line (fig. 1). The population in 1940 was 101,268, according to the U. S. Census Bureau figures, and South Bend was the third largest city in Indiana. The city has been an active industrial center for many years and during the war years 1941 to 1945 was particularly active in war production. It is believed that during the war period the population was considerably greater than during 1940. The city is bounded on the east by Mishawaka (1940 population, 28,298) another industrial city, which is included as part of the South Bend industrial area.

The other communities in St. Joseph County, including Walkerton, North Liberty, New Carlisle, Lakeville, Osceola, and Granger, are small agricultural towns, widely spaced throughout the county. Walkerton, North Liberty, New Carlisle, and Lakeville have municipal water-supply systems.

Climate

Climatological data have been recorded in the South Bend area by the U. S. Weather Bureau since 1862, although the earlier records are not continuous. In 1893 a weather station was established at the Federal Building and systematic collection of data was continued until 1938. In 1941 a first-order Weather Bureau station was established at the South Bend airport, about 4 miles northwest of the Federal Building, and detailed records of temperature, precipitation, and other weather data have been continued to date (25, 26).

Weather observations have been made at Notre Dame by the University of Notre Dame since 1912. The records are generally similar to those at the

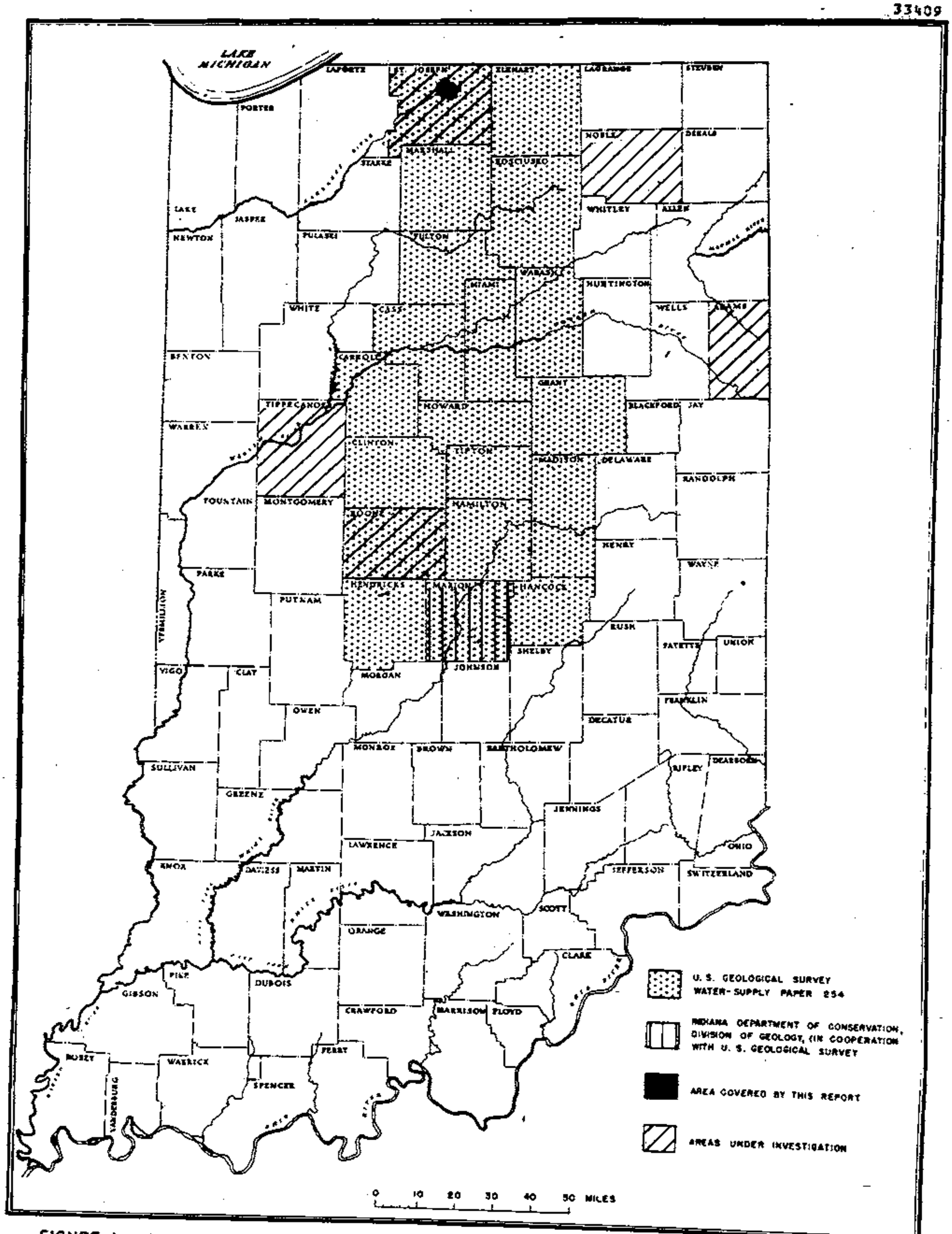


FIGURE 1. MAP OF INDIANA SHOWING LOCATION OF AREAS ON WHICH REPORTS HAVE BEEN PUBLISHED, AREA DESCRIBED IN THIS REPORT, AND AREAS UNDER INVESTIGATION

South Bend station. For the period from May 1938 to January 1941 the observations at Notre Dame are especially important, as no other records of climate were being maintained in the area during this period.

The climate of the South Bend area is typical of northern Indiana and southern Michigan. Although the area is comparatively close to Lake Michigan, the effect of the lake on climatic conditions is probably small. The prevailing wind is from the southwest.

The mean annual air temperature at South Bend is 48° F. The growing season between the last killing frost in spring and the first killing frost in fall is usually about 160 days. The temperature has ranged from a maximum of about 109° to a minimum of about -22° F. during the period of record.

Precipitation in the South Bend area is fairly well distributed throughout the year, although the winter months are usually somewhat drier than the remainder of the year. The average precipitation by months and seasons is given in table 1.

Table 1. Normal 2/ monthly and seasonal precipitation, in inches, at the Federal Building, South Bend, Indiana. (Based on records for 1894 to 1937, inclusive.)

Winter		Spring		Summer		Autumn	
December	2.56	March	2.83	June	3.21	September	3.32
January	2.25	April	2.95	July	3.01	October	2.88
February	1.73	May	3.73	August	3.44	November	2.85
	6.54		9.51		9.66		9.05

The normal annual precipitation at the Federal Building, on the basis of the U. S. Weather Bureau records, is 34.76 inches 2/. The heaviest precipitation generally falls in May, when conditions for ground-water recharge are especially favorable. During the spring months the ground is generally unfrozen and losses by evaporation and transpiration are low. During the summer months, although the average precipitation for the 3-month period is

2/ The normal as used by the U. S. Weather Bureau is an adopted normal based on the precipitation records at the South Bend airport and at the Notre Dame station.

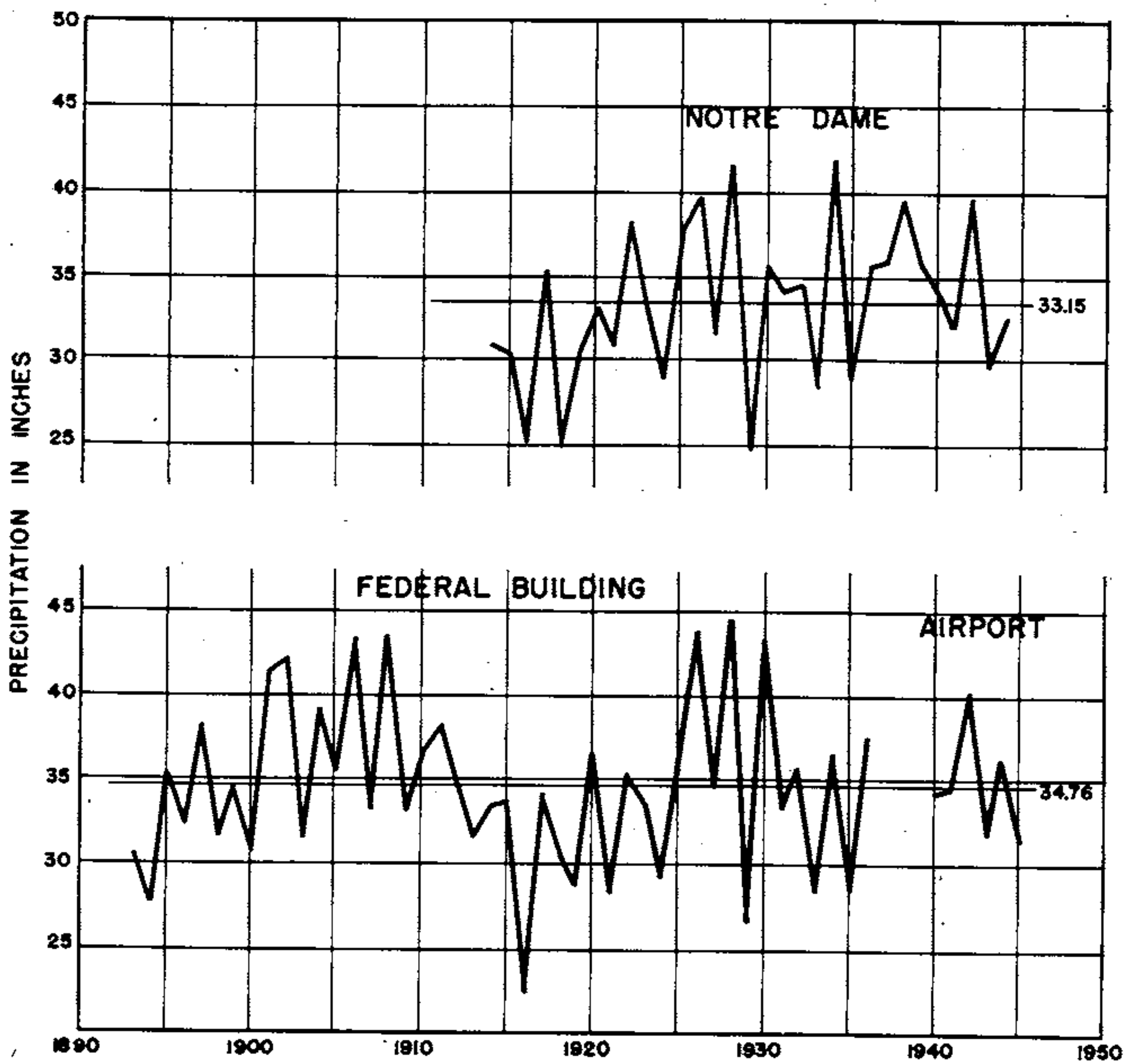
greater than during the spring, recharge to the ground-water reservoir is not particularly effective because of high losses due to evapo-transpiration and to replenishment of deficient soil moisture.

The annual precipitation at the Federal Building, South Bend, for the period 1894-1937, at Notre Dame for 1914-1946, and at the South Bend airport for 1941-1946, is shown in figure 2. During the period 1901 to 1913 the precipitation was in general above normal. This was followed by a period, 1913-1925, of below-normal precipitation. During the period 1926 to 1946, with the exception of the drought years 1930, 1934, 1936, and 1944, precipitation has been generally above normal. Thus, conditions for recharge from precipitation had been favorable for a considerable period of time prior to the present investigation.

Topography and drainage

The northern part of St. Joseph County is characterized by relatively flat plains crossed by low glacial ridges. The largest of the ridges, the Maxinkuckee moraine, rises in the southern part of South Bend (pl. 2) and extends south and southwest nearly to Rochester in Fulton County. The ridge is about 3 miles wide near its northern end and widens to nearly 13 miles near Lake Maxinkuckee. The ridge rises nearly 120 feet above the valley of the St. Joseph River at South Bend and reaches a maximum elevation of nearly 900 feet above sea level about 3 miles south of South Bend.

Two smaller ridges of the Kalamazoo moraine system extend southward from Michigan into St. Joseph County (16, pp. 173-184). One, east of the St. Joseph River, terminates northeast of the campus of the University of Notre Dame. Another narrow ridge, west of the river, extends southward near Lydick. The main moraine of the Valparaiso system cuts across the northwest



NORMAL ANNUAL PRECIPITATION FOR PERIOD OF RECORD

FEDERAL BUILDING	34.76
NOTRE DAME	33.15
AIRPORT	34.76

FIGURE 2. ANNUAL PRECIPITATION AT NOTRE DAME, FEDERAL BUILDING, AND AIRPORT, SOUTH BEND, ST. JOSEPH COUNTY, INDIANA

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corner of the county. These morainal ridges are considerably smaller than the Maxinkuckee moraine in the southern part of the county.

The remainder of the county is comparatively flat, consisting of the outwash plain and alluvial valley of the St. Joseph River, the sand plains adjacent to the Kankakee River, and the upland till-plain areas in the south-central and southeastern parts of the county.

Within the limits of South Bend the local relief is generally small. The valley of the St. Joseph River is about 70 feet below the level of the hills to the north and nearly 100 feet below the hills in the southern part of the city.

The St. Joseph River is the main stream of the area, entering the county east of Mishawaka, running westward to South Bend, where it swings northward in a sharp bend to enter Michigan west of Roseland, Indiana. The main tributary of the St. Joseph River in St. Joseph County is Baugo Creek, which drains the east-central part of the county through the Rogers Ditch, flows northeastward into Elkhart County, back into St. Joseph County, and enters the St. Joseph River near Osceola, Indiana. The State Ditch draining the northeastern part of the county flows westward to join the river north of Notre Dame. Bowman Creek, flowing northeast, joins the St. Joseph River in South Bend.

The Kankakee River, flowing southwest from South Bend, is now mainly a dredged drainage ditch. Its main tributaries are Geyer Ditch, draining the northwestern part of the county and joining the Kankakee near Crumstown, and Potato Creek, draining the southwest part of the county and entering the Kankakee west of North Liberty.

The flow of the St. Joseph River is controlled by dams throughout much of its length and is utilized extensively for power purposes, particularly at the Twin Branch plant of the Indiana and Michigan Electric Company, east of Mishawaka, at Mishawaka, and at South Bend. The use of the river for power by the smaller industries is declining, however, because of the availability of more convenient electric power.

GEOLOGY IN RELATION TO WATER SUPPLY

The occurrence of ground water is controlled to a large extent by the type and structure of the consolidated rocks and unconsolidated materials of the earth's crust. The present topographic and surficial geologic features of St. Joseph County are due mainly to changes made during the Pleistocene epoch of geologic time, during which the northern part of the United States was covered several times by vast ice sheets. The bedrock formations of St. Joseph County are buried beneath 100 to 250 feet of glacial deposits that constitute the large underground reservoirs from which the wells of the South Bend area obtain their water supply.

The geology and glacial history of St. Joseph County have been described in detail by Montgomery (19, 20, 21) and others (4, 15, 16). Much of the following discussion is taken from these reports.

Bedrock geology

Although the bedrock formations of St. Joseph County do not crop out at the surface and are buried everywhere by glacial material, they have been considered in the past as possible sources of ground water. Information regarding these formations must be obtained from deep drilling, most of which has been done in an unsuccessful search for oil and gas. The logs of several of these wells, included in Appendix B, serve to show the type of rock formations to considerable depths. The locations of these wells are shown on plate 2.

The youngest bedrock formations underlying the glacial drift are reported to be shales of Mississippian and Devonian age, corresponding in age to the shales of the Borden group and the New Albany shale of southern Indiana and the Coldwater and Antrim shales of southern Michigan. According to well logs, the total thickness of these shales ranges from about 35 feet to nearly 400 feet.

These formations are underlain by a series of limestones and dolomites of Devonian and Silurian age ranging in total thickness from about 700 to nearly 900 feet. These are underlain by shales of Ordovician age, 200 to 400 feet thick, and the Ordovician Trenton limestone, from which most of the oil and gas in northern Indiana is obtained.

The Mississippian and Devonian shales are essentially impermeable and non-water bearing and are generally considered as poor sources of water. Although the Devonian and Silurian limestones and dolomites underlying the shales yield fresh water in some parts of the State, it is believed that they are too deeply buried in St. Joseph County to yield potable water. The water from the still more deeply buried formations is likely to be highly mineralized and unsuitable for most uses. Ground-water supplies from wells tapping the bedrock formations in St. Joseph County have not been extensively used, primarily because the water supplies obtained from wells in the glacial deposits have been adequate.

Glacial history

The surface of St. Joseph County was exposed to the various agencies of weathering and erosion following the deposition of the bedrock formations and the disappearance of the great inland seas. The surface features of St. Joseph County are believed to have been those of a mature but rejuvenated stage of topographic development, with broad, gently rolling uplands dissected by narrow entrenched valleys. Evidence obtained from well records shows that the bedrock surface underlying the glacial deposits is irregular and that steep-walled valleys were deeply entrenched below the general upland levels. A contour map of the bedrock topography in the South Bend area is shown in plate 3. The maximum elevation of bedrock is found in the south-central part of the city. A hill of bedrock extends from a point just north of the Studebaker Aviation Corporation plant (Sj 39-T1 to Sj 39-T3) nearly to Washington Street, apparently forcing the stream which entered the area near the southeastern corner of the city to swing northward, probably passing between North and Central Stations. The main stream was joined near Wilber Street and Lincoln Way West by a tributary from the northeast. Other tributaries are shown in the northern, southern, and southwestern parts of the city.

The contour map shown in plate 3 is based on the records of wells and test borings, many of which are grouped in local areas. As additional wells are drilled in other parts of the city, it may be necessary to revise the map. In many of the well logs "blue clay" is reported lying on top of "blue shale". In preparing the map, it was necessary in several wells to assume that "blue clay" was really shale, rather than glacial blue clay. The surface elevations were estimated from bench marks of the City of South Bend.

The bedrock topography, as shown in plate 3, was probably somewhat different before it was modified during the Pleistocene epoch. It is believed that the main valleys and drainage lines had been established prior to the advance of the ice, but that considerable downcutting and deepening of the existing valleys may have occurred during the Pleistocene epoch, when the drainage system then existing was changed.

During the Pleistocene epoch, often called the "Great Ice Age", climatic changes caused large masses of ice to accumulate in the northern part of the North American continent. Large sheets of ice known as continental glaciers moved generally southward from the centers of accumulation and covered large areas in the northern part of the United States. The northern part of Indiana was covered, at least twice and perhaps four times, by continental glaciers. The last and perhaps, the most important glacier from the point of view of ground water is that of the Wisconsin stage, which is believed to have furnished much of the material for the ground-water reservoirs in the vicinity of South Bend.

As the ice sheets moved forward at a comparatively slow rate, the soil and weathered rock material were scraped off the underlying bedrock surface and were carried within the ice. The continental glaciers were eroding agents of great force, moving large quantities of material during their forward advance and redepositing the materials as the ice sheets melted. The southward advance of the ice sheets was halted when the rate of melting of the ice front equalled the forward movement of the ice. As the ice fronts melted, the material carried within the ice either was dropped in place with little sorting or stratification or was carried away from the ice front by the large streams of melt water, washed, sorted, and redeposited as stratified material. The unsorted material, composed of mixtures of clay, sand, and gravel, is called boulder clay or glacial till. The stratified deposits of sand and gravel are designated as glacial outwash.

Where the front of the ice sheet remained at about the same position for considerable periods of time, narrow ridges of glacial material called moraines were built up and remained when the ice disappeared. The accurate, detailed mapping of glacial moraines that has been done in Indiana has been important in showing the extent of the glaciated areas and the directions of movement of the different ice sheets and their lobes.

The present topographic features of St. Joseph County are due primarily to deposits formed during the retreat of the last ice sheet to cover the area, that of the Wisconsin stage, and to erosional changes during the Recent epoch. The ice sheet of Wisconsin age moved southward through the several basins of the present Great Lakes in a series of long, tongue-like lobes. One lobe, following the present basin of Saginaw Bay and referred to as the Saginaw lobe, moved southwestward and reached a point several miles west of Logansport, Indiana. The first recessional moraine deposited during the retreat of the Saginaw lobe, called the Maxinkuckee moraine, rises near the southern part of South Bend (see pl. 2) and extends southward nearly to Rochester as a broad ridge with an irregular surface. The ridge ranges from about 3 to 15 miles in width and rises generally 50 to 60 feet above the level of the surrounding till and outwash plains.

The Lake Michigan lobe, following the present basin of Lake Michigan, advanced as far as the northwest corner of St. Joseph County. The higher ridges deposited by this lobe are parts of the Valparaiso and Kalamazoo morainic systems and are characterized by irregular topography, lakes, and poor drainage. Two tongue-like extensions of the Kalamazoo morainic system extend into St. Joseph County. One is west of the St. Joseph River, following the Chain-o'-Lakes as far south as Chamberlin Lake, and the other is east of the river, forming the higher ground northeast of the University of Notre Dame.

During the retreat of the last ice sheet in Wisconsin time the present valley of the St. Joseph River was continuous with that of the Kankakee River, draining a large section of southeastern Michigan westward and southward, probably into the Illinois-Mississippi drainage system. The combined St. Joseph-Kankakee drainage carried large quantities of melt water from the retreating ice front. A large tributary, the Dowagiac River, flowed southward from south-central Michigan to join the main stream at South Bend.

As the ice front continued to move northward, a large lake was formed between the ice front and the terminal moraines at the south end of the Michigan Basin. It was known as glacial Lake Chicago and was the ancestor of the present Lake Michigan. One outlet of the lake flowed southeastward from St. Joseph, Michigan, to join the Dowagiac River near Niles, Michigan. The combined drainage flowed southward into the combined St. Joseph-Kankakee River near South Bend and on to the west. As the retreat of the ice front continued, an outlet for the lake water was formed near Chicago through the Des Plaines River and the higher St. Joseph outlet was abandoned. As the ice front continued to retreat, successively lower outlets were uncovered, the lake level continued to fall, and the flow in the Dowagiac River and its former tributary was reversed toward the lake because of the steeper gradient in that direction. The lower part of the Dowagiac River between Niles and South Bend was also reversed and flowed northward into the lake. By headward erosion, this tributary finally intercepted the entire flow of the old St. Joseph-Kankakee River above South Bend and the present course of the St. Joseph River into Lake Michigan was established.

During the period when the Kankakee River was carrying large quantities of water from the melting ice fronts, a large valley was excavated in the underlying rocks. When the flow of the river was decreased by the withdrawal of the ice and by the changes in drainage, large quantities of sand and gravel were deposited in the valley, forming the underground reservoirs from which large quantities of water may be pumped.

Glacial deposits

The bedrock formations of St. Joseph County are covered by glacial materials which range in thickness from about 70 feet to nearly 300 feet. These deposits were laid down under a complex set of natural conditions and may differ widely in character within short distances, both horizontally and vertically. The detailed correlation of one specific stratum from one well to another nearby is difficult and sometimes impossible. There are, however, several main types of material, the differentiation of which is important from the standpoint of ground-water supply.

The upland morainal and the till-plain deposits (pl. 2) are primarily boulder clay or clay with minor amounts of sand, gravel, and angular rock fragments. These materials were carried within the ice sheet and, as the ice melted, were dumped more or less in place without sorting or stratification. The clay deposits are generally non-water bearing, although small, discontinuous lenses of sand and gravel within the clay provide small water supplies for domestic and farm uses to wells in the moraine and till-plain areas.

The outwash plains and terraces adjacent to the moraines and along the valleys are underlain largely by sand and gravel deposited by glacial torrents from the melting ice fronts. Most of the silt and clay was carried beyond the outwash plains, leaving a comparatively coarse-textured deposit of sand and gravel. Where exposed in gravel pits and other excavations, these deposits are seen to be cross-bedded irregularly, and interfingering channel deposits of sand and gravel are common. Interbedded with the outwash deposits are lenticular beds of clay, some of which are of small areal extent and others may persist over broad areas. The clay deposits are believed to separate outwash materials of different ages. The deeper sands and gravels were deposited during an earlier substage of the Wisconsin stage than the shallow outwash or perhaps during the Illinoian stage. The clay beds may represent either glacial till deposits or lacustrine deposits laid down when the St. Joseph River was dammed temporarily.

The alluvial formations along the valley of St. Joseph River and along the abandoned channels of glacial streams are sand and gravel deposits, generally somewhat more uniform and finer in texture than those of the main outwash plain into which the valleys are cut. Relatively thin strata of clay, sometimes called hardpan, are interbedded with the sands and gravels. Some of the beds of clay are continuous over extensive areas, and other are discontinuous lenses which may pinch out within shore distances. The clay, although it may compose only a small part of the total thickness of the alluvial deposits, may be extremely important in confining the water in the underlying water-bearing beds under pressure, and it may hinder greatly the recharge of water to the water-bearing beds from precipitation, streams, and lakes.

In attempting to determine the relative potentialities of the surficial materials of St. Joseph County to absorb water from precipitation, Burdick (2) has made estimates of the areas of the county occupied by each type of deposit, as follows:

Till	24 percent
Moraine	24 percent
Outwash	7 percent
Alluvium	45 percent

Recent study of aerial photographs and an unpublished soils map (29) provided by H. P. Ulrich, of the Purdue University Agricultural Experiment Station, suggest that Burdick's estimates of the areas of till and moraine may be too high and that of the area of outwash too low.

Within the city limits of South Bend, fairly detailed information on the succession of glacial deposits has been obtained from the logs of 79 test wells drilled for the City of South Bend prior to 1942 and about 162 additional private wells drilled for industrial water supply and for test purposes. The information obtained from these wells is shown by several cross sections in plates 4 and 5. The locations of these sections are shown on plate 1.

In general the glacial deposits of the South Bend area may be separated into three zones that are generally but not always present throughout the city. A shallow zone of water-bearing sand and gravel is underlain by a zone in which clay and glacial till predominate. The clay zone is underlain in turn by a deeper zone of water-bearing sand and gravel. The material in the clay zone is sufficiently impermeable and continuous to act as a confining layer for the water in the deeper formations throughout a large part of the city.

Section AB (pl. 4) shows a profile of the glacial deposits across the St. Joseph River, near the north end of the city. The principal water-bearing beds lie immediately above the bedrock and range in thickness from about 25 to nearly 100 feet. The upper parts of these beds are quite sandy near the central part of the section. These are overlain by strata of clay and sandy clay which appear to be continuous over a considerable area. The continuity of the clay is further evidenced by the presence of flowing wells in the northern part of South Bend and by the results of pumping tests at North Station. The clay becomes thinner near the river, where it overlies very fine sand. The shallow sands and gravels overlie the clay, becoming thicker under the uplands away from the river.

The thinning of the clay near the river and the interbedding of lenses of fine sand with the clay in this area suggest that the clays may be missing in some localities, either because it has been cut out by stream erosion since its deposition or because it grades laterally into fine sand. If this is true, the clay may act as a confining layer for the underlying water-bearing beds and yet permit some leakage of water to the river. This is discussed later in the report.

Section CD (pl. 4), from the southwestern part of the city to Coquillard Station in the northeastern corner, shows that the deeper water-bearing beds are comparatively thick in the southwestern part of the city, reaching a maximum of nearly 110 feet in thickness. These beds thin quite rapidly to the east and in the vicinity of Lafayette and Main Streets, south of Sample Street, are only a few feet thick. North of Sample Street they are thicker. The deeper sands and gravels also become thicker again east and north of the river. The clay layer separating the shallow gravels from the deeper appears to be continuous on both sides of the river and under the river.

Section ED (pl. 4) in the eastern part of the city, from Erskine Park (Sj 6-3K) north to Coquillard Station (Sj 5-1), shows that the deeper sands and gravels are missing in the southern part of the city and are present only in the area north of the river. The deeply buried channel in the bedrock, shown in plate 3, is apparently filled with clay. The shallow sands and gravels, especially thick south of the river, apparently pinch out north of the river and are not connected with similar shallow sands and gravels at the Coquillard Station. The channel of the St. Joseph River is cut into the shallow sands and gravels in this area and conditions for natural discharge and recharge are favorable.

The geology of the glacial deposits in the southwestern part of the city is more complex than elsewhere, as shown by section FE, plate 5. The clays separating the shallow and deep sands and gravels are not continuous, but occur as discontinuous lenses of small areal extent. In the vicinity of the Bendix plant and the Oliver Park Station, the clay lenses are sufficiently large to create artesian conditions, but except in these areas the sands and gravels appear as one formation. The logs of wells Sj 6-16A, Sj 6-10A, Sj 6-7A, Sj 6-6A, Sj 6-3A, and Sj 6-2A showed no clay. The absence of the clay may indicate that a channel was cut through the clay beds and was later filled by permeable sands and gravels. However, the correlations between wells as shown in plate 5, section FE, must be regarded as tentative. South of Ewing Avenue the clay lenses become smaller and at South Station (wells Sj 7-T32 and Sj 3-4) the water in the sands and gravels is not confined. The water-bearing materials become finer in texture and more sandy in the southern part of the area.

In order to throw light on the question as to whether geologic conditions along the St. Joseph River would permit direct recharge to the deeper water-bearing beds from the river if the head in these beds were brought below river level, a cross-section GH (pl. 5) was constructed from St. Mary's Convent to Playland Park. The clay bed appears to pinch out in the vicinity of Sample Street (wells Sj 13-T1 and Sj 7-14). South and east of Sample Street the clay is absent and the sands and gravels underlie the surface and the channel of the river. This area probably serves as an intake area for the deeper water-bearing beds.

OCCURRENCE OF GROUND WATER

Water from precipitation on the earth's surface is disposed of by evaporation and transpiration; runs off as surface flow; or seeps into the ground, filling small voids or interstices in the rocks of the earth's crust and eventually reaching areas of ground-water discharge. Rocks differ greatly in the number, size, and shape of the voids they contain. In dense, consolidated rocks the voids are small cracks, joints, and fissures. In fragmental rocks, interstices exist between the individual particles of material. The interstices are usually interconnected, allowing water to flow through the rocks except where the interstices are so small, as in clay, that water moves through them slowly or not at all under the heads existing in nature.

Where porous and permeable material is exposed at the surface, water from precipitation and from surface bodies of water fills the interstices in the lower part of the material. The zone in which the interstices are filled with water is the zone of saturation and its upper surface is called the water table. Where the water-bearing formation or aquifer is exposed directly at the surface, ground water occurs under water-table conditions and the position of the water table is indicated in a general way by the water levels in wells. Under water-table conditions the aquifer acts primarily as a storage reservoir.

Where a saturated water-bearing formation is confined by relatively impermeable clay or glacial till, the water in the aquifer is under hydrostatic or artesian pressure. Recharge of water to the aquifer must take place through a relatively limited outcrop area or, where the artesian pressure is lowered sufficiently by pumping, in small quantities through the confining layers. Under artesian conditions, the surface indicated by the water levels in wells tapping the aquifer is the pressure-indicating or piezometric surface. Artesian aquifers act primarily as conduits through which the water passes and secondarily as storage reservoirs. This distinction is important in the South Bend area, as both types of conditions are present and control to some extent the quantities of water that can be pumped in certain locations.

The principles of occurrence of ground water are discussed in detail by Meinzer (17,18), Tolman (24), Wenzel (27), and others and the interested reader is referred to their works for additional study.

The property of having voids is called porosity and is expressed quantitatively as the percentage of the total volume that is occupied by voids; that is, not occupied by solid rock material (17). Porosity depends mainly on the uniformity of grain size and packing arrangement of the individual fragments, not on the size of the particles. A sand composed of well-rounded particles of uniform size may have a higher porosity than a poorly sorted gravel composed of particles of different sizes and shapes. Clays, although they are very fine-grained, usually have a high porosity.

In the zone of saturation, all interstices are presumably filled with water. As the water table is lowered, the interstices are partially emptied. Molecular forces, counteracting the force of gravity, cause water to be held on the surfaces of the individual particles. Therefore, the quantity of water released from the interstices by lowering the water table is not as great as the porosity, nor directly related to it. The ability of a rock to yield water is measured by its coefficient of storage, which is expressed as the quantity (in cubic feet) of water that is released from a vertical prism of the material, 1 square foot in cross-sectional area, when the pressure head in the formation is lowered 1 foot. Where the water-bearing materials are unconfined, and water-table conditions exist, the coefficient of storage is usually called the specific yield. Gravels may have high porosity and a high specific yield, whereas most clays have a high porosity and a low specific yield. In the South Bend area, water-table conditions exist at many localities. However, as the areal extent of these localities has not been determined in detail, the term "storage coefficient" as used in this report includes the term "specific yield" and is used to refer to the storage characteristics of the South Bend area as a whole.

The ability of a material to transmit water is measured by its coefficient of permeability, which is expressed as the rate of flow, in gallons a day, that will pass through a cross-sectional area of 1 square foot of material under a hydraulic gradient of 1 foot per foot at a temperature of 60° F. The coefficient of transmissibility is equal to the product of the coefficient of permeability and the saturated thickness of the formation, and is expressed as the number of gallons of water a day that will pass through a vertical strip of the water-bearing formation, 1 foot wide and having the full height of the saturated part of the aquifer, under a unit hydraulic gradient. It may also be expressed as the quantity of water in gallons a day that will flow through a section of the aquifer 1 mile wide under a hydraulic gradient of 1 foot per mile.

The coefficients of storage and transmissibility are hydraulic characteristics of a water-bearing formation that govern the flow of ground water through the formation and the interference effects between wells. These properties will be different for different aquifers and may change within short distances within the same aquifer. Such variability is especially marked in the aquifers of the South Bend area.

Methods for determining the coefficients of storage, specific yield, and transmissibility are discussed by Wenzel (27), Tolman (24), Theis (23), Cooper and Jacob (6), Jacob (9) and others. A complete discussion of these methods is beyond the scope of this report.

DEVELOPMENT OF GROUND WATER

Municipal well fields

The municipal water-supply system of South Bend is supplied by five well fields at widely spaced locations in the city. These well fields and pumping stations have been discussed in detail in a recent report (5) and only brief descriptions will be included in this report.

Central Pumping Station - The first public water supply was put into service in December 1873, utilizing water from the St. Joseph River through the Central Pumping Station, located on the west bank of the river at the foot of Washington Street. The use of river water was abandoned and by 1886 twenty-five wells (Sj 2-1 to Sj 2-25) had been drilled at Central Station, both on the south side of the mill race and on the island, where the construction office now stands (7, 30). These wells were 4 to 8 inches in diameter and had an average depth of about 87 feet. In 1906 the wells flowed, and the artesian head was about 2 feet above the land surface (4). The wells were originally pumped by steam suction pumps and the water was repumped through high-service pumps to the distribution system. By 1915 the number of wells at Central Station had been increased to 38, and in that year the average pumpage from the station was about 2.42 million gallons of water per day. In 1921 the station was rebuilt and electrified. The maximum pumpage from this system occurred in 1922, averaging 3.42 million gallons per day.

In 1942 a large gravel-wall well was drilled by the Layne-Northern Company at the southeast corner of the pumping station (Sj-2-36). The well has an outer casing 50 inches in diameter, an inner casing 38 inches in diameter, and a total depth of 108.5 feet. On test, 2,100 gallons per minute was pumped for 7 hours, with a drawdown of 43 feet. The 35 remaining wells of the old suction system were abandoned, and sealed in 1942. The well at Central Station is now used more or less intermittently to maintain high pressure in the downtown area of South Bend. The maximum monthly pumpage from June 1943 to June 1946 occurred during July 1945, when 58.6 million gallons or an average of 1.89 million gallons a day was pumped.

North Pumping Station - In 1895 a new pumping station, known as North Station, was built on a 6-acre tract east of Michigan Street and south of St. Joseph River. Thirty wells were drilled at this site on the assumption that the river would replenish the water pumped from the wells (7). (However, tests made during the present investigation in 1945 showed no direct connection between the river and the ground-water body in this area.) One of the first wells drilled had an artesian head of 11 feet above the land surface. The wells were 6 inches in diameter and had an average depth of about 85 feet. The wells were pumped by suction and the water was repumped through high-service pumps to the distribution system. Pumping was done by steam. A 6 million gallon covered ground reservoir was later added to provide storage. Additional wells were added to the system, as the demand increased, until 1939, by which time a total of 52 wells had been drilled in the well field.

In 1939 construction of three new large-diameter gravel-wall wells, (Sj 1-53, Sj 1-54, and Sj 1-55) was started by the Layne-Northern Company. These wells have an outer casing 60 inches in diameter and an inner casing 38 inches in diameter and are 103 to 110 feet deep. The original yield of each of these wells was about 2,200 gallons per minute, and the drawdowns ranged from 24 to 34 feet after 8 hours of pumping. A fourth well (Sj 1-56), similar to the other three wells, was drilled in November 1946 by the Layne-

Northern Company to augment the supply from North Station.

The maximum annual pumpage from the old suction system was in 1922, a total of 2,126 million gallons, or an average pumpage of 5.83 million gallons a day. The maximum monthly pumpage from the new system during the perion 1940 to June 1946 occurred in August 1941, when a total of 252.2 million gallons was pumped during the month, an average daily pumpage of 8.14 million gallons.

North Station is now the main station of the system and supplies a greater quantity of water than any of the other stations. The station was being completely electrified during 1947.

Oliver Park Pumping Station - In 1924 construction of a new well field and pumping station, known as the Oliver Park Station, was started in the southwestern part of the city near Olive and Sample Streets. The well field consists of 27 twelve-inch wells, ranging in depth from about 120 to 170 feet. The wells are connected to a common header and are pumped by suction into a clear well 48 feet deep.

The water is repumped by high-service pumps to the distribution system. Pumping is done by steam power. The maximum monthly pumpage during the period August 1924 to June 1946 was 172.5 million gallons in July 1929, or an average of 4.73 million gallons a day.

A new large-diameter gravel-wall well (Sj 4-28) was drilled in March 1947 by the Layne-Northern Company to provide additional water during peak periods. The well has an outer casing 38 inches in diameter, an inner casing 26 inches in diameter, and a depth of 170 feet. On test, a yield of 2,300 gallons per minute, pumping for 23 hours, was obtained with a drawdown of 22.0 feet. This is one of the most productive wells in the South Bend area and should provide ample water for high-service pumping at the Oliver Park Station.

The Oliver Park Station is well-situated to maintain adequate quantities of water and pressure to the industrial area of South Bend, which is mainly in the southwestern part of the city. The availability of railroad service and a good water supply in this area should encourage the establishment of industrial plants.

South Pumping Station - In 1927 construction of a fourth pumping station, known as South Station, was started in the southern part of the city, near Chippewa Avenue and the Pennsylvania Railroad. The original field consisted of three gravel-wall wells, each having an outer steel casing of unknown diameter and an inner concrete casing having an inside diameter of 18 inches. The depths were 80 to 90 feet. On test the original well (Sj 3-2) yielded 1,423 gallons per minute with a drawdown of 19.4 feet (3). The maximum monthly pumpage from this system was 111.1 million gallons, or an average of 3.7 million gallons a day, in September 1944. This station is pumped intermittently to maintain pressure and to supply a booster station serving the southern part of the city. The station is completely electrified.

In 1942 a fourth gravel-wall well (Sj 3-4) was drilled by the Layne-Northern Company. The well has an outer steel casing 38 inches in diameter, an inner casing 18 inches in diameter, and a depth of 111 feet. Because of shortages of construction materials during the war period, this well was not put into service until 1946.

Coquillard Pumping Station - In order to provide adequate water to the fast-developing residential area in the northeastern corner of the city, a fifth pumping station, known as the Coquillard Station, was established in 1931, about 2,900 feet north of the city limits and about 900 feet east of Ironwood Drive. A gravel-wall well (Sj 5-1) having an outer casing 50 inches in diameter and an inner casing 26 inches in diameter was drilled by the

Layne-Northern Company. The well is 205 feet deep. In a test in January 1945 the well yielded 1,600 gallons per minute for about 8 days with a drawdown of 15.3 feet. This station is electrified and is operated intermittently as needed.

Industrial water supplies

In addition to the large quantities of water pumped from wells in the South Bend area for municipal supply, an additional quantity of water is pumped from private wells for industrial use, including condenser cooling, and air conditioning. Because of its relatively constant temperature which, in most areas, is about equal to or slightly above the mean annual air temperature, ground water is preferred to surface water for many industrial processes and especially for air conditioning. In view of the fact that the well fields of several of the larger industries are comparable in size and yield to those of the city, these fields will be described briefly.

Bendix Aviation Corporation - The water supply for the Bendix plant, located in the western part of the city at Bendix Drive and Westmore Street, is taken from two wells, 20 inches in diameter and about 208 feet deep (Sj 23-1 and Sj 23-2). These wells are reported to yield 1,600 gallons per minute each with a drawdown of about 40 feet. Two other smaller wells (Sj 23-3 and Sj 23-4) are now abandoned, and one of these (Sj 23-3) is now used as an observation well. A graph of water levels in this well is given in figure 4. The operation of the supply wells is automatically controlled by the pressure in the distribution system. The water is aerated, softened, and chlorinated.

Drewry's, Ltd. - The water supply for the plant of Drewry's Ltd., on Elwood Avenue, east of Wilber Street, is taken from three wells (Sj 12-1, Sj 12-2, and Sj 12-3) 6 and 8 inches in diameter and 140-160 feet deep.

The yields of the wells range from 270 to 630 gallons per minute. The water is softened and is used for all purposes, largely for cooling. The temperature of the water in 1944 was 55° F.

Oliver Farm Equipment Company - The water supply for the Oliver Farm Equipment Company plant, at Chapin and Ford Streets, was originally taken from a large dug well (Sj 25-1) 12 feet in diameter and 30 feet deep, with an estimated yield of 800-900 gallons per minute. In 1945 a gravel-wall well (Sj 25-2) having a 50-inch outer casing and an 18-inch inner casing was drilled to a depth of 95½ feet. The yield of this well was 1,000 gallons per minute, for 7 hours, with a drawdown of 34 feet. The actual use of water at this plant is comparatively small.

Studebaker Corporation - Considerable difficulty has been experienced at the Studebaker Corporation plant, at Sample and Lafayette Streets, in maintaining an adequate ground-water supply. The depth to bedrock is about 100 feet and the glacial materials consist mainly of two water-bearing formations of sand and gravel, separated by nearly 40 feet of relatively impermeable clay. The thickness and character of the lower stratum differ from place to place, and as far as is known only one well (Sj 24-12) obtains water from the lower formation. The upper formation, although it is thicker than the lower, is primarily sand, containing little gravel, and yields only moderate supplies of water to wells. In June 1944 only six of nine available wells were in service, and several additional wells were shut down during 1945 and 1946.

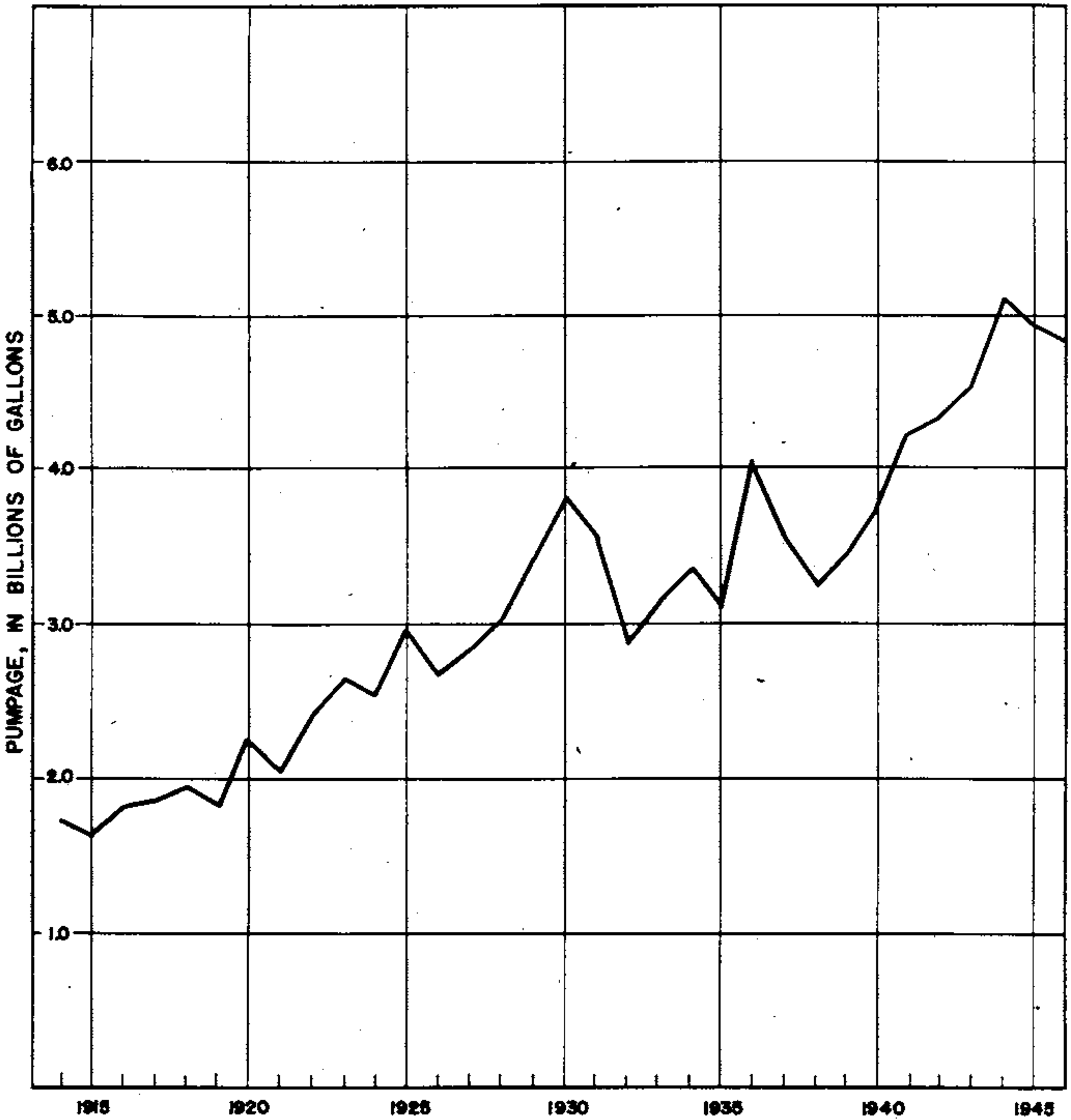
Wells for air conditioning - In the downtown area of South Bend many wells are used to provide water for air conditioning buildings, stores, theaters, and restaurants. The air-conditioning season usually lasts from June through September, and during this period the additional pumping for air-conditioning purposes is several million gallons of water a day. Although it is reported that the water level in the downtown area has declined because of this pumping, the decline does not appear to be serious. Conservation and re-use of water should be encouraged, however, to prevent waste of the ground-water supplies of the area.

PUMPAGE

A study of the quantities of water pumped and the rates of pumping from wells must be made in any quantitative treatment of ground-water problems and in estimating the safe yield of the water-bearing formations within a given area. A correlation of pumpage with the fluctuations of water levels in wells over a period of time should show in a rough way the yield of the ground-water reservoirs that can be expected perennially.

The pumpage of ground water for municipal supply has been a considerable part of the total pumpage from all wells for many years, and will serve as a general index of the total pumpage for the area. The total annual pumpage from all pumping stations of the municipal well system for the period 1914-1946, inclusive, is shown in figure 3. The average daily pumpage has increased from a minimum for the period of record of 4.45 million gallons in 1915 to a maximum of 14.01 million gallons in 1944. The pumpage has increased at a fairly uniform rate, except during the early 1930's, when it decreased, and the war years of 1940-1944, when it increased.

Estimates of the pumpage from industrial and other private wells within the South Bend area, excluding Mishawaka, for which no estimates were made, were based on records or estimates of pumpage made by the well owners and operators. In most industrial and air-conditioning plants the quantity of water pumped is not metered and must be estimated on the basis of hours operated, capacities of treatment plants, or use of water per individual process unit.



DATA COMPILED FROM RECORDS OF WATER DEPARTMENT

FIGURE 3. TOTAL PUMPAGE BY YEARS, FROM WELLS OF SOUTH BEND MUNICIPAL WATER-SUPPLY SYSTEM 1914 - 1946

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The average daily pumpage from wells in the South Bend area during 1945 is shown by industries in table 2. The rates of pumpage are highest during the four summer months, June through September. During this period the pumpage for the municipal supply is materially increased because of lawn sprinkling, swimming pools, and other reasons and the pumpage for air conditioning and other cooling purposes is also increased. The figure given for the average daily pumpage for the year is based on the assumption that the summer rate is in effect for 4 months and the winter rate for 8 months.

The average daily pumpage from all wells in the area, municipal and industrial, during the summer months was about 34 million gallons in 1945, although hourly and daily rates of pumpage were considerably higher. The maximum daily pumpage for municipal supply, nearly 25 million gallons, occurred on August 4, 1944. Assuming a maximum daily pumpage of 20 to 25 million gallons from all wells except those of the municipal system, it is evident that the maximum daily pumpage from wells in the South Bend area was between 45 and 50 million gallons in 1944.

The maximum annual pumpage from the ground-water reservoir occurred in 1944, when industrial activity for war production was at a maximum. During each of the succeeding years, 1945 and 1946, the total pumpage was somewhat less. However, although less water was pumped for industrial use, especially during the reconversion period, new construction caused an increase in the demand for water for domestic and sanitary use, and the net total for each year was only slightly less than the pumpage during 1944.

The total pumpage from wells may be expected to increase for both industrial use and municipal supply in the future. Observation wells in critical areas should be established in which the resulting trends of ground-water levels may be determined.

Table 2

Average daily pumpage from wells in the South Bend area, Indiana, 1945.

(Million gallons a day)

Private wells	Summer June-Sept.	Winter Oct.-May	Average for the year.
Air conditioning	1.70	0.10	0.64
Brewing	1.72	1.60	1.64
Ice and ice cream	.99	.50	.67
Dairy	.30	.25	.27
Laundry	.31	.33	.33
Railroad	.76	.76	.76
Hotels and institutions	1.98	1.50	1.66
Machines and metal working	7.61	7.00	7.21
Miscellaneous industries	2.57	2.50	2.52
Total	17.94	14.54	15.70
Municipal pumping stations			
North	6.61	4.39	5.13
Central	1.64	1.25	1.38
Oliver Park	4.54	3.82	4.06
South	2.47	2.10	2.23
Coquillard	0.81	0.81	0.81
Total	16.07	12.37	13.61
Grand total	34.01	26.91	29.31

The pumpage from wells in the South Bend area is fairly well distributed throughout the city, although nearly 11 million gallons a day is pumped from the downtown business section, including the North and Central Stations. Other concentrations of pumpage are in the west-central and south-central parts of the city.

GROUND-WATER LEVELS

Many well owners in the South Bend area have realized that the water levels in wells throughout the city have declined, but few have determined the actual amounts and rates of decline. The original wells of Central and North Stations flowed above the land surface when they were drilled, but now do not flow. Many of the wells originally pumped by suction are now equipped with deep-well pumps. It is obvious that the water level in the water-bearing beds has declined since the original wells were drilled.

Fragmentary records of water levels in past years, obtained from published reports and unpublished records of the City Water Department and industrial plants, are valuable in estimating the amount and rate of decline of water levels in the South Bend area, although continuous records over a period of years are not available. A thorough search of the records was made to obtain measurements of water level in the past years, and the information obtained is summarized in table 3. The measurements of water level were made in many different wells in various well fields, and no information is available as to the individual wells that were measured, the points of measurement, or as to whether nearby wells were pumping or idle. The data, however, indicate that the decline in ground-water levels has been comparatively uniform throughout the area, the average rate of decline per year ranging from 0.23 to 0.85 foot in different parts of the area and being about 0.47 foot for the area as a whole. The average net change is computed by comparing the earliest record of water level to the latest record of water level available. The computations are subject to revision as additional information is obtained.