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

BULLETIN NO. 3

GROUND WATER RESOURCES

OF

SAINT JOSEPH COUNTY, INDIANA

PART 1. SOUTH BEND AREA

By

FRED H. KLAER, JR., AND ROBERT W. STALLMAN

Prepared in cooperation with

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

STATE OF INDIANA

HONORABLE RALPH F. GATES

GOVERNOR

THE

INDIANA DEPARTMENT OF CONSERVATION

INDIANAPOLIS, INDIANA

MEMBERS

LISLE L. WALLACE, CHAIRMAN

EARL W. MERRY

WILLIAM J. SCHEIDLER

J. B. BLOOM

JOHN H. NIGH, DIRECTOR

BYRON C. KENNEDY, ASST. DIRECTOR

DIVISION OF WATER RESOURCES

CHARLES H. BECHERT, DIRECTOR

CONTENTS

ILLUSTRATIONS

TABLES

APPENDICES

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

33409

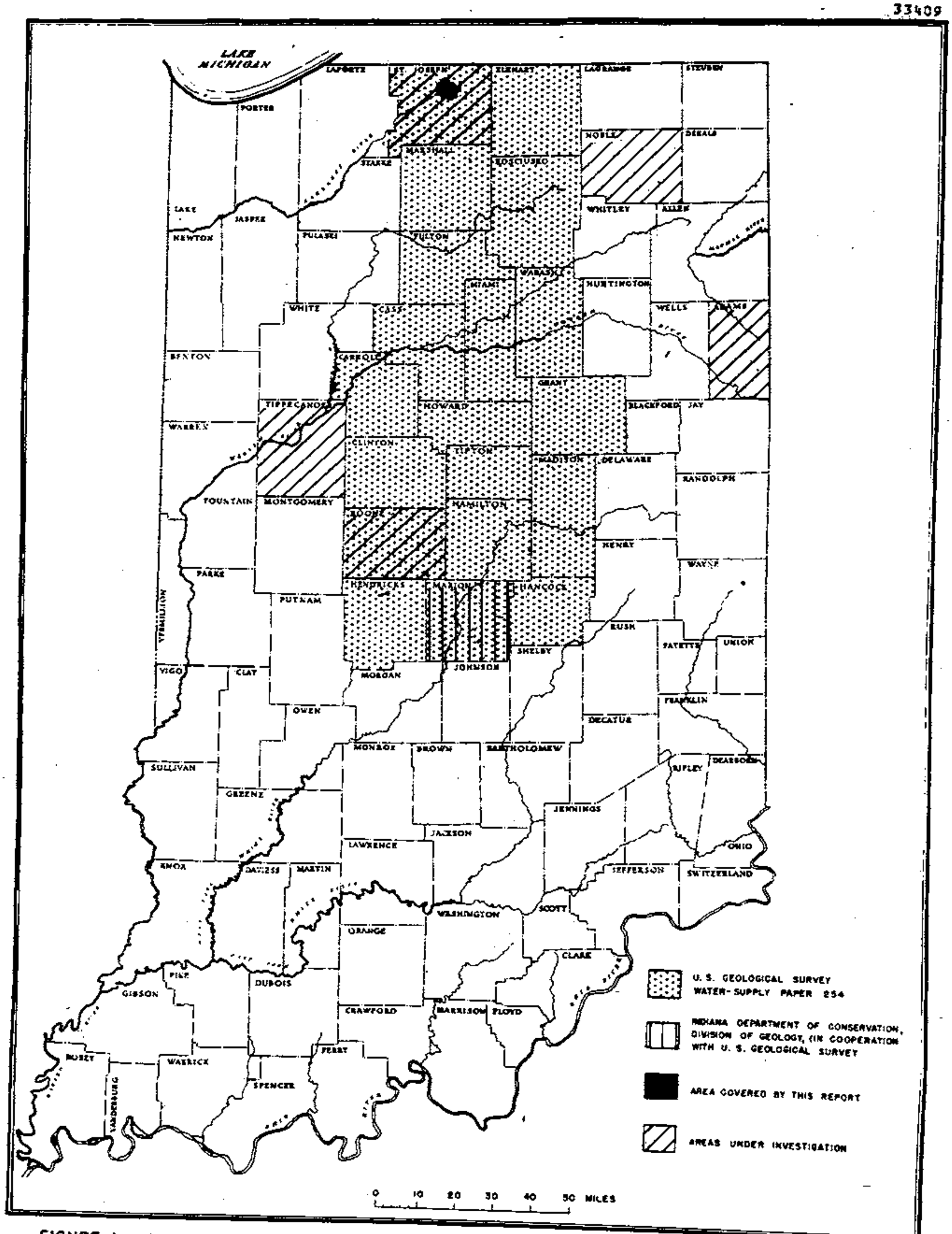


FIGURE 1. MAP OF INDIANA SHOWING LOCATION OF AREAS ON WHICH REPORTS HAVE BEEN PUBLISHED, AREA DESCRIBED IN THIS REPORT, AND AREAS UNDER INVESTIGATION

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.

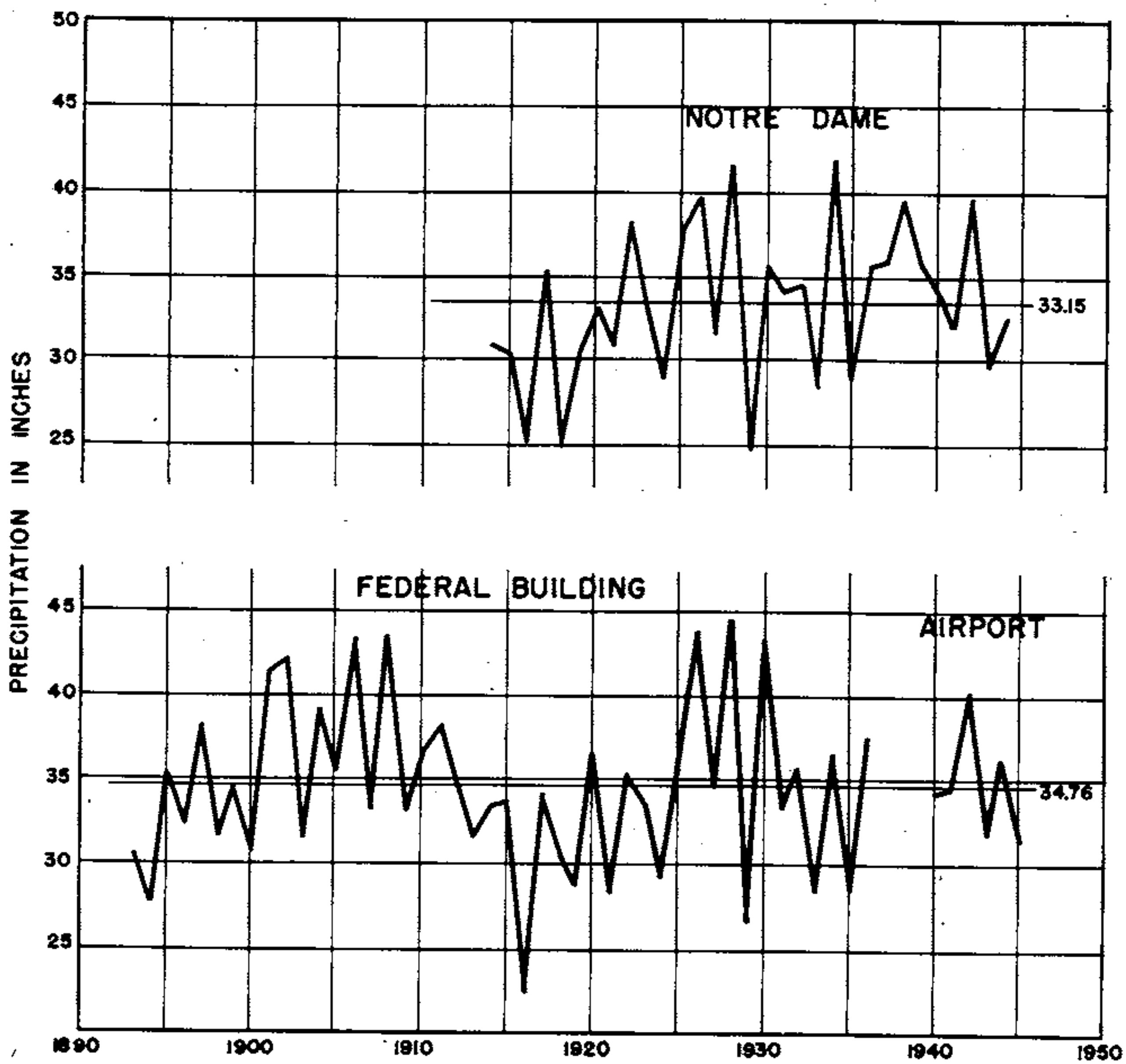
greater than during the spring, recharge to the ground-water reservoir is not particularly effective because of high losses due to evapo-transpiration and to replenishment of deficient soil moisture.

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

33409

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.

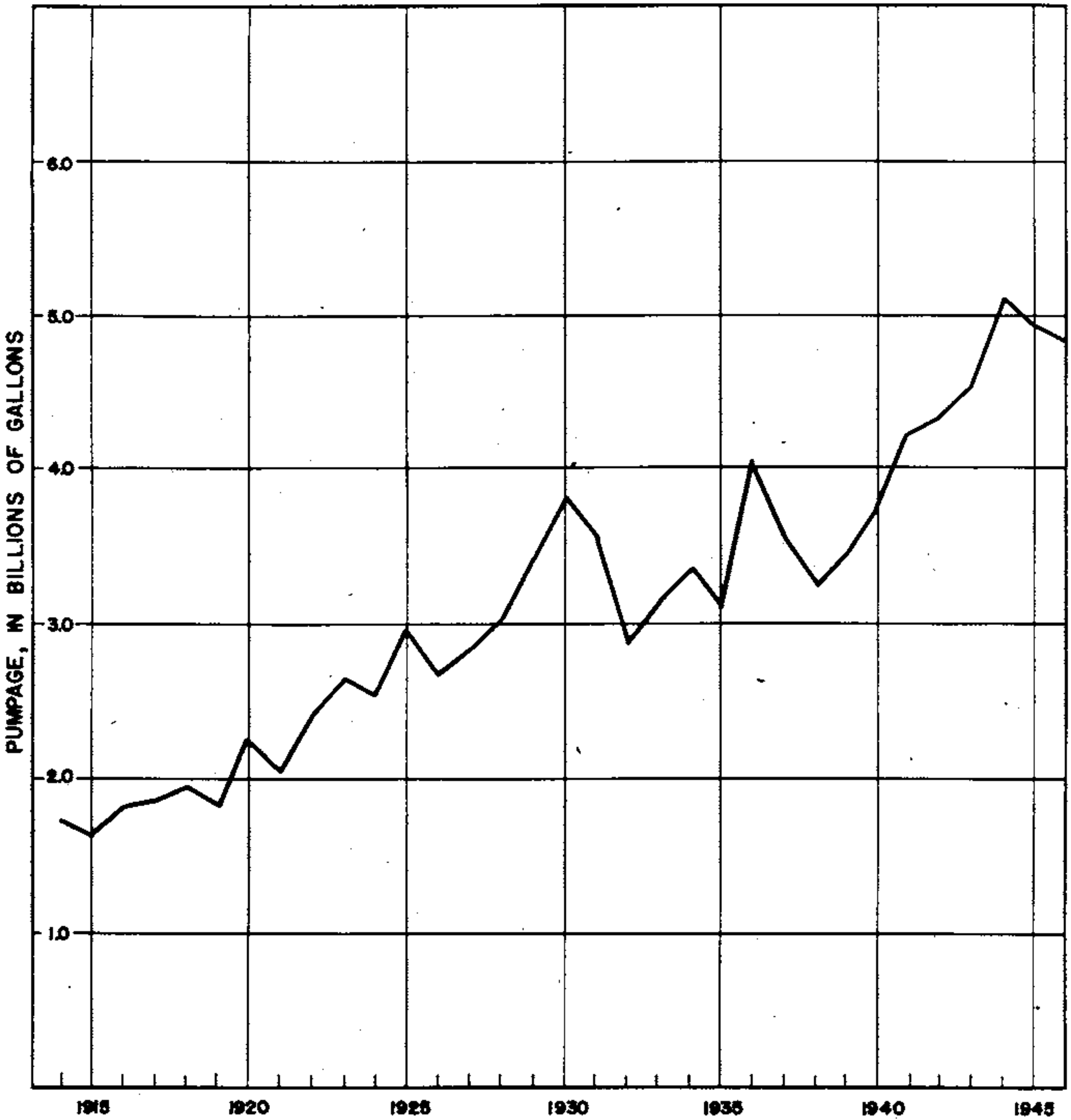
Wells for air conditioning - In the downtown area of South Bend many wells are used to provide water for air conditioning buildings, stores, theaters, and restaurants. The air-conditioning season usually lasts from June through September, and during this period the additional pumping for air-conditioning 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

33409

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.

Estimates made by John Toyne, formerly Superintendent of the South Bend Water Department, indicate a decline of 8 to 12 feet since 1913, and similar estimates by A. L. Cox, well-drilling contractor of South Bend, indicate a decline of 12 to 16 feet in the past 30 years.

Table 3

Water levels in South Bend, Indiana
1895 to 1945, inclusive

Well-field No.	Plant	Date	Water level above (+) or below (-) land surface (feet)	Authority	Net change (feet)	Period (years)	Average net change per year (feet)
Sj 2	City of South Bend, Central Station	1906	+2	1			
		1910	+7	2			
		1912	-1	3			
		1926	0+	7			
		1942	-4 to -9	5			
		1945	-10	8	-12	39	-0.32
Sj 1	City of South Bend, North Station	1895	+11	2			
		1906	+8	1			
		1910	+9	2			
		1912	+11	3			
		1942	-4.7	4			
		1945	-7.8	8	-18.8	33	-0.57
Sj 12	Drewry's Ltd.	1908	-9	3			
		1940	-22	4	-13	32	-0.41
Sj 52	Notre Dame University	1906	-25	1			
		1912	-23	3			
		1933	-58	5			
		1939	-32	5			
		1943	-28	5			
		1946	-35	5	-10	40	-0.25
Sj 25	Oliver Farm Equipment Co.	1899	-10	7			
		1906	-9½	1			
		1912	-12	2			
		1944	-30	7	-20	45	-0.45
Sj 15	Oliver Hotel	1903	-19	3			
		1940	-35	6	-16	37	-0.43
Sj 53	St. Mary's Convent	1906	-15 to +3	1			
		1910	+4	2			
		1912	+2	3			

Table 3 (Cont.)

Well-field No.	Plant	Date	Water level above (+) or below (-) land surface (feet)	Authority	Net change (feet)	Period (years)	Average net change per year (feet)
Sj 53	St. Mary's	1933	$-6\frac{1}{2}$, -10	4			
	Convent	1936	-10	5			
	(Cont.)	1945	-6.5	8	-10.5	35	-0.30
Sj 16	Singer Mfg.	1906	-12	1			
	Company	1908	-10	3			
		1909	-9.6	7			
		1925	-15.0	7			
		1927	-16.0	7			
		1928	-19.8	7			
		1929	-20.4	7			
		1930	-20.2	7			
		1931	-21.7	7			
		1944	-19.3	7			
		1945	-21.2	7	-9	39	-0.23
Sj 45	South Bend	1907	-5	3			
	Brewing Co.	1934	-28	5	-23	27	-0.85
Sj 24	Studebaker	1908	-20	3			
	Corp.	1926	-34	5			
		1932	-37	5			
		1937	-29, -33	5			
		1938	-31	5			
		1939	-32	5			
		1945	-35	8	-15	37	-0.41
Sj 79	Y.M.C.A.	1907	-13	3			
		1939	-30	5	-17	32	-0.52

<u>Average net decline per year</u>

According to tabulated data	0.47 foot
Estimate of John Toyne	0.27 to 0.40 foot
Estimate of A. L. Cox	0.40 to 0.53 foot

<u>Authority</u>

1. U. S. Geol. Survey Water-Supply Paper 254. (4)

2. Hammond, A. J., The deep well water supply of South Bend, Indiana: Municipal Engineering, vol. 38, pp. 156-160, Jan.-June 1910. (7)

3.

Authority (Cont.)

3. Burdick, C. B., A report of an increased water supply for the City of South Bend, Indiana: Univ. of Illinois, unpublished thesis, 67 pp., 21 exhibits, 1911. (2)

4. Records of Layne-Northern Company, Mishawaka, Indiana.

5. Records of Smith-Monroe Company, South Bend, Indiana.

6. Records of A. L. Cox and Company, South Bend, Indiana.

7. Plant records.

8. Measured by U. S. Geological Survey.

The average decline in water levels of about half a foot per year over a period of nearly 50 years may appear on first thought to be a serious matter, indicative of depletion of the available supplies. However, in order to pump the quantities of water being obtained from wells at the present time, some decline in water level is necessary to create a cone of depression to draw water to the individual wells. The rates of pumping today are many times those in 1900. For example, in 1894 the average daily pumpage for municipal supply was 1.89 million gallons a day. During 1944 the average daily pumpage was 14.3 million gallons, with a maximum daily pumpage of nearly 25 million gallons. The rate of pumping from wells, both municipal and industrial, has increased many times over the rates of pumping in the period 1890-1910.

The rate of decline of ground-water levels in the South Bend area has varied somewhat. The fluctuations of water level in wells are closely related to the rates of withdrawal of ground water and to the rates of recharge from precipitation and from the St. Joseph River. During years of heavy pumpage and low precipitation, ground-water levels will decline at an increased rate. During years of lower rates of pumping and excessive precipitation ground-water levels will generally rise. The records of total pumpage and water levels in past years are not sufficient to permit satisfactory correlation. It is likely, however, that the rate of decline has increased during the past 10 years. Water levels will probably continue to decline at an irregular rate until the rate of recharge is equal to the rate of total pumpage.

The apparent relative uniformity of the net decline in water level throughout the city is somewhat surprising, especially when the estimated rates of pumping at the times of the measurements are considered. The largest increase in pumpage probably has been at North Station, and yet the net decline in water level per year there is smaller than at several other localities where the increases in rates of pumping have not been as great. This may be explained in part by differences in the hydraulic characteristics of the water-bearing beds, and by the position of North Station in relation to the other centers of heavy pumping.

In order to obtain continuous records of the fluctuations and general trends in water levels in the South Bend area, a number of observation wells were established during the present investigation, in which measurements of water levels were made at regular intervals. Several observation wells were equipped with water-stage recorders that record continuously the changes of water levels in the wells. The wells have been measured by members of the City Engineer's Office and plant operators. The graphs of water levels in eight observation wells in the South Bend area are shown in figure 4.

The graphs of water levels in wells Sj 90 and Sj 4-T2 show the effects of local precipitation and seasonal trends, without much effect of pumping from nearby wells. The annual range in fluctuation in both wells is about 3 feet, the water level generally reaching its highest stage in the spring months and reaching its lowest stage in the fall and winter. In comparison to seasonal fluctuations of water levels in other observation wells throughout Indiana, the seasonal fluctuation in the South Bend area is comparatively.

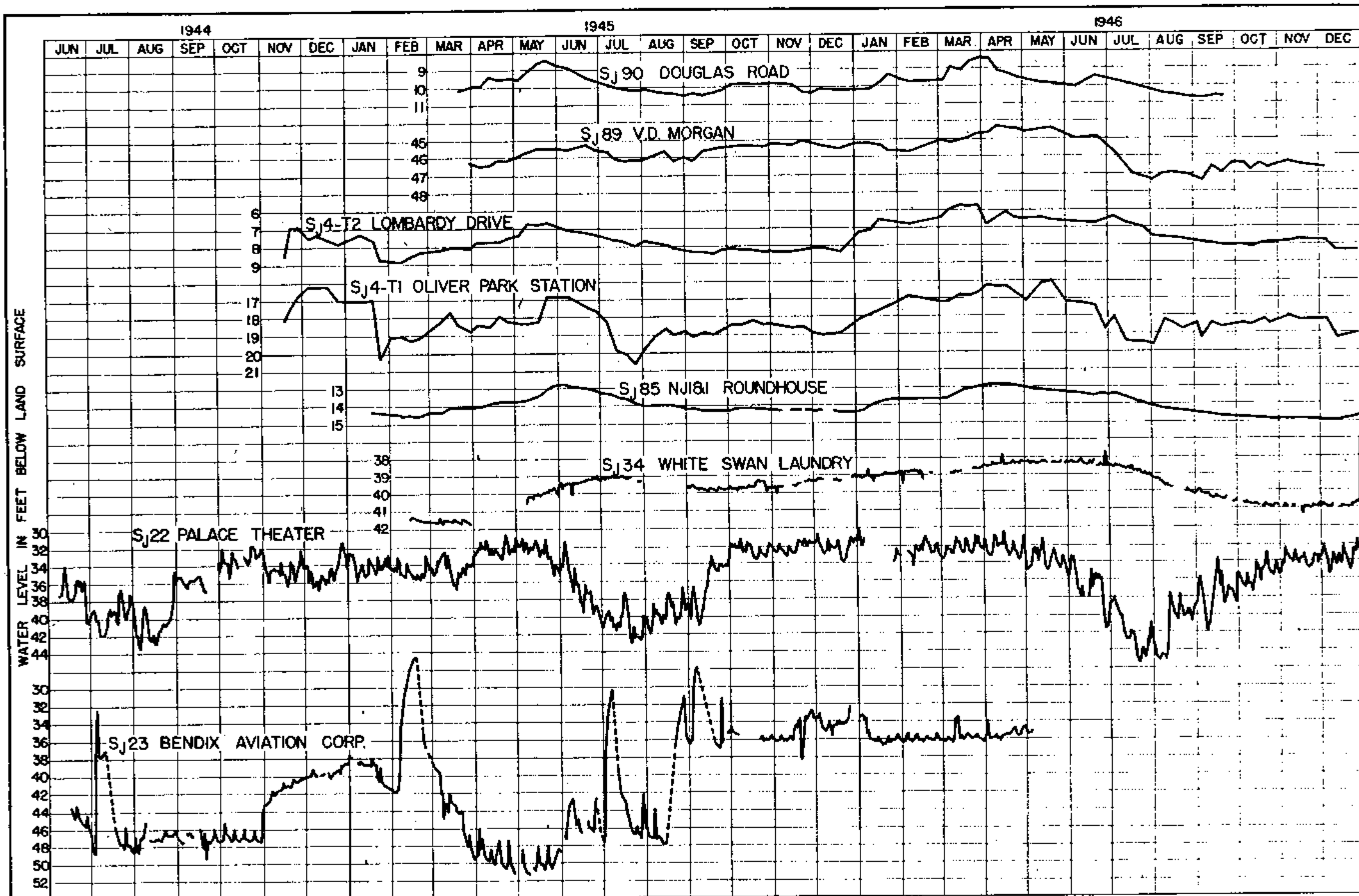


FIGURE 4. GRAPHS OF WATER LEVELS IN OBSERVATION WELLS IN THE SOUTH BEND AREA, ST. JOSEPH COUNTY, INDIANA

may have high coefficients of transmissibility and storage and that water may move through the formations comparatively easily.

The graph of the water level in well Sj 89 shows a seasonal trend similar to those in wells Sj 90, Sj 4-T2, and Sj 85. Superimposed on the seasonal trend, however, is the effect of pumping a nearby well at the Coquillard Station of the municipal water-supply system. The graph for well Sj 4-T1 is similar to that of well Sj 89, in that the water level in the former is affected by pumping from the wells of the Oliver Park Station. In both cases, the effect of pumping is comparatively small.

The water level in well Sj 34 is affected by the pumping of a nearby well used for supplying water to a laundry. The pumpage, however, is small and quite uniform, and the seasonal fluctuation is apparent in spite of the effect of pumping.

Well Sj 22 at the Palace Theater is located in the business section of South Bend, where comparatively large quantities of ground water are pumped for cooling purposes, including air conditioning. The seasonal fluctuation in this well differs from those mentioned above, in that the water level reaches its lowest stage in July, August, or September. During this period, pumping for air conditioning is at a maximum. This well is located between North and Central Stations of the municipal water-supply system and is affected by pumping at both stations.

The graph of water levels in well Sj 23 is an example for a well in which the water level appears to be controlled almost entirely by the pumping from nearby wells. Two nearby wells are operated automatically to maintain a constant pressure on the distribution system, and are turned on and off about once an hour. The effect of one pumping well on the observation well is about 3 feet, and of the other pumping well about a foot. The major rises in water level are due to the shut-down of one or both wells for a considerable period of time.

None of the graphs of water level shown in figure 4 cover a sufficient period of time to show general trends. It is hoped to continue the measurements of water levels in observation wells so that information on the general trends over a period of years may be available. It may be said, however, that although a general decline in water levels is apparent in the South Bend area, the decline does not appear to be serious, and there appears to be no immediate danger of a shortage of water because of declining water levels.

QUALITY OF WATER

In order to determine the chemical character of the ground water in the South Bend area, a number of samples of water from the municipal well fields and from the St. Joseph River were collected during the investigation and have been analyzed by the Indiana State Board of Health. These analyses and several others made by Infilco, Inc. (included in the recent report (5) of Consoer, Townsend and Associates), and by the U. S. Geological Survey are given in Appendix C at the end of this report.

The chemical quality of the ground water of the South Bend area is similar to that throughout much of northern Indiana and southern Michigan. The hardness is rather high, ranging from about 14 to more than 50 grains per gallon (240 to 850 parts per million) in various wells, and the water must be treated for boiler use. The iron content is variable, ranging from zero to as much as 7 parts per million in several wells. The wells of the municipal well fields are relatively iron-free. Chloride is generally less than 50 parts per million.

A study of Appendix C shows that, over a period of time, the chemical quality of the water, including total solids, total hardness, and alkalinity, has changed. The total hardness, as determined by the partial analyses by the Indiana State Board of Health, of the water from the five municipal well fields and the St. Joseph River is shown in figure 5 for the period January 1945 to March 1947. The fluctuations in hardness at each station are similar to those at the other stations, although the range is not the same for all stations. The fluctuations in hardness of the river water are less, in general, than those of the ground water.

The temperature of ground water in the South Bend area ranges from 51° F. to 56° F. and averages about 54° F. Because of its relatively constant tem-

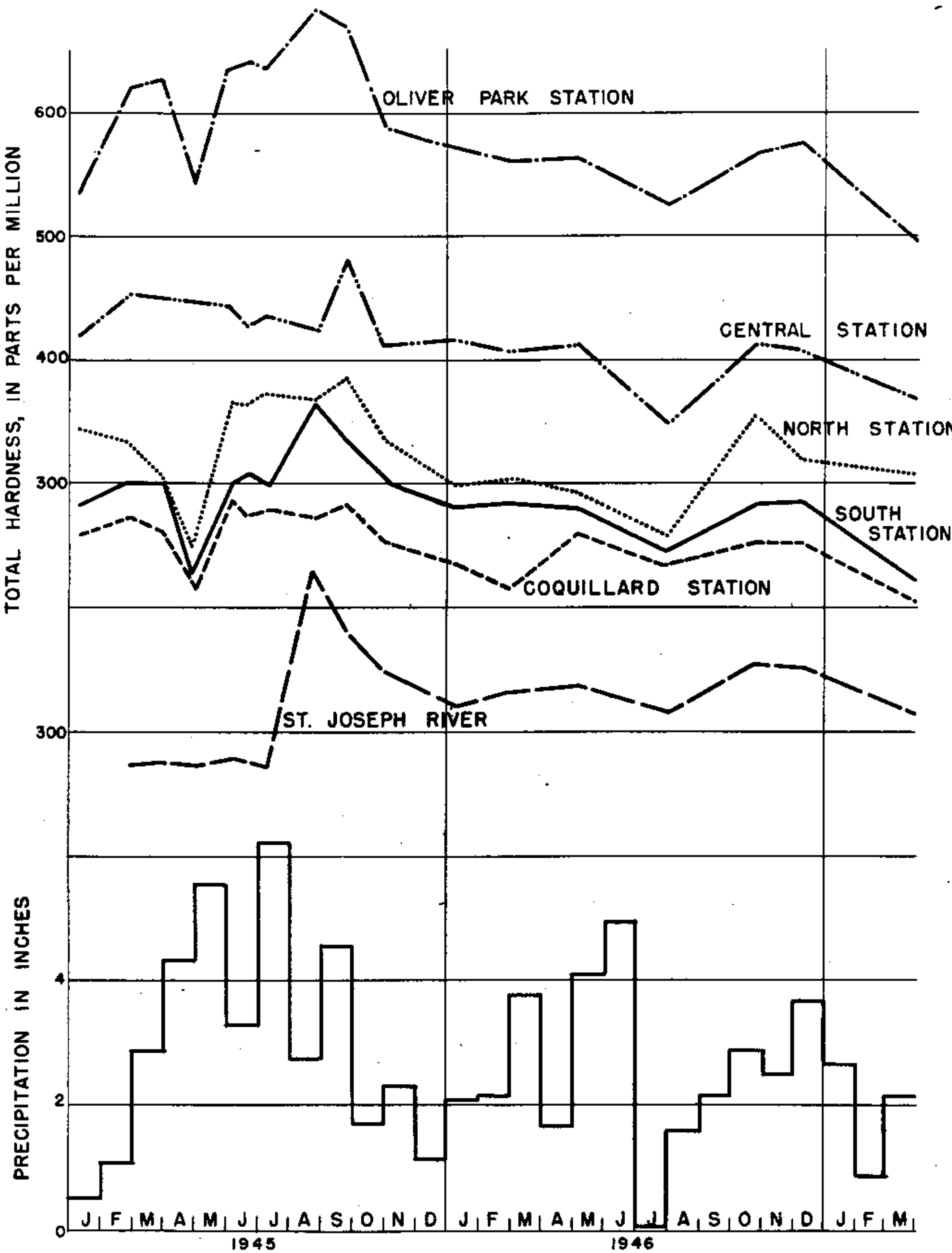


FIGURE 5. CHANGES IN TOTAL HARDNESS OF WATER FROM MUNICIPAL WATER-SUPPLY SYSTEM AND PRECIPITATION AT SOUTH BEND, INDIANA, JANUARY 1945 TO MARCH 1947

33409

perature, which is lower than that of surface water in the summer, ground water is greatly preferred to river water for cooling, air conditioning, and many industrial processes.

PUMPING TESTS

Introduction

Withdrawal of water from an aquifer causes water levels to decline in the vicinity of the point of withdrawal. The water table or the piezometric surface assumes the approximate shape of an inverted cone with the apex at the center of the point of withdrawal. The size, shape, and rate of growth of the cone of depression created by pumping a well are dependent on the rate and duration of pumping, the transmissibility and storage coefficient of the aquifer, the increase in recharge caused by the decline of water levels, the natural discharge that is salvaged, and the boundaries of the aquifer. The effect of the pumping at any point within the cone of depression is termed drawdown, and is dependent on the variables mentioned above and on the distance from the pumping well.

In order to express in a general equation the relationship among the variables that govern the magnitude of pumping effects certain basic assumptions are made. It is assumed that the aquifer is constant in thickness, infinite in areal extent, homogeneous, and isotropic (transmits water with equal facility in all directions). It is assumed further that there is no recharge to the formation during the period of pumping, or discharge other than that from the well in question, and that water may enter the well throughout the full thickness of the aquifer.

The relationship among the hydraulic properties of the formation and water-level changes caused by pumping a well in a given formation is expressed by the Theis non-equilibrium formula (23):

$$s = \frac{114.6\,Q}{T} \int_{\frac{1.87\,r^2 S}{Tt}}^{\infty} \frac{e^{-u}}{u}\,du \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (1)$$

Where: s = drawdown of water level, in feet.
Q = discharge of pumped well, in gallons per minute.
r = distance of observation well from pumped well, in feet.
T = coefficient of transmissibility, in gallons per day per foot under unit hydraulic gradient.
S = coefficient of storage, as a ratio or decimal fraction.
t = time well has been pumped, in days.

The exponential integral of formula (1) is replaced by the term $W(u)$ which is read "well-function of u", and the equation is rewritten as follows:

$$s = \frac{114.6\ Q}{T} W(u) \quad \ldots \quad (2)$$

The value of the integral is given by the following series:

$$W(u) = -0.577216 - \log_e u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} - \frac{u^4}{4 \cdot 4!} \quad \ldots \quad (3)$$

$$\text{where } u = \frac{1.87\ r^2 S}{Tt} \quad \ldots \quad (4)$$

Values of $W(u)$ for values of u between 9.9 and 1.0×10^{-15} are given by Wenzel (27). The "well function of u" is plotted against u on log paper to form a type curve for determining the transmissibility and the storage coefficient of the formation tested. The observed drawdowns are plotted versus $\frac{r^2}{t}$ on log paper. The graph of the observed data is matched with the type curve by superposition, keeping the axes of the two graphs parallel, and the values of $\frac{r^2}{t}$, s, $W(u)$ and u are selected at any convenient point. The value of transmissibility is obtained from equation 2, and the value of the storage coefficient is then obtained from equation 4.

A more convenient non-equilibrium solution for transmissibility and storage coefficient is possible by a procedure shown by Jacob (9,6). For small values of u (small r or large t), $W(u)$ given by equation 3 is approximately

$$W(u) = -0.577216 - \log_e u \quad \ldots \quad (5)$$

and

$$s = \frac{114.6\ Q}{T} \left(\log_e \frac{Tt}{1.87\ r^2 S} - 0.577216\right) \quad \ldots \quad (6)$$

The value of r is constant at a given observation well, and equation (6) may be written

$$s_2 - s_1 = \frac{114.6\ Q}{T} \left(\log_e \frac{Tt_2}{1.87\ r^2S} - \log_e \frac{Tt_1}{1.87\ r^2S}\right)$$

$$= \frac{114.6\ Q}{T} \left(\log_e \frac{t_2}{t_1}\right) = \frac{264\ Q}{T} \log_{10} \frac{t_2}{t_1} \quad . . . . (7)$$

where s_2 and s_1 are drawdowns observed at t_2 and t_1 respectively. Drawdown is plotted against the log of t on semi-log paper, producing a straight-line graph. If an interval of one-log cycle is selected from the time-drawdown graph of the observations made in any observation well near the pumping well, the value of transmissibility can be obtained from the following equation:

$$T = \frac{264\ Q}{s_2 - s_1} \quad . . . . (8)$$

where $s_2 - s_1$ is the difference in drawdowns through one log cycle.

Similarly, if more than one observation well is available for pumping test observations, t may be treated as a constant, and from the first form of equation (7) we obtain,

$$s_2 - s_1 = \frac{114.6\ Q}{T} \log_e \left(\frac{r_1}{r_2}\right)^2 = \frac{528\ Q}{T} \log_{10} \frac{r_1}{r_2} \quad . . . . (9)$$

where s_2 and s_1 are the drawdowns observed at r_2 and r_1 respectively, at a given time t. The drawdown observed in each of the observation wells at a given time is plotted against the log of r. Then the transmissibility can be computed directly from the slope of the resulting straight line using equation (9) in a form similar to that of equation (8) as follows:

$$T = \frac{528\ Q}{s_2 - s_1} \quad . . . . (10)$$

where $s_2 - s_1$ is the difference in drawdowns observed through one log cycle. The storage coefficient is obtained from equation (11).

$$S = 3.01x10^{-1} \frac{Tt}{r_e^2} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (11)$$

where r_e is the distance from the pumping well to the outer circumference of the cone of depression where s = 0. To determine r_e^2, equation (6) is plotted keeping t constant, and the line representing s versus r^2 is extended to s = 0. The value of r_e^2 is noted where s = 0. The storage coefficient can then be computed by equation (6).

Both methods of solving the non-equilibrium formula (log and semi-log plots) should be used in analyzing pumping-test data, for each has distinct advantages not possessed by the other.

A pumping test is made by changing the rate of pumping of one or more wells after a period during which pumping conditions in the area have been stable. The fluctuations in water level caused by the changes in discharge are measured in one or more nearby observation wells and, if possible, in the pumped well also. The changes in discharge and the distance from the pumping well to the observation wells are also measured. From these data, the transmissibilities and storage coefficients can be computed by the Theis graphical method (23), or by several other valid methods. Basically, all formulas for determining transmissibility and storage coefficient are similar in principle and should yield similar results if used properly.

Pumping tests were conducted to determine the hydraulic properties of the water-bearing formations at each of the five well fields of the municipal supply system. Additional tests were made on wells of the Bendix Products Division of the Bendix Aviation Corporation, the Oliver Farm Equipment Corporation, and the Studebaker Corporation. The pumping tests were made by J. G. Ferris and the junior author, assisted by B. W. Swartz and the senior author.

Grateful acknowledgement is made to all city and industrial officials and operators for their excellent cooperation during the tests. The results of the tests are summarized in a later section.

Well loss

The drawdown in a pumping well, or the difference between the pumping and non-pumping water levels, is composed of two parts--the drawdown in the formation outside the well face or screen and the so-called "well loss" or the head loss resulting from the movement of water through the screen openings and up the well casing to the pump intake. The drawdown outside the well face depends on the hydraulic characteristics and boundaries of the formation, the rate and duration of pumping, the diameter of the screen and the ratio of its length to the thickness of the formation, and the condition of the materials surrounding the screen.

Fine sand and silt are removed from unconsolidated water-bearing materials near the screen during initial development of the well, thereby increasing the permeability of these materials. The actual drawdown is thus reduced somewhat below the theoretical value. In many cases, the well loss may be sufficiently high to cause an actual drawdown greater than the theoretical value, even though development of the well had improved the permeability of materials surrounding the screen.

It is believed that well loss varies with discharge, the distance from the pump intake to the screen, the diameter and type of casing, and the condition, opening size, diameter, thickness, and length of the screen. Each well has individual well-loss characteristics, which will vary with time because of continued removal of fine materials from the water-bearing beds at the well face or the encrustation of the screen or well face. In large-diameter wells, the loss in head due to movement of water from the inside of the screen to the pump intake is small, and the major part of the well loss is due to the passage of water through the screen.

A method for computing well loss has been developed by Jacob (11). In the summation of drawdown in a pumping well, he assumed that the well loss varies as the square of the discharge. An analysis by the junior author of data collected during a test of a well, in glacial materials similar to those in the South Bend area, at Louisville, Ky., run by M. I. Rorabaugh 3/, showed that the well loss varied as the 1.54 power of the discharge. The Louisville test is the only one known to the writers in which the correlation between well loss and discharge could be determined directly and accurately. Well losses in several wells of the South Bend municipal supply were estimated at various rates of discharge for computing the potential yields of the various well fields. For the purpose of this report, it is assumed that the well loss varies as the 1.5 power of the discharge.

A summary of estimated well loss and total drawdowns in several of the wells of the municipal supply system is given in table 4. The total drawdowns and well losses at the rates of discharge during the actual test are given in columns 5 and 6. It is noted that in most wells the estimated well loss is a considerable part of the total drawdown. In order to compare the productivity of the wells, the well loss, total drawdown, and specific capacity at the end of a 24-hour period of continuous pumping at a rate of 2,000 gallons per minute were computed for several municipally owned wells. The specific capacity is obtained by dividing the discharge of the well by

3/ Unpublished data in the open file at the office of the U. S. Geological Survey, Louisville, Kentucky.

Table 4

Drawdowns in South Bend municipal wells.

		Results from pumping tests				Computed drawdown, well loss, and specific capacity at 2,000 gpm for 24 hrs.		
(1) Well number	(2) Date of test	(3) Discharge Q (gpm)	(4) Length of pumping time (days)	(5) Total drawdown (feet)	(6) Estimated well loss (feet)	(7) Total drawdown (feet)	(8) Well loss (feet)	(9) Specific capacity (gpm per foot of drawdown)
1-53	Jan. 1945	2,240	0.145	39.4	14	37	12	54
1-55	Jan. 1945	2,340	0.125	44.6	19	41	15.0	49
2-36[a]	May 1942	2,100	0.29	43	3	44	2.8	46
3-2	Mar. 1945	1,100	0.37	13.7	7.8	31	19.2	65
4-28[a]	Mar. 1947	2,300	0.96	23.6	12	10.4	9.3	108
5-1	Mar. 1945	1,600	6.96	14.25	7.6	18	10.6	111

(a) Data collected during acceptance tests by Layne-Northern Company, Mishawaka, Indiana.

the total drawdown observed after pumping for a given length of time, and is expressed as gallons per minute per foot of drawdown determined for a given discharge and length of pumping time. The specific capacity is used as a means of comparing the productivity of wells.

The well losses given in table 4 were estimated by computing the drawdown in the formation at the outer screen face and subtracting this from the drawdown observed in the pumping well. The formation drawdown was computed by means of the Theis non-equilibrium formula. Therefore, it is tacitly assumed that the screen has been placed in the well without disturbing the hydraulic properties of the sediments and that the sediments have not been disturbed by developing or pumping. However, all wells listed in table 4 were constructed with a gravel pack surrounding the screen. Wells 2-36 and 4-28 had not been operated previous to the drawdown tests cited in table 4, but the remaining wells had been operated for several years before the tests were made. As is shown in the following section, the values of transmissibility and storage coefficient used in computing the formation drawdown are, at best, approximate values. Therefore, considering the possible errors entering into the computation of the well losses given in table 4, it must be stressed that these values are only the general order of magnitude of the well loss rather than an exact determination.

Summary of pumping-test results

Short pumping tests of 3 to 8 hours each were made at all locations listed except Oliver Park Station, South Sataion, and Coquillard Station, where the tests were continued for 24 hours, 6 days, and 7 days, respectively. The results are summarized in table 5. The transmissibilities and storage coefficients were determined by the Theis non-equilibrium formula from data obtained during the test.

Table 5

Transmissibility and storage coefficients of water-bearing formation in South Bend area

(1) Location	(2) Date of test	(3) Transmissibility gpd per ft	(4) Average permeability, gpd per ft^2	(5) Storage coefficient
Central Station	Jan. 1945	100,000	4,100	3.0×10^{-4} [a]
North Station	Jan. 1945	165,000	2,950	3.0×10^{-4}
Oliver Park Station	Mar. 1947	500,000	5,500	3.0×10^{-4} [a]
South Station	Mar. 1945	260,000	4,100	0.14
Coquillard Station	Mar. 1945	450,000	6,250	2.0×10^{-4}
Bendix Products Division of the Bendix Aviation Corporation	Oct. 1944	160,000	-	5.0×10^{-4}
Oliver Farm Equipment Co.	Mar. 1945	215,000	-	0.15

a/ Estimated.

The accuracy of the results depends largely on how closely field conditions conform to the basic assumptions of the Theis formula. It has been shown in a previous section that the water-bearing formations are not homogeneous and that variations in thickness, size, and stratification occur within short distances.

In all the wells tested, the formations are only partially screened, the screens having been placed in the lower coarse gravels on or near the lower confining clay or shale. The screen penetration of the municipal wells ranges from about 36 to 82 percent of the full thickness of the aquifer. The effect of such partial penetration depends on the ratio of vertical to horizontal permeability, the degree of penetration of the pumping and observation wells, and the distances between pumping and observation wells. Generally, values of transmissibility determined by means of the Theis formula from partially penetrating wells are lower than the correct values for fully penetrating wells.

Although the clays confining the artesian aquifers are considered as impermeable, small quantities of water may move vertically through the clay layers. As the hydrostatic head in the aquifer is lowered in the vicinity of pumping wells, small quantities of recharge may reach the aquifers from sources above and below the confined bed.

Comparison of field conditions with the basic assumptions made in the development of the Theis non-equilibrium formula shows that the results of the pumping tests in the South Bend area should be used as only approximate values of the transmissibility and storage coefficient.

There is a considerable range in the values of the hydraulic characteristics of the water-bearing formations. The average transmissibility determined by means of the pumping tests is about 250,000 gpd per foot. The average storage coefficient where artesian conditions exist is about 3.0×10^{-4}; and where water-table conditions exist it is about 0.15. The specific yields obtained at South Station and at the Oliver Farm Equipment Corporation indicate that the shallow and deeper sands and gravels are hydraulically connected at these locations.

The average value of the transmissibilities given in table 5 is undoubtedly higher than the average transmissibility of the formations throughout the South Bend area. The present well fields of the municipal supply were located at least in part by the selection of areas where the water-bearing formations appeared to be most productive from the standpoint of geologic information obtained by test drilling.

Changes in water levels caused by the pumping of the Central Station well suggest that the confining clays may not separate the river from the water-bearing formation about 1,500 to 2,000 feet upstream from that station. However, the data are not sufficient to prove that large supplies, utilizing largely river recharge, may be developed in that area. At the North Station, pumping tests show that the clays confining the water-bearing sediments are rather extensive, and therefore only a low rate of direct recharge from the river to the water-bearing sediments is possible.

The optimum spacing of wells within a given well field is primarily a problem of economics, and as such is beyond the scope of this report. However, as an aid in the planning of future expansion of the well fields of the municipal supply system, general drawdown diagrams for each of the five stations are shown in figures 6 to 10, inclusive. The diagrams were computed by means of the Theis non-equilibrium formula, using the values of transmissibility and storage coefficient given in table 5. The diagrams show the drawdown in feet per hundred gallons per minute, at a distance, r feet, from the pumping well after a period of continuous pumping of t days.

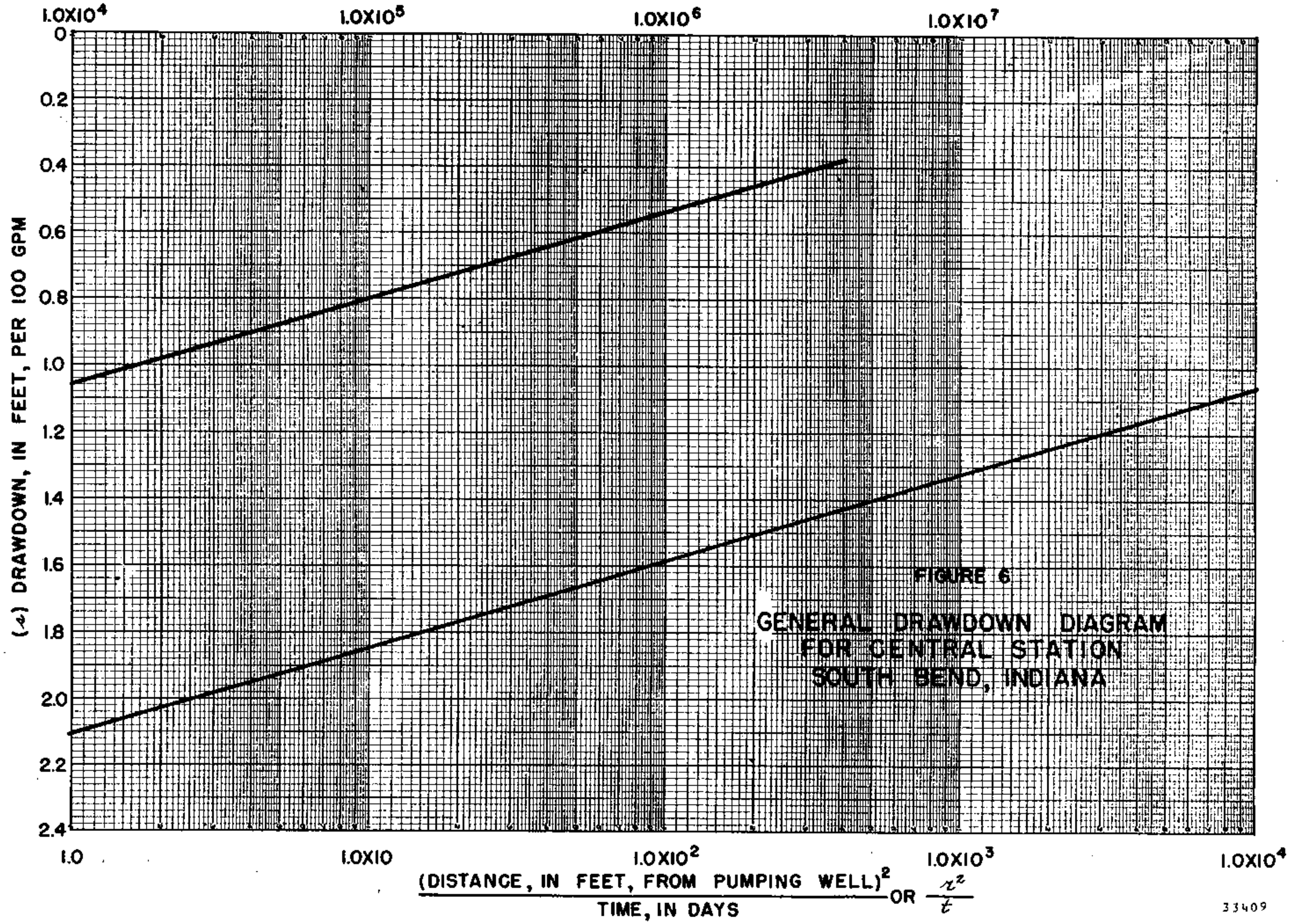


FIGURE 6

GENERAL DRAWDOWN DIAGRAM
FOR CENTRAL STATION
SOUTH BEND, INDIANA

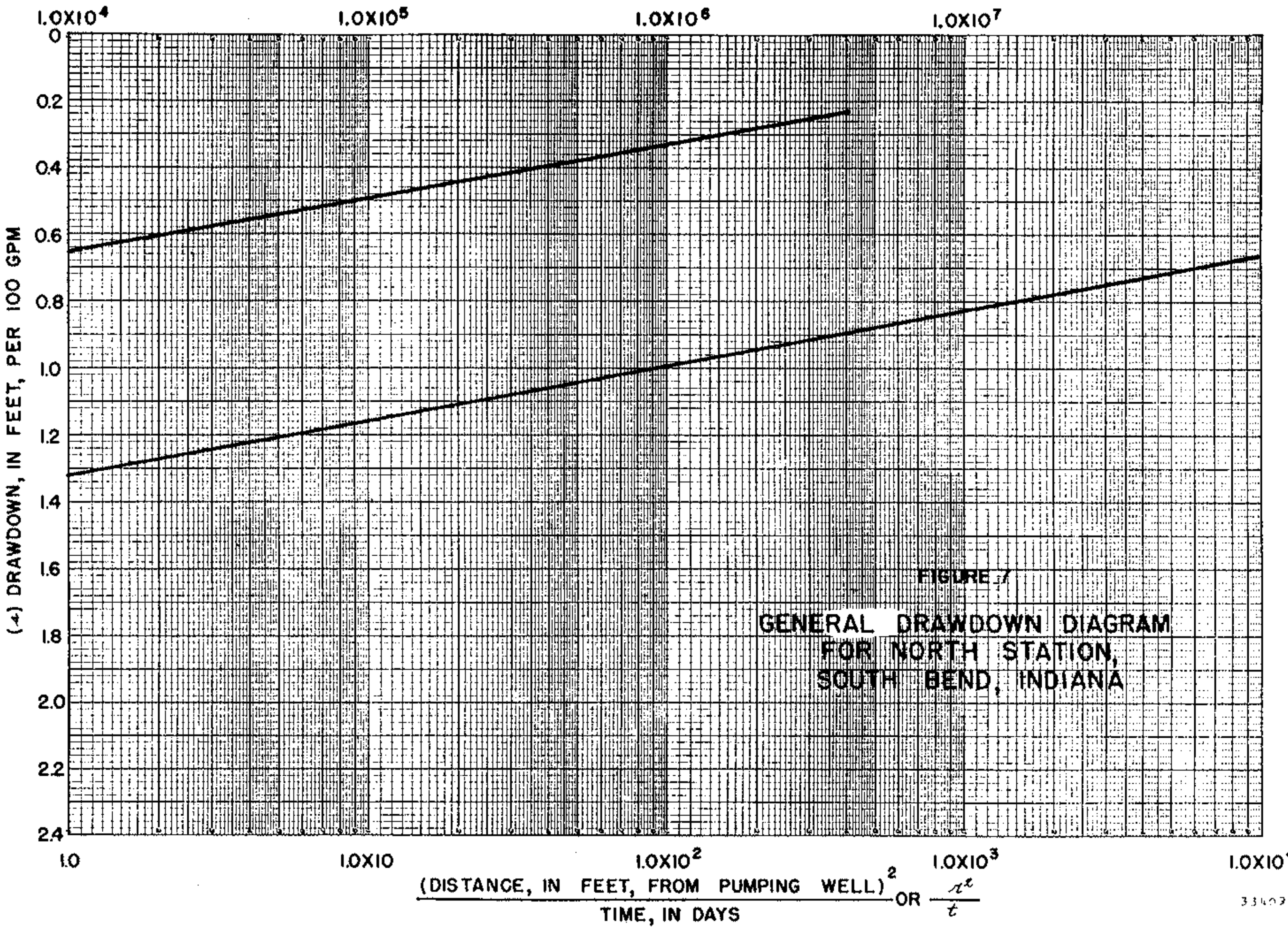


FIGURE 7

GENERAL DRAWDOWN DIAGRAM FOR NORTH STATION, SOUTH BEND, INDIANA

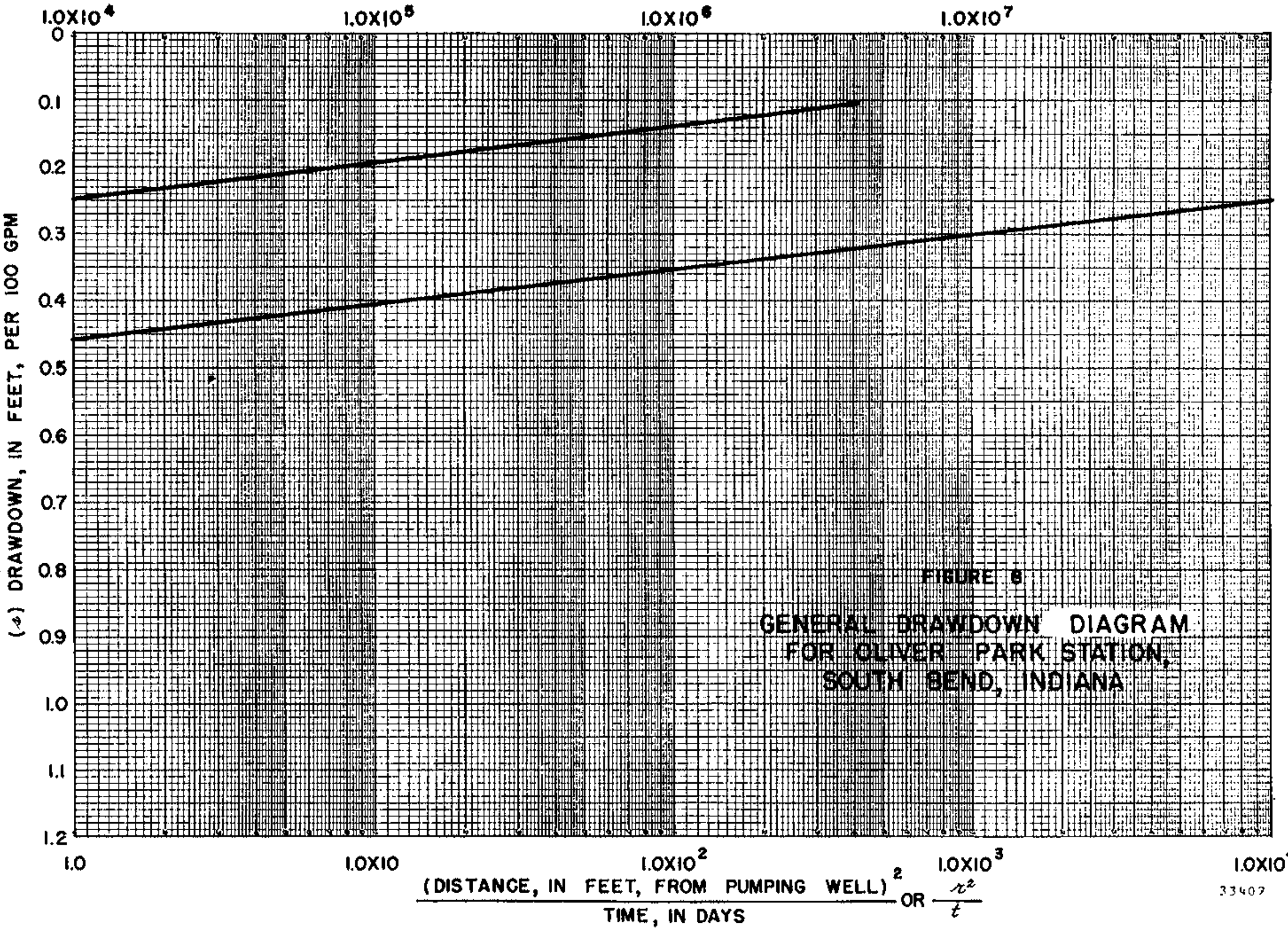


FIGURE 8

GENERAL DRAWDOWN DIAGRAM FOR OLIVER PARK STATION, SOUTH BEND, INDIANA

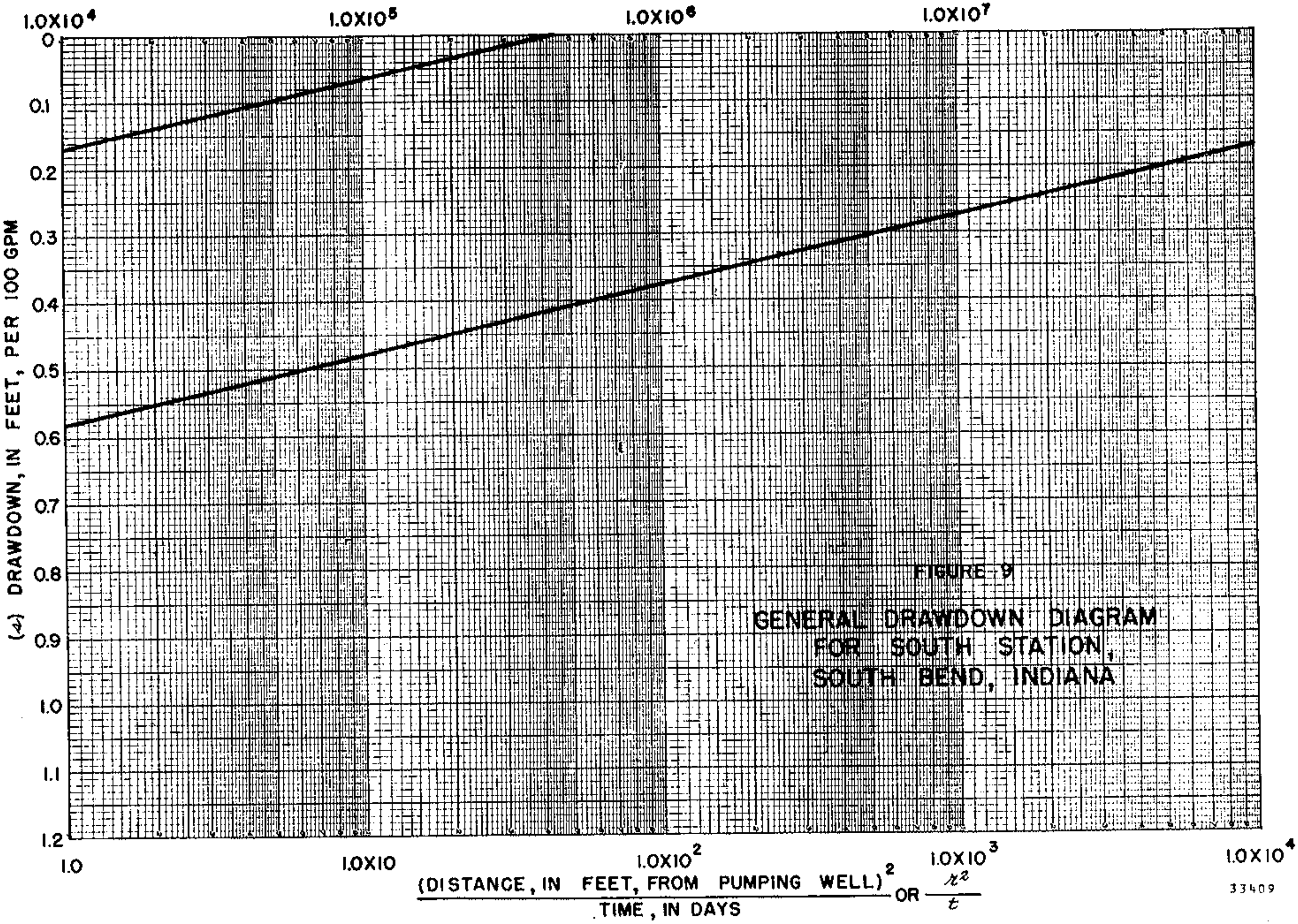


FIGURE 9

GENERAL DRAWDOWN DIAGRAM FOR SOUTH STATION, SOUTH BEND, INDIANA

33409

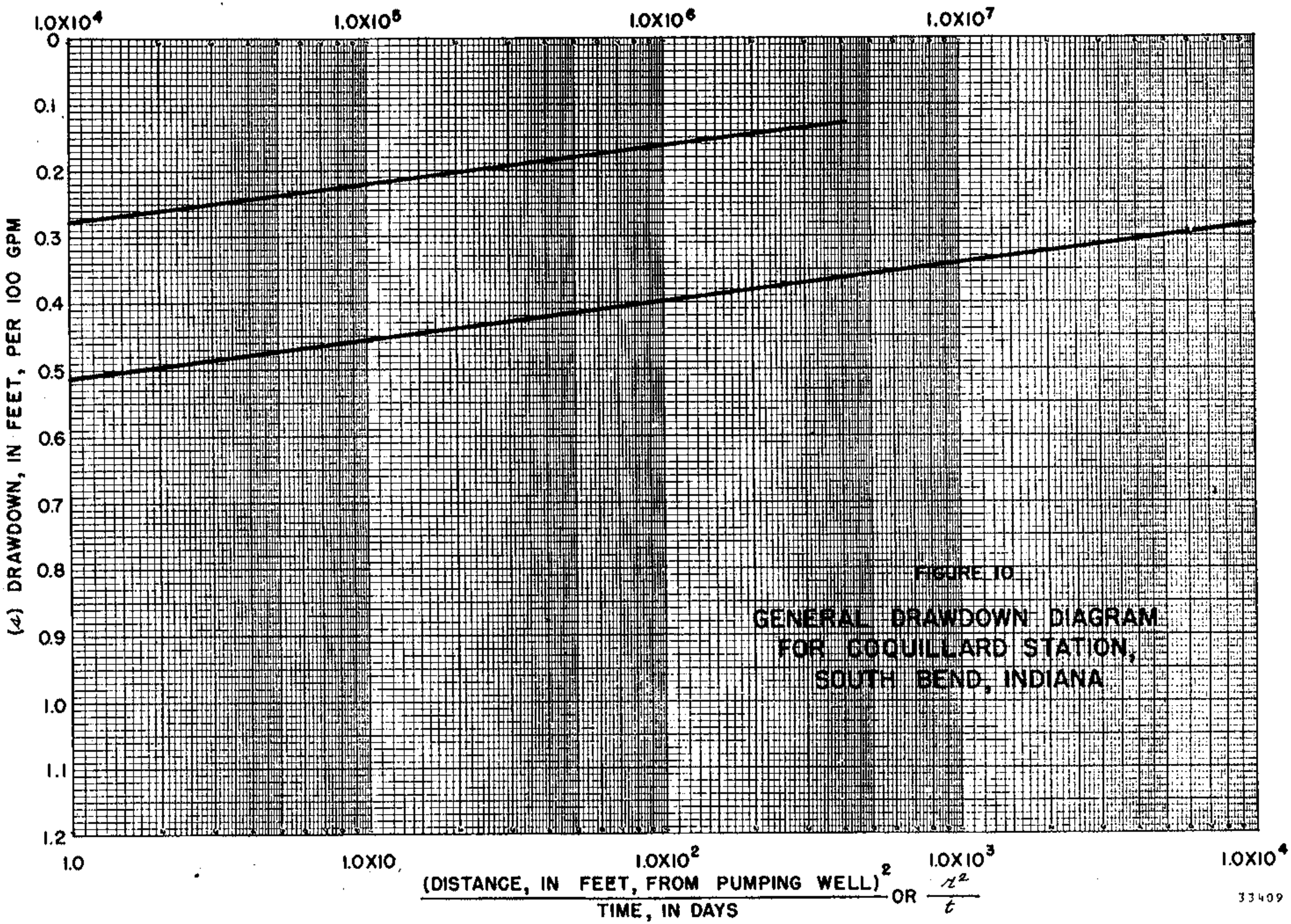


FIGURE 10

GENERAL DRAWDOWN DIAGRAM FOR COQUILLARD STATION, SOUTH BEND, INDIANA

The accuracy of the drawdowns estimated by use of the drawdown diagrams is dependent on the rate at which recharge enters the pumped area, changes in the hydraulic characteristics of the sediments in the area affected by pumping, and the degree of penetration of the pumping wells. The time required for a pumping well to reach equilibrium is variable, depending on the rate at which recharge flows or may be induced to flow into the pumped area. The logs of wells and pumping test results indicate that the hydraulic characteristics of the sediments vary within short distances. It is apparent that the use of the drawdown diagrams is limited. The value of r^2/t used in estimating drawdowns should not exceed 4.0×10^6. Values of r greater than 2,000 feet and values of t greater than 1 day should not be used in the diagrams. The limits given are somewhat arbitrary. However, it is likely that the errors in the estimated drawdowns within the limits given will be small.

The drawdown data for South Station must be corrected for the decrease in depth of flow as a result of pumping, using the correction developed by Jacob (9). Where water-table conditions exist, the saturated thickness of the aquifer decreases as pumping is continued, thereby decreasing the transmissibility.

The diagrams may be used to estimate the interference between two or more wells. For example, if an additional well is to be drilled at Central Station, at a distance of 300 feet from well 2-36, the drawdown caused by the new well in well 2-36 at the end of 10 days continuous pumping can be estimated. The radius (r) is 300 feet, and r^2/t is equal to $\frac{300^2}{10} = 9 \times 10^3$. The drawdown is determined from figure 6 as 1.7 feet per hundred gallons per minute. If the new well yields 1,000 gpm, the total drawdown caused by it in well 2-36 would be about 17 feet. The effect of well 2-36, which yields about 2,100 gpm, on the new well can be determined as 21 x 1.7 or about 35.7 feet. The total drawdown effect on one well of two or more pumping wells is equal to the sum of the effects of each individual well. It is believed that the drawdown diagrams presented will assist in the proper and economical expansion of the municipal well fields.

Potential yields of the municipal well fields

In order to show the potential yields of the various municipal well fields, including the wells in each field as they exist at present, maximum yields of each field as a unit were computed for periods of continuous pumping of 1, 5, and 30 days. It was assumed that: (1) all wells in any individual well field begin pumping simultaneously, (2) all wells are pumped continuously at a constant rate, (3) no interference occurs between well fields, and (4) all water pumped comes from storage, no recharge being added to the area affected by pumping. The estimates of potential yield are given in table 6. The well losses used in the computations are those given in table 4. The formation drawdowns were computed by the Theis non-equilibrium formula (23) using the values of transmissibility and storage coefficients given in table 5. The yields of Central, South, and Coquillard Stations were computed on the assumption that the pumping levels at the end of the pumping periods were at the tops of well screens, and the yield of the North Station well field was computed assuming an available drawdown of 63 feet.

Increasing the total pumping to that amount given in table 6 would undoubtedly cause a decline in water level throughout the South Bend area. Because it is assumed that no interference occurs between well fields, the computed total maximum yield of well fields in South Bend is probably too great if it is assumed that all available drawdown may be utilized at each station. The greatest interference effect of the increased pumping would

Table 6

Maximum yields of South Bend municipal well fields

Station		Yield (MGD) 1 day	5 days	30 days	Total drawdown (feet)
Central		5.4	5.0	4.6	84
North		13.1	10.5	9.2	63
Oliver Park	a.	7.4	7.2	7.0	62
	b.	12.5	12.3	12.0	112
South		11.2	9.7	8.4	40
Coquillard		13.3	13.0	12.7	130
Totals		50.4	45.4	41.9	

a. Assuming pumping level at top of water-bearing formation.

b. Assuming pumping level at top of screen.

occur in the downtown area. To compensate in part for this probable interference, the estimate of total available drawdown at North Station is reduced about 20 feet, leaving 63 feet of available drawdown. The available drawdown at Central Station is not reduced, as the reduction is of minor importance in the total maximum yield. Some adjustment of the maximum yield at each station would occur as the interference between well fields became effective.

At the stations where artesian conditions exist, the storage coefficient is about 3.0×10^{-4}. By utilizing all the available drawdown or maintaining a pumping level at the top of the well screen, the water level in the pumping well is lowered to a point below the upper confining clays. If the water level in the formation near the pumping well were lowered to a point below the upper confining clays there would be a change from artesian to water-table conditions and the storage coefficient would become about 0.15 in that region. In such a case the yield of the field would be somewhat more than that shown in table 6. However, the estimated well losses at the maximum pumping rates are only slightly less than or greater than the distance from the top of the screen to the bottom of the upper confining clay. Therefore, where artesian conditions exist, little error is introduced into the yield computations by assuming that the formation is completely saturated, or that the storage coefficient is about 3.0×10^{-4}, when the maximum available drawdown in the wells is utilized.

The suction-gang wells at Oliver Park Station (4-1 to 4-27) are limited in yield because the present system of pumping cannot fully utilize the available drawdown in the area. The present maximum yield from the suction system over long periods of heavy pumping is reported by the City to be about 7 mgd. Well 4-28 could produce this quantity alone if adequate pumping equipment could be installed in the well. Pumping well 4-28 continuously for 30 days at a rate of 7 mgd would result in a pumping level about 82 feet below the land surface at the well site, or at the top of the water-bearing formation. Theoretically 12 mgd could be pumped from well 4-28 for 30 days, if a pump of sufficient capacity could be installed. After 30 days at this rate the pumping level in well 4-28 would be about 132 feet below the land surface, or at the top of the screen.

According to the theoretical assumptions, the North Station wells (1-53 to 1-56), pumping continuously at a constant rate and developing an ultimate drawdown of 63 feet, would yield about 9 mgd over a period of about 30 days, or nearly 12 mgd for a period of about 48 hours. More water could probably be obtained at North Station by increasing the capacity of the present pumping equipment. However, unless considerable river recharge may be induced to flow into the downtown area by a lowering of the water table, further development at North Station may not be desirable. If large quantities of river recharge cannot be induced to flow into the downtown area, it is apparent that a greater volume of ground water could be obtained in the future by expanding the outlying pumping stations, Oliver, South, and Coquillard Stations. Expanding these stations fully would reduce the ground-water flow toward the downtown area considerably, perhaps to such an extent that insufficient ground water would be available to meet the demand of an expanded North Station.

Although the basic assumptions made in computation of yield seem restrictive, several compensating features of the area tend to reduce the errors resulting from the use of the restrictive assumptions. It is assumed that no recharge from precipitation or surface bodies of water enters the pumped formation. This in undoubtedly too strict an assumption, as it is evident that recharge from precipitation occurs, and furthermore that some recharge from the St. Joseph River is possible. On the other hand, the transmissibility of the sediments is assumed to remain constant through an infinite area. In a later section it is shown that the transmissibility of the sediments in the areas not tested is much lower than that of the present well fields. A decrease in transmissibility away from the well field would cause the actual yield to be less than the computed yield. If practical operation of the well fields is considered, the maximum yields given in table 6 probably would not be reached because continuous operation may not be desirable from the economic viewpoint. Assuming that the effect of recharge balances the effect of decreases in transmissibility away from the well fields, it may be said that the estimated theoretical maximum yields of the well fields as given are in the neighborhood of those to be expected if all fields are pumped continuously. If convenience of well operation is considered, the estimates of maximum yield should be reduced, the amount of reduction being dependent on storage facilities and economics of operation.

PIEZOMETRIC SURFACE IN THE SOUTH BEND AREA

The water-bearing formations of the South Bend area constitute a large underground reservoir in which many millions of gallons of water is stored. The water in the reservoir is replenished largely by recharge from precipitation and is depleted by natural discharge into the St. Joseph River, by losses due to transpiration and evaporation, and by discharge from wells. The extent to which the formation is replenished or depleted is shown by the changes of water levels in wells.

A contour map of the piezometric surface and the water table in the South Bend area is shown in plate 6. The map is based on reported and measured depths to water in wells obtained generally during 1945. Measurements made from 1939 to 1945 are included for several of the wells. It was not possible to measure the water levels in all the wells in the area because many are tightly covered by pump bases, and few are equipped with reliable air lines and altitude gages. The water levels used in the construction of the map were selected to show "static" conditions unaffected by strictly local pumping. Some errors doubtless remain in the final map because adequate information concerning the operation of nearby wells is not generally available for the time of water level measurement.

The contours on the map indicate lines of equal elevation of the water level or hydrostatic pressure. The direction of flow of the ground water is downgradient at right angles to the contours. The map shows, therefore, the shape of the piezometric surface and water table, the direction of flow of ground water, and the hydraulic gradients under which the ground water moves. Ground water will flow from points of high elevation or high hydrostatic pressure to points of low elevation or low hydrostativ pressure.

The piezometric surface slopes from a maximum elevation of about 740 feet above sea level in the southern part of the city to an elevation of less than 670 feet in the central business section. A large cone of depression has been developed in the downtown business section because of the pumping at Central Station and from wells used for air conditioning in the vicinity. Other small cones of depression have been developed in other parts of the city because of industrial pumping.

In the area east and north of the St. Joseph River ground water flows generally toward the river under a hydraulic gradient of about 16 to 55 feet per mile, the steeper gradients occurring near the north edge of the area. South of the river, ground water flows northward toward the river and the heavily pumped downtown area from the higher uplands south of the city, under a hydraulic gradient averaging about 22 feet per mile. Ground water apparently also flows eastward into the area from the west toward the Bendix plant and the other industrial well fields.

The shape of the piezometric surface north of Elwood and Angella Avenues is uncertain, as adequate information on water-level elevations is not available. Additional work in this area will be needed to show the true direction of flow of ground water in the northern part of the South Bend area.

The water level in the St. Joseph River is held at an elevation of about 680 feet above sea level from a point in Mishawaka downstream to the South Bend Dam, between Jefferson and Washington Streets. The contours of the water table suggest that ground water is escaping into the river by natural discharge as far downstream as Greenlawn Avenue. From that point northward, as far as the South Bend Dam, the piezometric surface is below river level and there is a possibility of recharge from the river to the water-bearing beds.

Below the South Bend Dam the water level in the St. Joseph River is at an elevation of about 668 feet above sea level and the ground-water levels are apparently higher than the water level in the river. Natural discharge to the river may be possible in the area north of North Station.

It is evident from section GH, plate 5, that the deeper water-bearing sands and gravels are overlain by a clay blanket from Central Station northward along the river. Evidence of continuity of the clay is shown by the fact that the static water levels in the North Station wells are higher at certain times than river level and also by the fact that wells flow above the land surface northwest of North Station.

Geologic evidence is not sufficient to prove that the clay is continuous. It may be breached in many places, permitting leakage of water into the river, yet it may confine water sufficiently to permit some wells to flow. The confining clay may be sufficiently sandy to be permeable and permit upward leakage to the river and yet be sufficiently impermeable to produce artesian conditions. If the contours as shown on plate 6 are correct, leakage of water from the aquifer to the river must take place either through actual breaches in the confining layer or through semi-permeable parts of the clay.

RECHARGE FROM PRECIPITATION

The area of diversion is defined as the area in which ground water flows, under equilibrium conditions, so as eventually to reach the pumping wells. It is the area contributing ground water to wells in the South Bend area. The boundaries of the area of diversion are dependent on rates and distribution of pumping and recharge and on the transmissibility of the water-bearing beds. These boundaries may change position over a period of time. During periods when rates of recharge are increased or the rates of pumping are decreased the area of diversion will decrease in areal extent, and when rates of recharge are lowered and rates of pumping increase, the area will expand.

The area of diversion contributing water to the wells of the South Bend area is large and includes a considerable part of St. Joseph County. The outer limits of the area of diversion lie beyond the area studied in detail in this investigation. The determination of the full extent of the area of diversion must await additional study in St. Joseph County.

Burdick (2) in 1911 estimated the area contributing ground water to the South Bend area to be about 87 square miles. At that time, the pumpage for municipal stpply was about 4.4 million gallons daily. The industrial pumpage was probably about equal and the total pumpage was probably about 9 million gallons a day. Artingstall (1) in 1921 estimated the area to be about 115 square miles, for a total pumpage estimated as about 12 million gallons a day. Evidence obtained during the present investigation suggests that the previous estimates of the contributing area may have been too high for the quantities of water being pumped.

In order to obtain an idea of the average rates of recharge from precipitation that can be expected in the South Bend area, a nearby drainage basin, that of the Elkhart River above Goshen, was selected for study. This drainage basin is believed to be roughly comparable from the standpoint of geology and topography to the drainage basin of the St. Joseph River in the South Bend area. An unpublished analysis of the rainfall and runoff characteristics of the basin, made by L. W. Furness, of the U. S. Geological Survey, Surface Water Division, Indianapolis, shows that the total runoff of the stream amounted to an average of about 11 inches of water per year over the basin, or about 35 percent of the average annual rainfall. About 7.5 inches of the total runoff was derived from ground-water flow or natural discharge from the ground-water reservoir to the stream. This is equivalent to about 24 percent of the average annual precipitation. The ground-water flow or "base flow" of a stream is about equal to the recharge to the ground-water reservoir, disregarding changes in storage. A major part of the recharge could be intercepted by pumping from wells instead of being discharged naturally to the stream if the water levels in the water-bearing formations were lowered by pumping. The "base flow" of a stream is therefore equal to recharge which might be salvaged by wells and put to beneficial use before discharging naturally into the streams.

A recharge rate of 7.5 inches per year is equivalent to an average of about 360,000 gallons per square mile per day. Recharge rates in similar glacial-outwash materials in the Miami Valley, Ohio (12), have been determined as 650,000 gallons per square mile per day, and at Canton, Ohio (22), as 374,000 to 460,000 gallons per square mile per day.

Conditions in the South Bend area are probably more favorable for recharge than those in the drainage basin of the Elkhart River, because of smaller evapo-transpiration losses and a generally deeper water table. The drainage basin of the Elkhart River is poorly drained and contains many lakes and marsh areas. The area of permeable outwash deposits is relatively greater at South Bend than in the Elkhart basin. However, it is desirable to assume a conservative average rate of 360,000 gallons per square mile per day for the South Bend area, until a more exact estimate can be made. Recharge at this rate in an area of about 80 square miles would be required to support an average daily pumpage of 29 million gallons, the pumpage in 1945, assuming no other source of recharge. However, the actual area may be much smaller if there is substantial recharge from the river, as seems probable, or if the rate of recharge from precipitation is more than 360,000 gallons per square mile per day.

SAFE YIELD OF THE WATER-BEARING FORMATIONS OF THE SOUTH BEND AREA

The safe yield of a water-bearing formation may be defined as the rate at which water may be drawn from it indefinitely, within economic limits, without impairing the quality of the supply. In the South Bend area, it may be regarded as the rate at which water can be pumped perennially from the ground-water reservoir without exceeding the amount that flows through the water-bearing beds naturally, plus the additional recharge that can be induced by lowering water levels by pumping. The safe yield is dependent on all the hydrologic and geologic features of the area, including the areal extent, thickness, and hydraulic characteristics of the water-bearing beds, the natural rate at which water is recharged to the water-bearing formations and the extent to which it may be possible to induce additional recharge by lowering ground-water levels, the precipitation in the area, the presence or absence of water of undesirable quality in beds hydraulically connected with the fresh water-bearing beds, the pumping lift, and the uses to which the water is to be put.

The geologic relations of the glacial deposits in the South Bend area are fairly well known from the logs of wells, although some doubt still remains as to the detailed structure in areas where few or no wells have been drilled. Although clay separating two or more zones of water-bearing materials was encountered in many wells, it is believed that the shallow sand and gravel aquifer is hydraulically connected with deeper water-bearing beds at several locations in the city, and that recharge from precipitation may reach the deeper beds through areas where permeable material connects them with the shallower beds. In many wells, however, it is difficult to determine the true thickness of water-bearing material through which ground water flows.

The pumping-test results show with considerable accuracy the hydraulic characteristics of the formations at the well fields where tests were made. However, as stressed previously, the formations differ in character within very short distances and the individual pumping-test results may be applied only within the area tested. As the well fields now in use were located where test drilling showed that the aquifers were likely to be most productive, the average permeability of about 4,000 gallons per day per square foot at the present well fields, as determined by pumping tests, may be considerably higher than the average permeability of the entire water-bearing formation in the South Bend area.

The map of the piezometric surface and water table indicates that the 700-foot contour nearly encloses the heavily pumped area of South Bend. Ground water flows across the 700-foot contour towards the areas of pumping in the downtown business section and in the western part of the city. In the area along the river southeast of Greenlawn Avenue, the water table is higher than the water level in the river and ground water discharges naturally into the river. The same situation apparently is true north of North Station. The ground water flowing across the 700-foot contour southeast of the line YZ and north of the line WX shown on plate 6, is discharged into the river and does not enter the heavily pumped area.

The average transmissibility of the water-bearing formations of the South Bend area can be estimated on the basis of total pumpage from the heavily pumped areas. According to table 3, the total pumpage during 1945 averaged 29.3 million gallons a day. Of this amount, nearly all but the pumpage at South and Coquillard Stations and at Drewry's Ltd., or about 25.3 million gallons a day, was pumped within the area bounded by the 700-foot contour of the piezometric surface and the water table shown on plate 6. Water crossing the 700-foot contour between the lines WX and YZ on plate 6 enters the pumped area. The measured length of the 700-foot contour across which water passes is about 9.2 miles. The average hydraulic gradient across the 700-foot contour is about 22 feet per mile.

The total pumpage from wells within the area considered above is equal to the quantity of water crossing the 700-foot contour between W and Y, and between X and Z, plus the recharge from precipitation within the area in question, plus recharge from the St. Joseph River, minus discharge into the river. Inasmuch as much of the area is built up, and much of the precipitation falls on paved streets, roofs and buildings, the recharge from precipitation is less than it would be in open country, though it may still be considerable. Although water is apparently recharged to the aquifer from the river between Greenlawn Avenue and the South Bend Dam, ground water apparently discharges to the river below the dam. The recharge to the aquifer may be substantially greater than the loss from it. However, for the present analysis it is assumed that they are the same and that recharge from precipitation is negligible.

On the basis of these assumptions, the average transmissibility, T_a, along the 700-foot contour can be computed as the total pumpage divided by the product of the hydraulic gradient and the length of the line across which ground water flows, or:

$$T_a = \frac{25,300,000}{22 \times 9.2} = 125,000 \text{ gallons a day per foot}$$

If there is substantial recharge from precipitation and if the recharge from the river exceeds the discharge into it in the stretch between lines WX and YZ, the true value is, of course, less.

The average transmissibility in the areas tested is about 250,000 gallons a day per foot. Thus it is evident that in a large part of the South Bend area the average permeability of the water-bearing sand and gravel is considerably lower than that determined in the tests and is probably in the order of magnitude of 2,000 gallons a day per square foot, or less. The differences in transmissibility are due to differences both in permeability and in thickness of the water-bearing beds.

An additional quantity of water crossing the 700-foot contour line east of the line YZ discharges into the river. This quantity is equal to the length of the 700-foot contour line south of the line YZ, the average transmissibility of the aquifers and the average hydraulic gradient across the contour. Assuming a transmissibility of 125,000 gallons a day per foot, it is:

$$Q = 4.7 \times 125{,}000 \times 28 = 16{,}500{,}00 \text{ gallons a day}$$

It should be noted that the average hydraulic gradient is somewhat greater in this area than in the area previously discussed. However, it is possible that the transmissibility is less than 125,000 gallons a day per foot. A large part of this water, which now discharges naturally into the St. Joseph River, could be salvaged by properly located wells.

If water levels are lowered by an increase in pumping, the area of diversion will increase, allowing more areal recharge from precipitation to reach the heavily pumped area. If the water table is lowered below river level by pumping, recharge from the river may also be induced or increased. Available data on present ground-water movements indicate that at least 50 mgd may be withdrawn from the water-bearing sediments in the South Bend area. Until the recharge potentialities of the St. Joseph River are determined, and the area of diversion of the South Bend area is completely investigated, a more exact estimate of the yield of the formations in the

South Bend area cannot be made. If it is found that river recharge would occur in large quantities if the ground-water levels are lowered below river level, the yield of the water-bearing sediments may be considerably more than 50 million gallons a day.

SUMMARY AND CONCLUSIONS

The City of South Bend has been dependent on ground water for municipal supply since about 1886, when the first wells were drilled at Central Station. The municipal supply system now includes five well fields at fairly widely separated locations. The average daily pumpage from the municipal well fields increased from about 4.45 million gallons a day in 1915 to about 14.0 million gallons a day during 1944.

In addition to the municipal pumpage, large quantities of water are pumped from private wells for industrial and private use, including air conditioning. The largest industrial well fields are those of the Bendix Aviation Corporation, the Studebaker Corporation, the Oliver Farm Equipment Corporation, Drewry's Ltd., and the Singer Manufacturing Company. The average daily pumpage in 1945 from industrial and private wells is estimated to have been about 15.7 million gallons, and from all wells in the South Bend area about 29.3 million gallons.

The sand and gravel deposits of glacial and alluvial origin in the South Bend area constitute a vast underground reservoir from which large quantities of water have been pumped during the past 60 years. The glacial deposits along the St. Joseph River and the headwaters of the Kankakee River are mainly glacial outwash deposits of sand and gravel. These deposits are chiefly sand and gravel, interbedded with which are beds and lenses of clay that may be of small areal extent and thickness in some parts of the area but fairly thick and extensive in others. The deposits can generally be divided into a shallow and deeper zone of water-bearing sand and gravel separated by a zone in which clays and sandy clays are predominant. The shallow and deeper sands and gravels are hydraulically connected in some parts of the city.

The water in the ground-water reservoir is replenished by recharge from precipitation and from the St. Joseph River. Water is withdrawn from the reservoir by natural discharge into the St. Joseph River, by evaporation and transpiration losses, and by pumping from wells. The stage to which the reservoir is full is shown by the water levels in wells.

Ground-water levels in the South Bend area have declined since pumping started, at a variable rate, which averages about 0.5 foot per year over a period of nearly 50 years. Wells that originally flowed above the land surface are now pumped, and many wells originally pumped by suction are now equipped with deep-well pumps. In general, however, the decline in water levels has not been serious and does not indicate a general overdevelopment of the available ground-water supplies. It has been due to the normal development of a regional cone of depression necessary to divert water to the pumping wells and must continue until equilibrium between pumping and recharge is established. Rough computations indicate that only 10 to 15 per cent of all the water pumped during the past 50 years has been taken from storage and that 85 to 90 per cent has been replenished annually by recharge.

The chemical quality of water from wells in the South Bend area is similar to the quality of ground water pumped throughout northern Indiana and southern Michigan. The total hardness is rather high. Chemical analyses of water from the five municipal well fields and from the St. Joseph River given in Appendix C show that the quality of both ground and surface water changes over a period of time.

A series of pumping tests to determine the hydraulic characteristics of the water-bearing materials showed transmissibilities at the five municipal and two industrial well fields ranging from about 100,000 to 500,000 gallons a day per foot, averaging about 250,000 gallons a day per foot, and coefficients of storage averaging about 0.15 for water-table conditions and about 3×10^{-4} for artesian conditions. The approximate values of well loss at given rates of pumping and estimates of the potential yields of the five municipal well fields are given. The results show a total potential yield from the municipal system as a whole of about 42 to 50 million gallons a day for short periods.

A study of the piezometric surface and water table shows that the area contributing water to the wells of the South Bend area extends beyond the limits of the area studied in detail in this investigation, and a more dependable determination of the safe yield of the area must await additional work in St. Joseph County. The piezometric surface indicates that ground water flows generally toward the river and the areas of heavy ground-water pumping, with hydraulic gradients of 16 to 55 feet per mile. In the area upstream from Greenlawn Avenue along the river, ground-water levels are higher than the river and the water-bearing sediments are discharging water to the river. A similar loss appears to occur north of North Station. Between Greenlawn Avenue and the South Bend Dam, the water-bearing beds may be receiving recharge from the river.

A study of stream flow from a nearby drainage basin, that of the Elkhart River above Goshen, indicates that recharge from precipitation in the South Bend area probably is not less than about 360,000 gallons a day per square mile. Assuming this rate of recharge and assuming that recharge from the St. Joseph River is small, the area contributing water to wells in the South Bend area would have to be 70 to 80 square miles to support an average daily pumpage of 29 million gallons. However, recharge from the river may be considerable and the average recharge from precipitation may be more than

360,000 gallons a day per square mile, so that the actual tributary area may be much smaller.

The safe yield of the South Bend area is dependent in large part on the distribution of pumpage, the hydraulic characteristics of the water-bearing materials, and the rates of recharge from precipitation and potential recharge from the river within the area of diversion. Although the total safe yield of the area as a whole cannot be determined until the limits of the area of diversion are known and the potential recharge from the river can be evaluated, minimum estimates of safe yield can be made.

The average transmissibility of the water-bearing formations of the South Bend area as a whole is estimated on the basis of pumpage from the downtown business section to be no more than about 125,000 gallons a day per foot. The discrepancy between this value and that obtained by individual pumping tests can be explained by differences in the permeabilities and thickness of the water-bearing materials. The municipal well fields were located where the formations appeared to be most productive, on the basis of the results of extensive test drilling. In large parts of the area, ground-water conditions are less favorable than at the localities tested.

The present pumpage from wells in the downtown business section, including North and Central Stations, is about 11 million gallons a day, and that from wells outside of the downtown business section is about 18 million gallons a day. Under the existing rates and distribution of pumpage about 29 million gallons a day of water is flowing into the area of diversion, including any water being recharged from the river, and about an additional 16 million gallons a day is being wasted into the river by natural discharge, southeast of line YZ on plate 6.

If additional well fields were located to intercept the ground water now discharging into the St. Joseph River, or if water levels were lowered sufficiently to include the area of natural discharge upstream from line YZ in the area of diversion, the safe yield would be at least 50 million gallons a day. Investigation of the recharge potentialities of the St. Joseph River would probably show that much more than 50 million gallons a day of ground water is available for pumping in the South Bend area.

The conclusions reached from the investigation described in this report indicate that the ground-water supplies of the South Bend area have not yet been developed fully, except in the downtown business section, and that considerable additional quantities of water may be pumped before full development throughout the area will occur. In order to develop fully the potential ground-water resources of the South Bend area, it will be necessary to redistribute the pumpage to well fields in the outlying parts of the city, which should eventually be used to supply the bulk of the demand. Adequate test drilling and test pumping should be done to evaluate the connection with the St. Joseph River. Additional wells or well fields can probably be developed along the St. Joseph River to utilize to full advantage the potential recharge that can be induced from the river in the areas north and southeast of the downtown business section. The area of diversion now tributary to South Bend should be outlined by additional observation wells, and a study of the piezometric surface and water table in St. Joseph County should be made beyond the limits of South Bend. Surveys of pumpage and ground-water levels should be made perhaps each 5 years to permit a comprehensive analysis of the effects of changes in pumping rates and distribution. Measurements of water levels should be made at regular intervals in a number of observation wells throughout the city and in the adjacent parts of the county to provide data for the construction of periodic maps of the piezometric surface. Wells do not now exist in some parts of the area where observations are desirable, and additional wells would have to be drilled specifically for observation purposes. Such a program may be expected to provide information to serve as a basis for the full and economic development of the ground-water resources of the South Bend area.

APPENDIX A

Records of wells in the South Bend area

St. Joseph County, Indiana

See plate 1 for locations.

SOUTH BEND

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 1-1-52	North Pumping Station, Leeper Park, North Michigan St. at St. Joseph River	City of South Bend	American Well Works Robert Kersey	1895-1926	-	Public supply
Sj 1-53	276 feet north of Bartlett Street and 426 feet east of N. Michigan St.	do.	Layne-Northern Co.	Sept. 21, 1939	21.9 CD 679.7 MSL	do.
Sj 1-54	546 feet north of Bartlett St. and 313 feet east of N. Michigan St.	do.	do.	Feb. 14, 1940	21.9 CD 679.7 MSL	do.
Sj 1-55	156 feet north of Park Lane and 206 feet west of N. Michigan St.	do.	do.	Apr. 24, 1940	20.9 CD 673.7 MSL	do.
Sj 1-T1	32 feet north of swimming pool and 68 feet west of storage tank, Leeper Park	do.	do.	July 15, 1939	-	Test
Sj 1-T2	300 feet north of well 53 and 278 feet east of Michigan Street	do.	do.	Dec. 14, 1939	-	do.
Sj 1-T3	144 feet north of Park Lane and 189 feet west of Michigan Street	do.	do.	Dec. 30, 1939	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal.)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 1-1-52	87-109	6-12	-	-	Gravel	-	+8	Oct. 1, 1907	-	-	-	-	-	-	I1(1)
Sj 1-53	103	60-38	76	27	Sand and gravel	-	-	-	2,220 2,140	Sept. 21, 1939 Jan. 24, 1945	39.76	2,140	-	-	I1 Well 1
Sj 1-54	110	60-38	54	56	do.	110	3.58 6.34	Feb. 14, 1940 Jan. 24, 1945	2,200	Feb. 14, 1940	24.25	2,200	214	52	I1 Well 2
Sj 1-55	112	60-38	80	32	do.	-	-	-	2,200	Apr. 24, 1940	34.0	2,200	20	-	I1 Well 3
Sj 1-T1	100	6	56	44	do.	-	-	-	-	-	-	-	-	-	I1
Sj 1-T2	110	6	54	56	do.	-	-	-	-	-	-	-	-	-	I1
Sj 1-T3	115	6	54	58	do.	112	-	-	-	-	-	-	-	-	I1

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 1-T4	150 feet north of Bartlett St. and 150 feet east of Michigan Street	City of South Bend	Layne-Northern Co.	Jan. 1940	-	Test
Sj 2-1-30	Central Pumping Station, E. Washington St. at St. Joseph River	do.	-	1883-1906	25 CD 633 MSL	Abandoned
Sj 2-31	Central Station on island between mill race and main channel St. Joseph River	do.	-	1906	25 CD 633 MSL	do.
Sj 2-32	do.	do.	Robert Kersey	1906	25 CD 633 MSL	do.
Sj 2-33	do.	do.	do.	1906	25 CD 633 MSL	do.
Sj 2-34	do.	do.	do.	1906	25 CD 633 MSL	do.
Sj 2-36	Central Pumping Station, south end	do.	Layne-Northern Co.	Apr. 25, 1942	26.0 CD 683.8 MSL	Public Supply
Sj 2-T1	Central Pumping Station, southeast corner	do.	do.	Dec. 20, 1941	26.0 CD 683.8 MSL	Test
Sj 3-1	South Station, southwest corner of property	do.	Austin Drilling Co.	1929	113.9 CD 771.7 MSL	Public supply

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 1-T4	110	6	68	42	Gravel	110	-	-	-	-	-	-	-	-	I1
Sj 2-1-30	79-113	4-10	-	-	Sand and gravel	-	-	-	1,390	1926	-	-	-	-	H12 (2)
Sj 2-31	87	12	48	39	do.	-	Flowing	Apr. 13, 1926	251	Apr. 13, 1926	-	-	-	-	H12 (3)
Sj 2-32	96	12	80	16	do.	-	Flowing	Apr. 16, 1926	192	Apr. 16, 1926	-	-	-	-	H12 (3)
Sj 2-33	93	4	71	22	Gravel	-	-	-	131	Aug. 11, 1930	-	-	-	-	H12 (3)
Sj 2-34	99	4	77	22	do.	-	-	-	-	-	-	-	-	-	H12 (3)
Sj 2-36	108.5	50-38	84	24½	do.	-	+1to-4	Apr. 25, 1942	2,100	May 18, 1942	37-42	2100	25.9	56	H12
Sj 2-T1	110	6	82	27	do.	109	-	-	-	-	-	-	-	-	H12
Sj 3-1	103	24-18	-	-	-	-	33.75	Aug. 11, 1941	950 975	Aug. 11, 1941 Jan. 16, 1946	12	950	-	52	H23

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 3-2	South Station, 720 feet north of well 1 along west side of property	City of South Bend	Austin Drilling Co.	1929	110.3 CD 768.1 MSL	Public supply
Sj 3-3	South Station, 600 feet north of well 2 along west side of property	do.	do.	1929	113.9 CD 771.7 MSL	do.
Sj 3-4	South Station, 320 feet south of control house	do.	Layne-Northern Co.	Apr. 16, 1942	132.5 CD 790.3 MSL	do.
Sj 3-T1	South Station, 235 feet south of control house and 220 feet west of property line	do.	do.	June 27, 1941	132.0 CD 790.0 MSL	Test
Sj 3-T2	South Station, 317 feet north of control house and 426 feet southeast of well 3	do.	do.	July 7, 1941	-	Test
Sj 4-1-27	Oliver Park Station, Olive St. and New York Central Railroad	do.	-	1924	60.2 CD 718.0 MSL	Public supply
Sj 4-28	Oliver Park Station, Olive St. and New York Central Railroad	do.	Layne-Northern Co.	Mar. 25, 1947	60 CD 718 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 3-2	90.5	24-18	61	29½	Sand and gravel	-	34.75 31.54	Aug. 11, 1941 Mar. 5, 1945	1,050 975	Aug. 11, 1941 Jan. 16, 1946	19.3 12.3	1423 1050	17.5	-	H23
Sj 3-3	-	24-18	-	-	-	-	32.50	Aug. 11, 1941	950 835	Aug. 11, 1941 Jan. 16, 1946	24.3	950	-	-	H23
Sj 3-4	111	38-18	77	32	Sand	-	46 51.5	Apr. 13, 1942 Mar. 5, 1945	1,110	Apr. 13, 1942	14	1110	-	-	H23
Sj 3-T1	116	6	53	61	Sand and gravel	-	-	-	-	-	-	-	-	-	H23
Sj 3-T2	112	6	66	39	do.	-	48	July 7, 1941	-	-	-	-	-	-	H23
Sj 4-1-27	121-170	12	-	-	-	-	-	-	5,600±	1945	-	-	37.2	54	H15
Sj 4-28	170	38-26	79	91	Sand and gravel	171 191	16.8	Mar. 25, 1947	2,300	Mar. 25, 1947	22.2	2300	-	-	H15

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 4-T1	Oliver Park Station, 140 feet east of west property line and 200 feet south of NYC Railroad	City of South Bend	Layne-Northern Co.	Oct. 19, 1944	60 CD 718 MSL	Test
Sj 4-T2	15 feet west of east line of Lombardy Drive, 60 feet south of Orchard Ave.	do.	do.	Nov. 4, 1944	57 CD 715 MSL	do.
Sj 4-T3	Oliver Park Station, 400 feet west of Olive St., and 200 feet north of south property line	do.	do.	Sept. 6, 1946	60 CD 718 MSL	do.
Sj 5-1	Coquillard Pumping Station, 990 feet east of Ironwood Drive and 700± feet north of city limits	do.	do.	Dec. 1930	93.1 CD 750.9 MSL	Public Supply
Sj 5-T1	321 feet west of Ironwood Drive and 60 feet north of city limits	do.	Harmon-Ness Co.	Oct. 31, 1930	90+ CD 748− MSL	Test
Sj 5-T2	200 feet west of Ironwood Drive and 300 feet north of city limits	do.	do.	Nov. 4, 1930	90± CD 748 MSL	do.
Sj 5-T3	200 feet west of Ironwood Drive and 1250 feet north of city limits	do.	do.	Nov. 24, 1930	90± CD 748 MSL	do.

			Principal Aquifer				Water level		Yield		Drawdown				
Well No.	Depth (feet)	Diameter (inches)	Depth to top of bed (feet)	Thickness (feet)	Material	Depth to bedrock (feet)	Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 4-T1	171	3-1½	118	47	Sand and gravel	165	20.6	Oct. 19, 1944	-	-	-	-	-	-	H15
Sj 4-T2	166	3-1½	128	33	do.	161	19	Nov. 4, 1944	10	Nov. 4, 1944	-	-	-	-	H15
Sj 4-T3	193	6	129	41	do.	191	18.8	Sept. 6, 1946	-	-	-	-	-	-	H15
Sj 5-1	205	60-26	133	72	do.	-	35.0 36.35	1930 Jan. 27, 1945	1,600	Jan. 27, 1945	15.31	1600	16.7	53	I5
Sj 5-T1	189	6-2	152	33	Gravel	-	30	Oct. 31, 1930	-	-	-	-	-	-	I5
Sj 5-T2	70	6	-	-	-	-	Dry	Nov. 4, 1930	-	-	-	-	-	-	I5
Sj 5-T3	213	6	168	44	Sand and gravel	212	30	Nov. 24, 1930	-	-	-	-	-	-	I5

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 5-T4	990 feet east of Ironwood Drive and 700± feet north of city limits	City of South Bend	Harmon-Ness Co.	Dec. 11, 1930	90± CD 748 MSL	Test
Sj 10-1	1225 S. Main St., south of plant building in alley, 50 feet west of southeast corner of building	City Dairy Company	Layne-Northern Co.	Jan. 23, 1935	74 CD 732 MSL	Dairy
Sj 10-2	1225 S. Main St., 150 feet west of southeast corner of building, 5 feet north of south wall	do.	Smith-Monroe Co.	July 1, 1937	74 CD 732 MSL	do.
Sj 11-1	2200 feet south of Sample St., on Chicago St., if extended	Grand Trunk Railroad	Layne-Northern Co.	Jan. 11, 1946	55 CD 713 MSL	Railroad
Sj 11-T1	South of Sample St., 50 feet northeast of coal dock	do.	do.	Nov. 6, 1937	55 CD 713 MSL	Test
Sj 12-1	1408 Elwood Ave., west of power house	Drewry's Ltd.	do.	-	43 CD 701 MSL	Industrial
Sj 12-2	1408 Elwood Ave., east corner of brew house	do.	do.	Mar. 30, 1940	43 CD 701 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal.)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 5-T4	206	6	133	73	Sand and gravel	206	30	Dec. 11, 1930	-	-	-	-	-	-	I5
Sj 10-1	58	8	44	19	do.	-	36 36.8	Jan. 23, 1935 Feb. 8, 1946	60	Jan. 1935	-	-	-	-	I13 (4)
Sj 10-2	53.5	12	44	9	do.	-	33 36.8	July 1, 1937 Feb. 8, 1946	90	July 1, 1937	20	90	-	-	I13 (5)
Sj 11-1	174	34-18	91	83	do.	-	11	Jan. 11, 1946	830	Jan. 11, 1946	13	830	-	-	H16
Sj 11-T1	170	6	91	79	do.	-	8	Nov. 6, 1937	-	-	-	-	50	-	H16
Sj 12-1	120	6	-	-	-	-	-	-	400	1944	-	-	-	-	H2
Sj 12-2	142	12	177	25+	Sand	-	22	Mar. 30, 1940	270	Mar. 30, 1940	21	610	16	55	H2

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 12-3	1408 Elwood Ave., north of bottling plant	Drewry's Ltd.	Layne-Northern Co.	Nov. 30, 1943	43 CD 701 MSL	Industrial
Sj 12-T1	1408 Elwood Ave., near water tower	do.	Layne-Ohio Co.	July 13, 1933	43 CD 701 MSL	Test
Sj 12-T3	1408 Elwood Ave., 110 feet south of southwest corner of building near railroad tracks	do.	Layne-Northern Co.	Sept. 14, 1943	43 CD 701 MSL	do.
Sj 13-1	921 Louise Street	National Milk Co.	do.	-	45 CD 703 MSL	do.
Sj 13-2	921 Louise Street	do.	Smith-Monroe Co.	Nov. 2, 1937	45 CD 703 MSL	Destroyed
Sj 13-3	912 Louise Street, north side of plant, 100 feet west of Louise St.	do.	do.	Aug. 31, 1943	45 CD 703 MSL	Dairy
Sj 13-T1	921 Louise Street	do.	do.	Aug. 20, 1943	45 CD 703 MSL	Test
Sj 14-1	East of High St., between Broadway and Pennsylvania Avenue	Northern Indiana Public Service Company	do.	Apr., 1936	-	Industrial

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 12-3	147	26-12	94	53	Sand and gravel	-	17	Nov. 30, 1943	630	Nov. 30, 1943	20	1000	-	-	H2
Sj 12-T1	128	6	62	66	do.	-	-	-	-	-	-	-	-	-	H2 (6)
Sj 12-T3	163	6	95	68	Sand	163	20	Sept. 14, 1943	-	-	-	-	-	-	H2
Sj 13-1	80	2	58	7	Sand and gravel	-	20	-	-	-	-	-	-	-	I18 (7)
Sj 13-2	67	12	24	43	do.	-	13	Nov. 2, 1937	175	Nov. 2, 1937	17	175	-	-	I18
Sj 13-3	74	8	25	49	do.	-	23	Aug. 31, 1943	90 60	Aug. 31, 1943 Dec. 15, 1944	18	90	27	-	I18
Sj 13-T1	147	8	24	51	do.	147	-	-	-	-	-	-	-	-	I18
Sj 14-1	-	16	-	-	-	-	6	Apr. 1936	425	Apr. 1936	40	425	-	-	H13

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 14-2	East of High St., between Broadway and Pennsylvania Avenue, 60 feet southeast of holder	Northern Indiana Public Service Company	Layne-Northern Co.	Sept. 27, 1937	-	Industrial
Sj 15-1	Northwest corner, Main and Washington Streets	Oliver Hotel	A. L. Cox and Co.	May 20, 1940	50 CD 703 MSL	Domestic and air conditioning
Sj 16-1	Western Ave. and Olive Street, 192 feet east of Olive Street, N. of Western Avenue	Singer Manufacturing Co.	Layne-Northern Co.	Aug. 6, 1934	55 CD 714 MSL	Industrial
Sj 16-T1	Western Ave., and Olive Street, near reservoir	do.	do.	July 1934	55 CD 714 MSL	Test
Sj 16-2	Western Ave., and Olive Street	do.	-	-	55 CD 714 MSL	Observation
Sj 16-F	Western Ave., and Olive Street	do.	-	Prior to 1906	55 CD 714 MSL	Fire protection
Sj 17-1	1108 High St., west side of boiler room	South Bend Bait Co.	Layne-Northern Co.	Jan. 6, 1936	64 CD 722 MSL	Industrial
Sj 19-1	Near Lilac and Cleveland Roads, southeast of mess hall	National Youth Administration	do.	April 18, 1941	-	Domestic

			Principal Aquifer				Water level		Yield		Drawdown				
Well No.	Depth (feet)	Diameter (inches)	Depth to top of bed (feet)	Thickness (feet)	Material	Depth to bedrock (feet)	Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 14-2	98	-	37	43	Sand and gravel	-	17	Sept. 27, 1937	-	-	-	-	-	-	H13
Sj 15-1	135	12	114	21	Gravel	-	35	May 1940	-	-	-	-	-	-	H12
Sj 16-1	118	30-18	90	28	Sand	-	27.5	Aug. 1934	500	Aug. 1934	18.5	500	38	-	H10
Sj 16-T1	138	6-4	90	36	Sand and gravel	-	-	-	-	-	-	-	-	-	H10
Sj 16-2	118	6	-	-	-	-	29.86	June 28, 1944	-	-	-	-	-	-	H10 (8)
Sj 16-F	40	480	-	-	-	-	13.99 19.28	Dec. 5, 1909 June 28, 1944	-	--	-	-	-	-	H10
Sj 17-1	75	8	55	20	Sand and gravel	-	36.0	Jan. 6, 1936	200	Jan. 6, 1936	9	200	-	52	H13
Sj 19-1	80	-	50	29	do.	-	23	Apr. 1941	-	-	-	-	-	-	C26

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 20-1	1/4 mile west of Butternut Road, 1/3 mile north of Lincoln Trail, (U. S. Highway 20)	Clarence Mathews Dairy	-	June 5, 1937	-	Dairy
Sj 21-1	Peach Road, north of Railroad Trail, northwest corner of boiler house	Kankakee Valley Foods	Layne-Northern Co.	March 16, 1942	-	Canning
Sj 22-1	Colfax Ave., and Michigan St.	Palace Theater	Robert Kersey	1923	50 CD 708 MSL	Abandoned, observation
Sj 22-2	do.	do.	do.	1923	50 CD 708 MSL	Abandoned
Sj 22-3	do.	do.	Howard E. Cowell	Aug. 1939	50 CD 708 MSL	Air conditioning
Sj 23-1	North Bendix Drive, near Gate 1, Bendix Plant	Bendix Aviation Corp.	A. L. Cox Co.	Sept. 1941	55 CD 713 MSL	Industrial
Sj 23-2	Bendix Plant, North Bendix Drive, west of power house	do.	do.	Sept. 1941	55 CD 713 MSL	do.
Sj 23-3	Bendix Plant, North Bendix Drive, south of electric furnace room	do.	Smith-Monroe Co.	Nov. 1934	55 CD 713 MSL	Observation

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal.)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 20-1	100	6	-	-	-	-	60	June 5, 1937	-	-	-	-	-	-	C29
Sj 21-1	137	-	120	16	Sand and gravel	136	-	-	-	-	-	-	-	-	G36
Sj 22-1	142	12	120	22	do.	-	37.22	June 8, 1944	500	July 1931	75	500	-	54	H12 (9)
Sj 22-2	139	12	-	-	-	-	29.5	1931	400	1923	-	-	-	-	H12 (10)
Sj 22-3	149	12	-	-	-	-	39.6	Aug. 1939	400	1939	-	-	-	54.6	H12
Sj 23-1	201	20	141	60	Sand and gravel	-	40	Sept. 1941	1600	Sept. 1941	40	1600	45.5	-	H3 (10)
Sj 23-2	209½	20	134	74	do.	208	40	Sept. 1941	1600	Sept. 1941	40	1600	36.8	-	H3 (9)
Sj 23-3	198	12	159	32½	do.	-	22 27	Nov. 15, 1934 Sept. 6, 1945	-	-	-	-	-	-	H3

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 23-4	Bendix Plant, North Bendix Drive, 500 feet west of Bendix Drive, 250 feet north of south property line	Bendix Aviation Corp.	Smith-Monroe Co.	Oct. 1934	55 CD 713 MSL	Abandoned
Sj 24-1	630 feet north of Sample St., and 780 feet west of Lafayette St.	Studebaker Corporation	Robert Kersey	1910	62 CD 720 MSL	Industrial
Sj 24-5	65 feet north of Sample St., and 1,160 feet west of Lafayette St.	do.	Smith-Monroe Co.	July 1923	62 CD 720 MSL	do.
Sj 24-6	730 feet south of Sample Street and 960 feet west of Franklin Street	do.	-	July 1923	62 CD 720 MSL	do.
Sj 24-7	720 feet south of Sample Street and 1,060 feet west of Franklin Street	do.	-	July 1923	62 CD 720 MSL	do.
Sj 24-9	1,610 feet south of Sample Street and 1,190 feet west of Franklin Street	do.	-	May 1926	62 CD 720 MSL	do.
Sj 24-10	Studebaker Proving Grounds, about 8 miles west of South Bend	do.	Layne-Northern Co.	-	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal.)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 23-4	200	6	159	39	Sand and gravel	-	25	Oct. 1934	100	Oct. 1934	15	100	-	-	H3 (11)
Sj 24-1	90	12	-	-	do.	-	37	Jan. 15, 1932	680 350	Original 1945	21	450	23	-	H11
Sj 24-5	72½	12	0	72	do.	94	32	Dec. 18, 1939	400 140	Dec. 18, 1939 Nov. 8, 1945	16	400	-	-	H11 (12)
Sj 24-6	65	16-12	0	65	do.	-	52 29	1923 Mar. 1937	740 400	1923 1946	16	375	-	-	H14 (13)
Sj 24-7	65	16-12	0	65	do.	-	29	1923	550 400	1923 1944	-	-	-	-	H14 (13)
Sj 24-9	58	38	-	-	-	-	30.9	1926	400	1944	13.7	400	-	-	H14 (13)
Sj 24-10	63	6	8	52	Sand	-	7.5	-	90	-	8	90	-	-	F11

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 24-11	Studebaker Proving Grounds, about 8 miles west of South Bend	Studebaker Corporation	Smith-Monroe Co.	Aug. 1926	96 CD 754 MSL	-
Sj 24-12	430 feet north of Sample St., and 820 feet west of Lafayette St.	do.	A.L. Cox and Co.	Mar. 3, 1941	65 CD 723 MSL	-
Sj 24-14	Studebaker Plant	do.	-	Prior to 1906	-	-
Sj 24-T1-T32	do.	do.	-	-	-	Test
Sj 25-1	Chapin and Dunham Streets	Oliver Farm Equipment Co.	-	Prior to 1906	60 CD 718 MSL	Industrial
Sj 25-2	do.	do.	Layne-Northern Co.	Jan. 1945	60 CD 718 MSL	do.
Sj 25-T1	do.	do.	do.	Nov. 1, 1944	60 CD 718 MSL	Test
Sj 26-1	1145 North Side Boulevard	Eckrich and Sons	-	-	-	-
Sj 27-1	Darden Road at St. Joseph River	Healthwin Hospital	Smith-Monroe Co.	July 19, 1938	-	Hospital
Sj 27-2	do.	do.	Layne-Northern Co.	Nov. 16, 1944	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 24-11	96	16	-	-	-	-	17	Aug. 1926	-	-	-	-	-	-	F11
Sj 24-12	94	12	-	-	-	-	36 36.1	Mar. 3, 1941 Oct. 6, 1945	250	Mar. 3, 1941	16	250	-	-	H11
Sj 24-14	103	-	94	9	Sandy gravel	-	-	-	-	-	-	-	-	-	H11 (14)
Sj 24-T1-T32	62-120	-	-	-	-	-	-	-	-	-	-	-	-	-	H11 (15)
Sj 25-1	30	144	-	-	Sand and gravel	-	10 30	1899 1944	800	1944	-	-	18 (1937) 17-21	-	H11 (16)
Sj 25-2	95.5	50-18	-	-	-	-	-	-	1,000	Jan. 1945	37	1000	-	-	H11
Sj 25-T1	125	6	80	27	Sand and gravel	-	30.3	Nov. 1, 1944	-	-	-	-	17-21	-	H11
Sj 26-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I18
Sj 27-1	67	8	11	56	Sand and gravel	-	35	July 19, 1938	165	July 19, 1938	12	165	-	-	C26
Sj 27-2	140	16	100	45	do.	-	23	Nov. 16, 1944	500	Nov. 16, 1944	16	500	19	-	C26

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 27-T1	Darden Road at St. Joseph River, 150 feet east and 50 feet north of water tank	Healthwin Hospital	Layne-Northern Co.	Sept. 11, 1944	-	Test
Sj 28-1	1217 S. Walnut St., about 400 feet west of main entrance	Oliver Farm Equipment Co. (820th AAF Depot)	-	1910	62 CD 720 MSL	Obser-vation
Sj 28-2	1217 S. Walnut St.	do.	Layne-Northern Co.	Oct. 22, 1941	62 CD 720 MSL	Indus-trial
Sj 29-1	1008 W. Sample St., about 300 ft. south of street	Wilson Brothers	-	1900	62 CD 720 MSL	-
Sj 29-2	1008 W. Sample St., about 300 ft. south of street and 50 feet east of well 1	do.	Smith-Monroe Co.	June 29, 1944	62 CD 720 MSL	Indus-trial
Sj 30-1	525 N. Niles Street	Artificial Ice Company	A. L. Cox and Co.	-	34 CD 692 MSL	Cooling
Sj 30-2	525 N. Niles Street	do.	do.	-	34 CD 692 MSL	do.
Sj 31	317 Lincoln Way East	Slick Laundry and Dry Cleaning Company	Smith-Monroe Co.	Feb. 26, 1936	50 CD 708 MSL	Laundry
Sj 32	117 S. Lafayette Street	Davies Laundry	do.	Sept. 1937	50 CD 708 MSL	Laundry

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 27-T1	147	6	100	47	Sand and gravel	-	23	Sept. 11, 1944	-	-	-	-	-	51	C26
Sj 28-1	146	12	-	-	-	146	18.3	Mar. 8, 1945	-	-	-	-	-	-	H15 (17)
Sj 28-2	86.2	12-10	-	-	-	-	17.3	Oct. 1941	320	Oct. 1941	22	320	-	-	H15
Sj 29-1	77	12	-	-	-	-	-	-	-	-	-	-	-	-	H14 (18)
Sj 29-2	70	12	45	25	Sand	-	26	June 29, 1944	585	June 29, 1944	15	585	-	-	H14
Sj 30-1	-	10	-	-	-	-	-	-	-	-	-	-	-	-	H1
Sj 30-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	H1
Sj 31	128	12	96	32	Sand and gravel	-	25 38	1936 1944	175	Feb. 26, 1936	5	175	-	-	H12
Sj 32	140	10	83	57	do.	-	36	Sept. 1937	150	Sept. 1937	14	150	-	-	H12

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 33	120 W. Colfax Avenue	Colfax Theater	Happ	1938	50 CD 708 MSL	Air conditioning
Sj 34-1	127 E. Sample St., 125 ft. north of Sample St., and 125 ft. west of alley	White Swan Laundry	-	-	68 CD 726 MSL	Observation
Sj 34-2	127 E. Sample St., 250 ft. northeast of Sj 34-1	do.	Smith-Monroe Co.	Dec. 31, 1941	68 CD 726 MSL	Laundry
Sj 34-T1	127 E. Sample St.	do.	do.	Dec. 11, 1941	68 CD 726 MSL	Test
Sj 35	Northeast corner Main and Washington Streets	J. M. S. Building	J. F. Kersey Smith-Monroe Co.	1909	50 CD 708 MSL	Commercial
Sj 36	West Sample St. and Webster St., 500 ft. south of Sample Street	N. P. Bowsher Company	Smith-Monroe Co.	1937	60 CD 718 MSL	Industrial
Sj 37	212 N. Michigan Street	Granada Theater	A. L. Cox and Co.	Mar. 1927	34 CD 692 MSL	Air conditioning
Sj 38	1011 S. Walnut Street	Landers Lumber Company	-	1924	60 CD 718 MSL	Industrial

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal.)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 33	160	-	-	-	-	-	-	-	125	June 1944	-	-	-	-	H12
Sj 34-1	81	12	-	-	-	-	40	Dec. 30, 1941	140	Dec. 31, 1941	35	140	-	-	H12 (18)
Sj 34-2	95	12	65	30	Sand and gravel	-	42	Dec. 31, 1941	175	Dec. 31, 1941	9	175	23	-	H12
Sj 34-T1	97	6	64	33	do.	-	38	Dec. 31, 1941	-	-	-	-	-	-	H12
Sj 35	142	6	120	22	do.	-	26	July 1931	-	-	-	-	-	-	H12 (19)
Sj 36	77	6	-	-	-	-	-	-	25	June 1944	-	-	-	-	H14
Sj 37	124	12	-	-	-	-	24	May 30, 1942	450	Mar. 1927	-	-	-	-	H12
Sj 38	100	6	-	-	-	-	24	1942	-	-	-	-	-	-	H14

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 39-T1	0.2 mile north of Chippewa St., and 500 ft. west of Pennsylvania R.R.	Studebaker Aviation Corp.	Layne-Northern Co.	Nov. 1940	-	Test
Sj 39-T2	0.3 mile north of Chippewa St., and 20 ft. west of Pennsylvania R.R.	do.	do.	do.	-	do.
Sj 39-T3	0.5 mile north of Chippewa St., and 30 ft. west of Pennsylvania R.R.	do.	do.	do.	-	do.
Sj 40	3702 W. Sample Street	Torrington Corporation	Smith-Monroe Co.	Oct. 1936	55 CD 713 MSL	Indus-trial
Sj 41-1	Northwest corner Sample and Main Streets	Furnas Ice Cream Co.	Layne-Northern Co.	1932	69 CD 727 MSL	Cooling
Sj 41-2	Northwest corner Sample and Main St., northeast corner of plant, 50 ft. west of sidewalk	do.	Smith-Monroe Co.	Feb. 24, 1938	69 CD 727 MSL	do.
Sj 42	Northeast corner Colfax and Lafayette Streets	South Bend Tribune	do.	May 21, 1941	50 CD 708 MSL	Air con-dition-ing
Sj 43	1/2 mile east of U. S. Highway 31 and 280 feet south of Ireland Road	Walter Eckler	Layne-Northern Co.	Oct. 25, 1944	-	Domestic

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 39-T1	23	-	-	-	-	-	-	-	-	-	-	-	-	-	H23
Sj 39-T2	25	-	-	-	-	-	-	-	-	-	-	-	-	-	H23
Sj 39-T3	34	-	-	-	-	-	8	Nov. 1940	-	-	-	-	-	-	H23
Sj 40	102	8	85	17	Sand and gravel	-	16	Oct. 1936	150	Oct. 1936	40	150	-	-	H16
Sj 41-1	60	8	-	-	-	-	36	1932	80	1932	-	-	-	-	H12
Sj 41-2	73	10	45	28	Sand	-	37	Feb. 24, 1938	160	Feb. 24, 1938	7 14	90 160	-	-	H12 (20)
Sj 42	135	12	110	25	Gravel	-	41	May 21, 1941	600	May 21, 1944	11	600	-	-	H12
Sj 43	144	6	17	127	Gravel and Sand	-	92	Oct. 25, 1944	50	Oct. 25, 1944	-	-	-	56	H25

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 44	Northeast corner, LaSalle and Michigan Streets, 75 ft. north and 50 ft. east of southwest corner of building	Michiana Hotel	Smith-Monroe Co.	Aug. 1936	35 CD 693 MSL	Air conditioning and domestic
Sj 45-1	739 College Avenue	South Bend Brewing Co. Hoosier Brewing Co. Polar Ice and Fuel Co.	Smith-Monroe Co.	May 1934	55 CD 713 MSL	Cooling
Sj 45-2	739 College Avenue	do.	-	1920±	55 CD 713 MSL	Cooling
Sj 46-1	332 E. Colfax Avenue	Smoler Brothers Inc.	Robert Kersey	1930	30 CD 688 MSL	Industrial
Sj 46-2	332 E. Colfax Avenue	do.	do.	-	30 CD 688 MSL	do.
Sj 47	Calvert Street Yards, near Calvert and Main Streets	Pennsylvanis Railroad	-	Feb. 1937	-	Railroad
Sj 48	220 S. Michigan Street	J. C. Penney Company	Howard Cowles	June 29, 1937	51 CD 709 MSL	-
Sj 49	416 W. Calvert Street	South Bend Pure Milk Co.	A. L. Cox and Co.	Jan. 23, 1935	95 CD 753 MSL	Dairy
Sj 50	213 N. Sycamore Street	Superior Laundry Company	Smith-Monroe Co.	May 1931	28 CD 686 MSL	Laundry

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 44	138	12	111	27	Sand and gravel	-	32	Aug. 1936	-	-	-	-	-	-	H12
Sj 45-1	133	12	90	43	Sand and gravel	-	28	May 1934	600	May 1934	4	200	-	-	H3
Sj 45-2	135	12	-	-	-	-	-	-	250	1920	-	-	-	-	H3
Sj 46-1	120	8	80	36	Sand and gravel	-	-	-	150	1930	-	-	-	-	H12
Sj 46-2	120	4	-	-	-	-	-	-	80	1945	-	-	-	-	H12
Sj 47	77	8	62	15	Sand and gravel	-	32	Feb. 1937	-	-	-	-	26.6	-	H13 (21)
Sj 48	160	-	-	-	-	110	-	-	Dry	-	-	-	-	-	H12
Sj 49	93	8	-	-	Sand and gravel	-	-	-	150	Jan. 23, 1935	-	-	-	-	H14
Sj 50	110	12	80	30	Sand and gravel	-	14	May 1931	-	-	-	-	-	-	H12

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 52-1	Notre Dame Campus	Notre Dame University	-	1895	90 CD 748 MSL	Domestic
Sj 52-2	Laundry, Notre Dame University	do.	-	1927	90 CD 748 MSL	do.
Sj 52-3	Dining Hall, Notre Dame University	do.	Robert Kersey	1927	90 CD 748 MSL	do.
Sj 52-4	Northwest of St. Joseph's Lake, near north edge of campus	do.	Smith-Monroe Co.	Oct. 12, 1939	90 CD 748 MSL	do.
Sj 52-5	Golf course, near south edge of campus	do.	do.	May 13, 1943	86 CD 744 MSL	Domestic and lake
Sj 52-T1	Rockne Memorial Building, Notre Dame Campus	do.	do.	Nov. 1937	90 CD 748 MSL	Test
Sj 52-T2	do.	do.	do.	do.	90 CD 748 MSL	do.
Sj 52-T3	do.	do.	do.	do.	90 CD 748 MSL	do.
Sj 52-T4	do,	do.	do.	do.	90 CD 748 MSL	do.
Sj 52-T5	do.	do.	do.	do.	90 CD 748 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 52-1	140	8	-	-	-	-	25	1895	-	-	-	-	16.8	-	C36
Sj 52-2	170.5	8	146	24.5	Sand	-	58	Sept. 1933	170 200	Sept. 1933 Apr. 1936	44	170	14.3	-	C36 (22)
Sj 52-3	161	12	-	-	-	-	34.4	Feb. 13, 1945	265	Nov. 11, 1937	28.7	265	-	-	C36 (23)
Sj 52-4	157	12	110	47	Sand and gravel	-	32	Oct. 12, 1939	185 300	Oct. 12, 1939 Feb. 1945	3	185	-	-	C36 (24)
Sj 52-5	180	12	133	47	Gravel	-	28	May 13, 1943	900 800	May 1943 Feb. 1945	10.6	900	-	-	C36 (25)
Sj 52-T1	40	6	-	-	-	-	-	-	-	-	-	-	-	-	C36
Sj 52-T2	40	6	-	-	-	-	-	-	-	-	-	-	-	-	C36
Sj 52-T3	35	6	-	-	-	-	-	-	-	-	-	-	-	-	C36
Sj 52-T4	8	6	-	-	-	-	-	-	-	-	-	-	-	-	C36
Sj 52-T5	32	6	-	-	-	-	-	-	-	-	-	-	-	-	C36

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 52-T6	Southeast corner of Cartier Field	Notre Dame University	Smith-Monroe Co.	July 17, 1946	90 CD 748 MSL	Test
Sj 53-1	East side of St. Joseph River, about 4,000 ft. north of Angella Boulevard	St. Marys Academy	-	-	20 CD 678 MSL	Domestic
Sj 53-2	do.	do.	-	-	20 CD 678 MSL	Abandoned
Sj 53-3	do.	do.	-	-	20 CD 678 MSL	do.
Sj 53-4	do.	do.	-	-	20 CD 678 MSL	do.
Sj 53-5	do.	do.	-	-	20 CD 678 MSL	Observation
Sj 53-6	do.	do.	-	-	20 CD 678 MSL	Abandoned
Sj 55-1	1916 South Main Street	South Bend Tool and Die Co.	Smith-Monroe Co.	June 30, 1939	87 CD 745 MSL	Industrial
Sj 55-2	1916 South Main Street	do.	do.	May 2, 1944	87 CD 745 MSL	do.
Sj 56	3113 Lincoln Way West	South Bend Sand and Gravel Co.	do.	Mar. 28, 1940	79 CD 737 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 52-T6	200	6	129	71	Sand and gravel	200	30-35	July 1946	-	-	-	-	-	-	C36
Sj 53-1	104	12	40	64	do.	-	10 10	July 1, 1933 Sept. 1936	150	-	1	150	14-15	-	C35 (26)
Sj 53-2	90	10	-	-	-	-	10	July 1, 1933	75	July 1936	20	70	-	-	C35
Sj 53-3	101	8	-	-	-	-	9.8	do.	150	do.	14	150	-	-	C35
Sj 53-4	95	8	-	-	-	-	2	do.	150	do.	8	150	-	-	C35
Sj 53-5	120	12	-	-	-	-	8	do.	150	do.	$3\frac{1}{2}$	150	-	-	C35
Sj 53-6	108	8	-	-	-	-	$1\frac{1}{2}$	do.	-	-	-	-	-	-	C35
Sj 55-1	103	8	88	15	Sand and gravel	-	28	June 30, 1939	60	June 30, 1939	50	60	-	-	H13
Sj 55-2	80	8	12	68	do.	-	26	May 2, 1944	100	May 2, 1939	1	100	-	-	H13
Sj 56	156	12	128	28	do.	-	26	Mar. 28. 1940	-	-	-	-	-	-	H3

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 57	Chain-O'-Lakes Road, 7 miles southwest of South Bend	Ray Bird Mission	Smith-Monroe Co.	Aug. 24, 1940	-	Domestic
Sj 58	405 E. Madison Street	Manufacturers Heating Co.	do.	-	34 CD 692 MSL	Industrial
Sj 59	Bendix Aviation Corp., Turret Bldg.	Capitol Elevator Company	do.	Apr. 3, 1942	-	Shaft
Sj 60	2100 E. Ewing Street	Concrete Products Co.	do.	July 14, 1943	89 CD 747 MSL	Industrial
Sj 61	223 S. Main Street	H. N. Light Company	do.	July 7, 1943	51 CD 709 MSL	do.
Sj 62	1026 King Street	Sobenite, Inc.	do.	June 3, 1943	42 CD 700 MSL	do.
Sj 63-1	South of Sample St., and west of Olive Street	New York Central Railroad	do.	Sept. 1931	60 CD 718 MSL	Railroad
Sj 63-2	do.	do.	do.	Sept. 1931	60 CD 718 MSL	do.
Sj 64	Monroe and Columbia Streets	Grand Trunk Railroad	do.	Aug. 17, 1929	51 CD 709 MSL	-
Sj 65-1	909 East Broadway	Reliable Dairy	do.	Jan. 1933	64 CD 722 MSL	Dairy

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal.)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 57	72	6	60	12	Sand and gravel	-	35	Aug. 24, 1940	50	Aug. 24, 1940	15	50	-	-	-
Sj 58	97.5	8-6	-	-	-	-	13	Aug. 21, 1941	-	-	-	-	-	-	H1 (27)
Sj 59	60	18	38	22	Sand and gravel	-	19	Apr. 3, 1942	-	-	-	-	-	-	H4 (28)
Sj 60	91	4	0	91	do.	-	48	July 14, 1943	28	July 14, 1943	12	28	-	-	I19
Sj 61	122	4	105	17	Sand	-	27	July 7, 1943	28	July 7, 1943	18	28	-	-	H12
Sj 62	124	8	65	60	Sand and gravel	-	+1	June 3, 1943	35	June 3, 1943	-	-	-	-	C35
Sj 63-1	152	12	110	42	do.	-	-	-	-	-	-	-	-	-	H16
Sj 63-2	155	12	110	45	do.	-	-	-	-	-	-	-	-	-	H16
Sj 64	121	6	109	12	Sand	-	30	Aug. 17, 1929	50	Aug. 17, 1929	-	-	-	-	H12
Sj 65-1	80	8	-	-	-	-	-	-	-	-	-	-	-	-	H13

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 65-2	909 East Broadway	Reliable Dairy	Smith-Monroe Co.	June 8, 1946	64 CD 722 MSL	Dairy
Sj 66-1	401 S. Notre Dame Avenue	Ullery Ice and Cold Storage Company	do.	Apr. 1934	40 CL 698 MSL	Cooling
Sj 66-2	do.	do.	do.	Feb. 1945	40 CD 698 MSL	do.
Sj 67	Taylor Street and South Street	Quick Service Laundry	do.	Mar. 21, 1929	63 CD 721 MSL	Laundry
Sj 68	1314 Kinyon Street	O. J. Wittner's Dairy	-	-	44 CD 702 MSL	Dairy
Sj 69	120 W. LaSalle Street	Geo. Hoffman Company	Smith-Monroe Co.	Nov. 28, 1929	50 CD 708 MSL	Domestic
Sj 70-1	-	Ind.-Mich. Power Co.	do.	Mar. 1930	-	-
Sj 70-2	-	do.	do.	Aug. 1936	-	-
Sj 71	Dixie Highway and Cleveland Road	Julius Christman	do.	Mar. 18, 1936	-	Domestic
Sj 72-T1	-	Howard and John Edwards	do.	May 9, 1930	-	Test
Sj 72-T2	-	do.	do.	May 9, 1930	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal.)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 65-2	96	10	75	21	Gravel	-	32	June 8, 1946	75	June 8, 1946	20	75	-	-	H13
Sj 66-1	92	6	72	20	Sand and gravel	-	16 20	Apr. 1934 Nov. 3, 1938	85	Nov. 30, 1938	60	85	-	-	H12
Sj 66-2	94	6	78	16	do.	-	-	-	-	-	-	-	-	-	H12
Sj 67	62½	10	35	27½	Sand	-	30	Mar. 21, 1929	200	Mar. 21, 1929	48	200	-	-	H11 (29)
Sj 68	97	6	-	-	-	-	16	July 11, 1929	30	July 11, 1929	28	30	-	-	C35 (30)
Sj 69	145	16	43	20	Gravel	-	-	-	225	Nov. 28, 1929	35	225	-	-	H12
Sj 70-1	65	6	30	35	Sand	-	28	Mar. 8, 1930	30	Mar. 8, 1930	-	-	-	-	-
Sj 70-2	137.5	12	111	24	Sand and gravel	-	38	Aug. 1936	125	Aug. 1936	1	125	-	-	-
Sj 71	46	6	20	26	do.	-	19.6	Mar. 18, 1930	50	Mar. 18, 1930	44	50	-	-	D25
Sj 72-T1	40	6	6	34	do.	-	21	May 9, 1930	-	-	-	-	-	-	-
Sj 72-T2	46	6	6	40	do.	-	21	May 9, 1930	-	-	-	-	-	-	-

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 73	-	Midwest Sand and Gravel Co.	Smith-Monroe Co.	July 19, 1931	-	Industrial
Sj 74	729 N. Brookfield Street	Suabedissen and Wittner Dairy	do.	Apr. 11, 1931	56 CD 714 MSL	Dairy
Sj 75	1702 Franklin Street	U. S. Gypsum Company	-	-	-	Industrial
Sj 76	534 Lincoln Way East	Haughton Elevator Co.	Smith-Monroe Co.	June 1937	45 CD 703 MSL	Elevator shaft
Sj 77	Roosevelt Road	Gentner Packing Co.	do.	Sept. 1937	-	Packing
Sj 78	3902 W. Sample Street	Roach Appleton Mfg. Co.	do.	Mar. 2, 1939	55 CD 713 MSL	Cooling
Sj 79	236 S. Main Street	Young Men's Christian Association	do.	Sept. 23, 1939	51 CD 709 MSL	Domestic
Sj 80-1	1012 S. High Street	South Bend Toy Company	Robert Kersey	-	66 CD 724 MSL	Industrial
Sj 80-2	1012 S. High Street	do.	Smith-Monroe Co.	May 31, 1944	66 CD 724 MSL	do.
Sj 81	106 N. Michigan Street	Clarks Lunch Room	do.	Mar. 21, 1939	50 CD 708 MSL	Air conditioning

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 73	43	10	28	15	Sand and gravel	-	-	-	-	-	-	-	-	-	-
Sj 74	129	8	112	17	Gravel	-	28	Apr. 11, 1931	-	-	-	-	-	-	H3
Sj 75	58	10	-	-	-	-	43	Feb. 1937	-	-	-	-	-	-	H14
Sj 76	27	10	-	-	-	-	-	-	-	-	-	-	-	-	H12 (31)
Sj 77	176	8	158	18	Gravel	-	51	Sept. 1937	160	Sept. 1937	20	160	-	-	M10
Sj 78	110	8	90	20	Sand and gravel	-	9	Mar. 2, 1939	150	Mar. 2, 1939	12	150	-	-	H16
Sj 79	99	8	38	61	do.	99 ?	30	Sept. 23, 1939	150	Sept. 23, 1939	10 22	50 150	-	-	H12
Sj 80-1	94	8-6	-	-	-	-	-	-	-	-	-	-	-	-	H13
Sj 80-2	38	10	6	82	Sand and gravel	-	39	May 31, 1944	100	May 31, 1944	10	100	-	-	H13
Sj 81	124	8	102	22	Gravel and sand	-	23	Mar. 21, 1939	150	Mar. 21, 1939	8	150	-	-	H12

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj 82-1	Edwardsburg Road, about 3 miles northeast of South Bend	St. Joseph Valley Memorial Park	Smith-Monroe Co.	May 21, 1930	-	Irrigation
Sj 82-2	do.	do.	do.	May 31, 1931	-	-
Sj 85	412 ft. west of Olive St. and about 100 ft. south of Indiana Ave., extended	New Jersey, Indiana and Illinois Railroad	-	-	-	Observation
Sj 86	Northeast corner Eddy and Jefferson Streets	Studebaker Estate	-	Prior to 1888	87 CD 745 MSL	Test
Sj 87	80 ft. east of Kessler Blvd., and 100 ft. south of Kinyon Street	D. W. Lynch	-	-	-	Observation
Sj 88	Ironwood Drive and U. S. Highway 20	Morris Park Country Club	-	-	-	do.
Sj 89	Hawthorne Drive, south of McKinley Blvd., 302 N. Coquillard Drive	V. D. Morgan	-	-	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 82-1	119	12	99	20	Sand and gravel	-	30±	May 21, 1930	350	May 21, 1930	70	350	-	-	D28
Sj 82-2	81	12	20	61	do.	-	30	Mar. 31, 1931	500	Mar. 31, 1931	20	500	-	-	D28
Sj 85	80	8	-	-	-	-	-	-	-	-	-	-	-	-	H15 (32)
Sj 86	2,027	6	-	-	-	160	-	-	-	-	-	-	-	-	I7 (33)
Sj 87	-	1½	-	-	-	-	-	-	-	-	-	-	-	-	C35
Sj 88	86	12	-	-	-	-	10.28	Mar. 6, 1944	-	-	-	-	-	-	I5
Sj 89	142.2	2	-	-	-	-	45.46	Mar. 17, 1945	-	-	-	-	-	-	I7

NOTES

1. Original wells in suction gang abandoned and sealed 1942-1943.
2. Original wells in suction gang abandoned and sealed 1942.
3. Abandoned and sealed.
4. Originally 92 feet deep. Unused Jan. 1946.
5. Unused Jan. 1946.
6. Formerly Muessel Brewery.
7. Formerly Old Wilida Dairy.
8. Three other wells, dia. 6 inches, depth 96-123 feet.
9. West well.
10. East well.
11. Drilled to 206 ft.
12. Redrilled by Smith-Monroe Co., Dec. 18, 1939.
13. Redrilled 1937.
14. Water-Supply Paper 254, p. 208, 1906.
15. 32 test wells.
16. Water-Supply Paper 254, p. 212, 1906.
17. Abandoned. Measured depth Mar. 8, 1945, 71.9'.
18. Abandoned.
19. Well rehabilitated 1931. Now abandoned.
20. Drilled to 90 feet.
21. Rehabilitated 1942. Now 68 feet deep.
22. Laundry well.
23. Dining Hall.
24. North well.
25. Golf course well.
26. Redrilled Sept. 1936 by Smith-Monroe Co.
27. Repaired Aug. 21, 1941.
28. Elevator shaft.
29. Abandoned in 1935.
30. Cleaned July 11, 1929, by Smith-Monroe Co.
31. Stantz Cheese Co.
32. Drilled to 120 feet.
33. Water-Supply Paper 254, p. 208.

Records of wells in Mishawaka

See plate 3 for locations

MISHAWAKA

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj Ill-1-1	Mishawaka - Water Works Park 200 feet north of Water Works	City of Mishawaka	Layne-Northern Co.	Feb. 20, 1937	-	Public Supply
Sj Ill-1-2	Mishawaka - North end of Home St., S. side St. Joseph River	do.	do.	May 19, 1941	-	do.
Sj Ill-1-3	Mishawaka - 900± feet north of Prospect Drive, and 1,500± feet east of Byrkit Ave., extended	do.	-	1929	-	do.
Sj Ill-1-4	Mishawaka - 550± feet north of section line and 750 feet east of Byrkit Ave., extended	do.	-	1929	-	do.
Sj Ill-1-T1	Mishawaka, north of Water Plant	do.	Layne-Northern Co.	Jan. 8, 1937	-	Test
Sj Ill-1-T2	Mishawaka, foot of Home St. on Eberhart Golf Course	do.	do.	Mar. 4, 1941	-	do.
Sj Ill-1-T3	Mishawaka, Petro Park southeast corner, 110± ft. north of river and 50 ft. west of east property line	do.	do.	Sept. 13, 1941	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj Ill-1-1	99½	20	65	34½	Sand and gravel	-	9	Feb. 20, 1937	1,200	Feb. 20, 1937	-	-	-	-	-
Sj Ill-1-2	107	20	7	100	do.	-	11.5	May 19, 1941	1,100	May 19, 1941	8	1,000	-	-	-
Sj Ill-1-3	-	18	-	-	-	-	-	-	1,200	1929	-	-	25	-	Well 1-29
Sj Ill-1-4	-	18	-	-	-	-	-	-	1,000	1929	-	-	25	-	Well 2-29
Sj Ill-1-T1	112	6	55	55	Sand and gravel	-	-	-	-	-	-	-	-	-	-
Sj Ill-1-T2	110	6	12½	89½	do.	-	10.5	Mar. 4, 1941	-	-	-	-	-	-	-
Sj Ill-1-T3	119	6	65	23	do.	119 ?	-	-	-	-	-	-	-	-	-

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj Ill-1-T4	Petro Park, 875 ft. north of T-3 and 25 ft. west of east property line	City of Mishawaka	Layne-Northern Co.	Sept. 19, 1941	-	Test
Sj Ill-1-T5	Petro Park, 108 ft. north of river wall and 684 ft. west of east property line	do.	do.	Sept. 24, 1941	-	do.
Sj Ill-1-T6	Petro Park, 1,356 ft. west of east property line and 90 ft. north of river wall	do.	do.	Sept. 25, 1941	-	do.
Sj Ill-1-T7	Petro Park, 624 ft. north of river wall and 900 ft. west of east property line	do.	do.	Sept. 27, 1941	-	do.
Sj Ill-1-T8	Petro Park, northwest corner, 110 ft. east of river	do.	do.	Oct. 5, 1941	-	do.
Sj Ill-1-T9	Petro Park, 1,050 ft. west of east end of park and 200 ft. north of river	do.	do.	Dec. 11, 1941	-	do.
Sj Ill-1-T10	Petro Park, 100± ft. north of river and 150 ft. west of east property line	do.	do.	Nov. 25, 1946	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal aquifer: Depth to top of bed (feet)	Principal aquifer: Thickness (feet)	Principal aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj Ill-1-T4	100	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Sj Ill-1-T5	130	6	115	7	Sand and gravel	-	-	-	-	-	-	-	-	-	-
Sj Ill-1-T6	133	6	100	33	do.	-	7	Sept. 25, 1941	-	-	-	-	-	-	-
Sj Ill-1-T7	130	6	100 117	3 3	Gravel	-	-	-	-	-	-	-	-	-	-
Sj Ill-1-T8	143	6	-	-	-	114	-	-	-	-	-	-	-	-	-
Sj Ill-1-T9	121	6	53 88 110	6 7 10	Sand and gravel	120	-	-	-	-	-	-	-	-	-
Sj Ill-1-T10	120	6	0 83	50 12	do.	-	Flows at surface	Nov. 25, 1946	-	-	-	-	-	-	-

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj I12-1-1	Twin Branch Plant	Indiana-Michigan Power Co.	-	-	-	Domestic
Sj I12-1-2	Twin Branch Plant	do.	-	-	-	do.
Sj I13-1	Mishawaka - 350 ft. east of Capitol Ave. and 50 ft. south of York St.	Harry Hess	Layne-Northern Co.	Dec. 30, 1943	-	do.
Sj I15-1	331 S. Byrkit Ave., Mishawaka	Clarks Laundry and Dry Cleaning Company	Smith-Monroe Co.	April 1929 Redrilled July, 1937		Indus-trial
Sj I16-1-1	Towle Ave. and Front St.	Kamm and Schellinger	-	Prior to 1906	-	Test
Sj I16-1-2	West end of plant next to Lincoln Park	do.	Layne-Northern Co.	Aug. 11, 1934	-	Indus-trial
Sj I16-1-T1	-	do.	Smith-Monroe Co.	May 1933	-	Test
Sj I16-1-T2	East end of plant	do.	Layne-Northern Co.	June 14, 1934	-	do.
Sj I16-1-T3	West end of plant on west property line	do.	do.	June 23, 1934	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj I12-1-1	103	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Sj I12-1-2	111	6	83	28	Sand	-	+11	Feb. 10, 1944	115	Feb. 10, 1944	-	-	-	-	-
Sj I13-1	39	-	3	35	Sand and gravel	-	13.5	Dec. 30, 1943	-	-	-	-	-	-	-
Sj-I15-1	99	10	83	18	do.	-	16	July 1937	150	July 1937	9	150	-	-	-
Sj I16-1-1	723	6	125	5	Sand	130	-	-	-	-	-	-	-	-	-
Sj I16-1-2	137	30-18	-	-	-	-	28	Aug. 11, 1934	550	Aug. 11, 1934	70.5	550	-	-	-
Sj I16-1-T1	127	6	113	14	Sand and gravel	-	20	May 1933	125	May 1933	70	125	-	-	-
Sj I16-1-T2	123	6	7	16.7	do.	-	-	-	-	-	-	-	-	-	-
Sj I16-1-T3	135	6	93	42	do.	-	20	June 23, 1934	-	-	-	-	-	-	-

Well No.	Location	Owner	Driller	Date completed	Altitude of land surface (feet)	Use
Sj I16-1-T4	25 ft. south of electric wires and 100 feet west of No. 6 well	Kamm and Schellinger	Smith-Monroe Co.	May 16, 1946	-	Test
Sj I16-2-T1	312 N. Mill Street, 75 ft. northwest of railroad between river and mill race	Mishawaka Rubber and Woolen Mfg. Company	Layne-Northern Co.	Sept. 8, 1937	-	Test
Sj I16-2-T2	312 N. Mill Street, 55 ft. east of Main St. and 35 ft. north of mill race	do.	do.	Sept. 1937	-	do.
Sj I16-2-T3	312 N. Mill Street, 150 ft. west of West St. and 10 ft. north of Water St.	do.	do.	Sept. 1937	-	do.
Sj I16-2-T4	312 N. Mill St., 90 ft. south of Front St., east of Mill St.	do.	do.	Sept. 1937	-	do.
Sj I16-2-T5	312 N. Mill St., 30 ft. east of Hose House 3	do.	do.	Sept. 16, 1937	-	do.
Sj I16-2-T6	Corner of Water and West Streets	do.	do.	Sept. 20, 1937	-	do.
Sj I16-2-T7	312 N. Mill St., 40 ft. west of northwest corner of Plant 2	do.	do.	Sept. 1937	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj I16-1-T4	125	6	42	18	Sand	-	40	May 1946	-	-	-	-	-	-	-
Sj I16-2-T1	63.5	6	-	-	-	49	-	-	-	-	-	-	-	-	-
Sj I16-2-T2	33	6	10	8	Sand and gravel	23	8	Sept. 1937	-	-	-	-	-	-	-
Sj I16-2-T3	37	6	8 18	6 9	do.	29	7	Sept. 1937	-	-	-	-	-	-	-
Sj I16-2-T4	42	6	3	12	do.	38	6	Sept. 1937	-	-	-	-	-	-	-
Sj I16-2-T5	50	6	-	-	-	-	-	Sept. 16, 1937	-	-	-	-	-	-	-
Sj I16-2-T6	43	6	26	11	Sand and gravel	40	8.7	Sept. 20, 1937	-	-	-	-	-	-	-
Sj I16-2-T7	47	6	0	19	do.	44	6.5	Sept. 1937	-	-	-	-	-	-	-

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj I16-2-T8	312 N. Mill St.	Mishawaka Rubber and Woolen Mfg. Co.	Layne-Northern Co.	May 28, 1939	-	Test
Sj I16-3-1	1121 W. 11th St.	Major Bros. Packing Co.	Smith-Monroe Co.	-	-	Industrial
Sj I16-3-2	1121 W. 11th St.	do.	do.	Nov. 30, 1942	-	do.
Sj I16-4	716 Lincoln Way West	H. B. Morrow	do.	Sept. 18, 1942	-	Domestic
Sj I16-5-1	724 S. Main St.	Mishawaka Farmers Dairy	do.	Feb. 1934	-	Cooling
Sj I16-5-2	do.	do.	do.	June 1939	-	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (oF)	Notes
Sj I16-2-1B	47	6	9	10	Sand and gravel	44	20	May 28, 1939	-	-	-	-	-	-	
			35	9	Sand										
Sj I16-3-1	75	10	-	-	-	-	-	-	-	-	-	-	-	-	-
Sj I16-3-2	89	12	67	22	Sand and gravel	-	5	Nov. 30, 1942	130	Nov. 30, 1942	76	130	-	-	-
Sj I16-4	116	-	98	18	Gravel	-	-	-	-	-	-	-	-	-	-
Sj I16-5-1	29	10	10	19	do.	-	12	Feb. 1934	-	-	-	-	-	-	Drilled to 46 feet
Sj I16-5-2	30	10	12	18	do.	-	5	June 1939	150	June 1939	5	150	-	-	-

RECORDS OF TEST WELLS IN THE SOUTH BEND AREA,
ST. JOSEPH COUNTY, INDIANA

Wells Sj 6-1A to Sj 6-25A taken from report by William Artingstall (1) 1921.

Wells Sj 6-1B to Sj 6-3K taken from records of South Bend Water Department.

Wells Sj 7-1 to Sj 7-32 taken from report by Burns and McDonnell Engineering Company (3) 1928.

Wells Sj 8-1 to Sj 8-38 taken from report by C. B. Burdick (2) 1911.

See plate 1 for locations.

TEST WELLS

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 6-1A	Walnut St., 100 feet north of Indiana Avenue	City of South Bend	-	Prior to 1921	65.42 CD 723.24 MSL	Test
Sj 6-2A	300 feet west of Gertrude St. and 100 feet north of Indiana Avenue	do.	-	do.	63.77 CD 721.59 MSL	do.
Sj 6-3A	Indiana Avenue and Brookfield Street	do.	-	do.	62.3 CD 720.1 MSL	do.
Sj 6-4A	Indiana Avenue and Olive Street	do.	-	do.	60.38 CD 718.20 MSL	do.
Sj 6-5A	Olive St., midway between Indiana Avenue and Sample Street	do.	-	do.	58.23 CD 716.05 MSL	do.
Sj 6-6A	Olive St., 100± feet south of South Bend, St. Joe and So. Ry.	do.	-	do.	60.8 CD 718.7 MSL	do.
Sj 6-7A	Sample St., just west of Olive Street	do.	-	do.	56.48 CD 714.30 MSL	do.
Sj 6-8A	Sample St. and Camden St.	do.	-	do.	56.78 CD 714.60 MSL	do.
Sj 6-9A	Dunham St. and Camden St.	do.	-	do.	57.14 CD 714.96 MSL	do.

			Principal Aquifer				Water level		Yield		Drawdown				
Well No.	Depth (feet)	Diameter (inches)	Depth to top of bed (feet)	Thickness (feet)	Material	Depth to bedrock (feet)	Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 6-1A	132	-	56	76	Sand and gravel	-	12	Prior to 1921	-	-	-	-	-	-	H14 (1)
Sj 6-2A	135	-	10	125	do.	-	-	-	-	-	-	-	-	-	H15
Sj 6-3A	80	-	20	60	do.	-	-	-	-	-	-	-	-	-	H15
Sj 6-4A	173	-	63	110	do.	-	13	Prior to 1921	-	-	-	-	-	-	H15
Sj 6-5A	177.8	-	63	114.8	do.	177.8	8	do.	-	-	-	-	-	-	H15
Sj 6-6A	180	-	160	20	Fine sand	-	-	-	-	-	-	-	-	-	H15
Sj 6-7A	184	-	35	141	Sand and gravel	176	8	Prior to 1921	-	-	-	-	-	-	H10
Sj 6-8A	194	-	127	53	Sand	188	5.94	do.	-	-	-	-	-	-	H10
Sj 6-9A	182	-	100	60	Gravel and sand	180	5.41	do.	-	-	-	-	-	-	H10

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 6-10A	Ford St. and Camden St.	City of South Bend	-	Prior to 1921	57.14 CD 714.96 MSL	Test
Sj 6-11A	Camden St., 100 feet north of Western Avenue	do.	-	do.	54.98 CD 712.80 MSL	do.
Sj 6-12A	Camden St., 150 feet south of West Washington Street	do.	-	do.	55.42 CD 713.24 MSL	do.
Sj 6-13A	Southeast corner LaSalle Lake (now drained)	do.	-	do.	51.26 CD 709.08 MSL	do.
Sj 6-14A	Northwest corner LaSalle Lake	do.	-	do.	51.7 CD 709.5 MSL	do.
Sj 6-15A	Near LaSalle Lake, 100± feet north of R. R.	do.	-	do.	52.94 CD 710.76 MSL	do.
Sj 6-16A	Iowa St. and Huron St.	do.	-	do.	56.17 CD 713.99 MSL	do.
Sj 6-17A	Near LaSalle Lake, 100± feet north of R. R.	do.	-	do.	52.94 CD 710.76 MSL	do.
Sj 6-18A	Northwest corner Kaley Park, at creek.	do.	-	do.	53.24 CD 711.06 MSL	do.
Sj 6-19A	Southwest corner of City property.	do.	-	do.	56.01 CD 713.83 MSL	do.

			Principal Aquifer				Water level		Yield		Drawdown				
Well No.	Depth (feet)	Diameter (inches)	Depth to top of bed (feet)	Thickness (feet)	Material	Depth to bedrock (feet)	Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (oF)	Notes
Sj 6-10A	198	-	78	119	Sand and gravel	197	5.41	Prior to 1921	-	-	-	-	-	-	H10
Sj 6-11A	211	-	80	110	do.	211	5.8	do.	-	-	-	-	-	-	H10
Sj 6-12A	210	-	80	130	do.	207	6.92	do.	-	-	-	-	-	-	H10
Sj 6-13A	186	-	130	56	Sand	-	-	-	-	-	-	-	-	-	H10
Sj 6-14A	203	-	51	152	Sand and gravel	200	0.31	Prior to 1921	-	-	-	-	-	-	H9
Sj 6-15A	100	-	52	8	Gravel	-	2.49	do.	-	-	-	-	-	-	H4
Sj 6-16A	193	-	10	183	Sand and gravel	193	4.70	do.	-	-	-	-	-	-	H9
Sj 6-17A	170	-	80	90	do.	-	2.48	do.	-	-	-	-	-	-	H4 (2)
Sj 6-18A	196	-	163	32	do.	195	14.0	do.	-	-	-	-	-	-	H4
Sj 6-19A	200	-	80	120	do.	-	4.5	do.	-	-	-	-	-	-	H9

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 6-20A	Olive St. and Rupel St. (extended)	City of South Bend	-	Prior to 1921	52.14 CD 709.96 MSL	Test
Sj 6-21A	Sample St. and Fakon St. (extended)	do.	-	do.	55.93 CD 713.75 MSL	do.
Sj 6-22A	Brookfield St. and Old Creek	do.	-	do.	53.09 CD 710.91 MSL	do.
Sj 6-23A	Sancome St. and Old Creek just north of Van Buren St.	do.	-	do.	51.65 CD 709.47 MSL	do.
Sj 6-24A	Olive St., south of Sample Street	do.	-	do.	60.79 CD 718.61 MSL	do.
Sj 6-25A	Olive St. 200 feet south of Sample Street	do.	-	do.	58.98 CD 716.80 MSL	do.
Sj 6-1B	Sample St. and Lafayette St.	do.	-	-	68.0 CD 726.0 MSL	do.
Sj 6-6B	Prairie Ave., 200 feet south of Garst St.	do.	-	-	60 CD 718 MSL	do.
Sj 6-9B	Blaine Ave. and Portage Ave.	do.	-	-	48 CD 706 MSL	do.
Sj 6-16B	Kentucky St., near LaSalle Lake	do.	-	-	50 CD 708 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 6-20A	186	-	120	66	Sand and gravel	-	18.00	Prior to 1921	-	-	-	-	-	-	H3
Sj 6-21A	200	-	90	110	do.	200	3.70	do.	-	-	-	-	-	-	H9
Sj 6-22A	187	-	108	79	do.	-	21.71	do.	-	-	-	-	-	-	H3
Sj 6-23A	215	-	180	34	Sand	214	24.75	do.	-	-	-	-	-	-	H2
Sj 6-24A	170	-	90	80	Sand and gravel	-	12.20	do.	-	-	-	-	-	-	H15
Sj 6-25A	159	12	50	109	do.	-	10.4	do.	305	Sept. 15, 1921	22.1	305	-	-	H15 (3)
Sj 6-1B	102	-	86	11	do.	97	-	-	-	-	-	-	-	-	H13
Sj 6-6B	100	-	89	11	Sand	100	19	-	-	-	-	-	-	-	H14
Sj 6-9B	146	-	44	100	Sand and gravel	144	-	-	-	-	-	-	-	-	H2
Sj 6-16B	136	-	34	102	do.	-	-	-	-	-	-	-	-	-	H9

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 6-17B	Northeast corner LaSalle Lake	City of South Bend	-	-	-	Test
Sj 6-24B	Bronson St. between Main St. and Lafayette St.	do.	-	-	64 CD 722 MSL	do.
Sj 6-3K	Erskine Park, north end	do.	Robert Kersey	Aug. 1, 1926	138 CD 796 MSL	do.
Sj 7-1	South end of 18th St., near river	do.	Austin Drilling Co.	Feb. 15, 1926	35.4 CD 693.2 MSL	do.
Sj 7-2	South end of Esther St., near river	do.	do.	Feb. 27, 1926	34.67 CD 682.19 MSL	do.
Sj 7-3	Potawatomi Park, east end	do.	do.	Mar. 11, 1926	48.5 CD 706.3 MSL	do.
Sj 7-4	End of Clover St., near river	do.	do.	Mar. 15, 1926	29.84 CD 687.66 MSL	do.
Sj 7-5	Ewing Ave. and Kline St.	do.	do.	Apr. 12, 1926	74.05 CD 731.87 MSL	do.
Sj 7-6	600 ft. south of Kline St. on Ewing Ave.	do.	do.	Apr. 19, 1926	70.0 727.8 MSL	do.
Sj 7-7	Ernspberger St. (Ironwood Dr.) and Bowman St.	do.	do.	Apr. 18, 1926	57.63 CD 715.45 MSL	do.
Sj 7-8	Sampson St. and Randolph St.	do.	do.	Apr. 29, 1926	49.05 CD 706.87 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 6-17B	134	-	38	96	Sand and gravel	-	-	-	-	-	-	-	-	-	H9
Sj 6-24B	100	-	89	9	do.	98	45.5	-	-	-	-	-	-	-	H12
Sj 6-3K	185	-	0	125	Sand	180	92	Aug. 1926	-	-	-	-	-	-	H25
Sj 7-1	70	-	0	68	do.	68	-	-	-	-	-	-	-	-	I18 (4)
Sj 7-2	70	-	0	68	do.	68	-	-	-	-	-	-	-	-	I18
Sj 7-3	122	-	0	115	do.	115	-	-	-	-	-	-	-	-	I7
Sj 7-4	70	-	0	68	do.	68	-	-	-	-	-	-	-	-	I18
Sj 7-5	130	-	0	116	do.	-	-	-	-	-	-	-	-	-	I19
Sj 7-6	116	-	0	115	do.	-	26	Apr. 19, 1926	-	-	-	-	-	-	I19
Sj 7-7	140	-	0	130	do.	-	27	Apr. 18, 1926	-	-	-	-	-	-	I18
Sj 7-8	103	-	0	100	do.	-	32	Apr. 29, 1926	-	-	-	-	-	-	I18

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 7-9	South of watch factory near River	City of South Bend	Austin Drilling Co.	Apr. 20, 1926	34.67 CD 692.49 MSL	Test
Sj 7-10	Ewing Ave. and Kline St.	do.	do.	June 7, 1926	74.05 CD 731.87 MSL	do.
Sj 7-11	Playland Park	do.	do.	June 18, 1926	25.94 CD 683.76 MSL	do.
Sj 7-12	LaSalle Park	do.	do.	June 1926	33.56 CD 691.38 MSL	do.
Sj 7-13	Mishawaka Ave. and Roberts Ave.	do.	do.	July 18, 1926	47.77 CD 705.59 MSL	do.
Sj 7-14	Mishawaka Ave. and Roberts Ave. (near River)	do.	do.	July 30, 1926	34.1 CD 691.9 MSL	do.
Sj 7-15	Ewing Ave. west of perfume factory	do.	do.	Aug. 24, 1926	101.41 CD 749.23 MSL	do.
Sj 7-16	Donald St. and Taylor St.	do.	do.	Sept. 17, 1926	109.82 CD 767.64 MSL	do.
Sj 7-17	South of Ewing Ave. near SJ 7-15	do.	do.	Oct. 6, 1926	-	do.
Sj 7-18	Playland Park, 100 feet west of race track	do.	do.	Oct. 15, 1926	24.47 CD 682.29 MSL	do.

			Principal Aquifer				Water level		Yield		Drawdown				
Well No.	Depth (feet)	Diameter (inches)	Depth to top of bed (feet)	Thickness (feet)	Material	Depth to bedrock (feet)	Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 7-9	169	-	0	68	Sand	-	-	-	-	-	-	-	-	-	I18
Sj 7-10	183	-	0	115	do.	175	27	June 7, 1926	-	-	-	-	-	-	I19
Sj 7-11	105	-	0	100	do.	-	3.0	June 18, 1926	-	-	-	-	-	-	I18
Sj 7-12	333	-	45	35	do.	285?	15	June 1926	-	-	-	-	-	-	H12
Sj 7-13	151	-	25	45	do.	120	26	July 18, 1926	-	-	-	-	-	-	I7
Sj 7-14	112	-	0	70	Sand and gravel	-	24	July 30, 1926	-	-	-	-	-	-	I18
Sj 7-15	205	-	0	130	do.	195	27	Aug. 24, 1926	-	-	-	-	-	-	H23
Sj 7-16	155	-	70	81	do.	-	29.8	Sept. 17, 1926	-	-	-	-	-	-	H14
Sj 7-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	H23
Sj 7-18	100	-	0	75	Sand	95	2.5	Oct. 15, 1926	-	-	-	-	-	-	I18

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 7-19	South end of Bellevue Ave. extended, near River	City of South Bend	Austin Drilling Co.	Nov. 4, 1926	32.50 CD 690.3 MSL	Test
Sj 7-20	Donmoyer St., 100 feet east of Michigan St.	do.	Gray Drilling Co.	Dec. 20, 1926	131.62 CD 789.44 MSL	do.
Sj 7-21	Donmoyer St. and Carroll St.	do.	do.	Jan. 1927	144.79 CD 802.61 MSL	do.
Sj 7-22	Potawatomie Park, north end.	do.	Austin Drilling Co.	Feb. 22, 1927	49.76 CD 707.58 MSL	do.
Sj 7-23	18th St., south of Hildreth St.	do.	do.	Mar. 9, 1927	34.11 CD 691.93 MSL	do.
Sj 7-24	South of Perfume Factory	do.	do.	Mar. 18, 1927	88.68 CD 746.50 MSL	do.
Sj 7-25	Marine St. and Ridgedale Blvd.	do.	do.	Apr. 7, 1927	98.14 CD 755.96 MSL	do.
Sj 7-26	Chippewa Ave. and Penna. R. R.	do.	do.	Apr. 21, 1927	103.48 CD 761.30 MSL	do.
Sj 7-27	Chippewa Ave., west of Penna. R. R.	do.	do.	May 6, 1927	109.81 CD 767.63 MSL	do.
Sj 7-28	Eckman St., west of Penna. R. R.	do.	do.	May 24, 1927	91.30 CD 749.12 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 7-19	220	-	0	68	Sand and gravel	219?	22.5	Nov. 4, 1926	-	-	-	-	-	-	I18
Sj 7-20	185	-	0	100	Sand	185?	-	-	-	-	-	-	-	-	H24
Sj 7-21	200	-	0	130	Fine sand	195?	-	-	-	-	-	-	-	-	H24
Sj 7-22	134	-	55	69.5	Sand and gravel	127	32	Feb. 22, 1927	-	-	-	-	-	-	I7
Sj 7-23	85	-	0	62.5	do.	75	5	Mar. 9, 1927	-	-	-	-	-	-	I18
Sj 7-24	129	-	4	66	do.	125.5	10.98	Mar. 18, 1927	-	-	-	-	-	-	H23
Sj 7-25	167.5	-	0 78	47 12	do.	161.5	20.54	Apr. 7, 1927	-	-	-	-	-	-	I19
Sj 7-26	160	-	0	116	do.	158	21.98	Apr. 21, 1927	-	-	-	-	-	-	H23
Sj 7-27	165	-	0	83	do.	163	28.01	May 6, 1927	-	-	-	-	-	-	H23
Sj 7-28	83	-	29	43	do.	72	11.0	May 24, 1927	-	-	-	-	-	-	H24

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 7-29	Eckman St., north of Studebaker Warehouse	City of South Bend	Austin Drilling Co.	May 26, 1927	93.2 CD 751.0 MSL	Test
Sj 7-30	Broadway and Dale St.	do.	do.	June 4, 1927	55.4 CD 713.2 MSL	do.
Sj 7-31	South of Sample St. and west of Lincoln Way West	do.	do.	June 16, 1927	39.52 CD 697.34 MSL	do.
Sj 7-32	North of Chippewa Ave. and east of Penna. R. R.	do.	do.	Nov. 26, 1927	109 CD 767 MSL	do.
Sj 8-1	Allen St. and Queen St.	do.	-	Prior to 1911	20.0 CD 678.0 MSL	do.
Sj 8-2	Northeast corner Sherman St. and Rose St.	do.	-	do.	18.6 CD 676.4 MSL	do.
Sj 8-3	Blaine Ave., near tracks	do.	-	do.	24.1 CD 631.9 MSL	do.
Sj 8-4	Angella Ave., 1,500 feet east of River	do.	-	do.	13.6 CD 676.4 MSL	do.
Sj 8-5	Humboldt St. and Allen St.	do.	-	do.	49.2 CD 707.0 MSL	do.
Sj 8-6	Angella Ave., 225 feet east of river	do.	-	do.	16.2 CD 674.0 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (oF)	Notes
Sj 7-29	86	-	5	76	Sand and gravel	-	9	May 26, 1927	-	-	-	-	-	-	H24
Sj 7-30	115	-	47	29.5	do.	110	20	June 4, 1927	-	-	-	-	-	-	H13
Sj 7-31	91	-	16	43	do.	87	20	June 16, 1927	-	-	-	-	-	-	H13
Sj 7-32	105	24-18	0	92.5	do.	-	18.5	Nov. 28, 1927	1,423	Feb. 5, 1928	19.4	1,423	-	-	H23 (5)
Sj 8-1	147	2.5	46	100	do.	146	+5.0	Prior to 1911	-	-	-	-	-	-	C35 (6)
Sj 8-2	146	2.5	64	90.5	do.	145.5	+5.7	do.	-	-	-	-	-	-	C35
Sj 8-3	144	2.5	46.5	97.5	do.	-	+5.7	do.	-	-	-	-	-	-	H2
Sj 8-4	125	-	44	74	do.	124	+4.0	do.	-	-	-	-	-	-	H2
Sj 8-5	152	-	77	75	do.	152	19.0	do.	-	-	-	-	-	-	H2
Sj 8-6	148	-	47	101	do.	148	+4.0	do.	-	-	-	-	-	-	H2

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 8-7	Portage Park	City of South Bend	-	Prior to 1911	21.5 CD 679.3 MSL	Test
Sj 8-8	LaSalle Park, Eddy St. at River	do.	-	Jan. 1911	31 CD 689 MSL	do.
Sj 8-9	Eckman St. and Lafayette St.	do.	-	-	95 CD 753 MSL	do.
Sj 8-10	Near Chapin and Warren Sts.	do.	-	-	107 CD 765 MSL	do.
Sj 8-11	Leeper Park	do.	-	-	17.5 CD 675.3 MSL	do.
Sj 8-14	North Pumping Station	do.	-	-	13.13 CD 670.95 MSL	do.
Sj 8-18	Central Station	do.	-	-	25.4 CD 683.2 MSL	do.
Sj 8-20	Washington and Main Sts.	Oliver Hotel	-	1903	51 CD 709 MSL	-
Sj 8-21	Main and Wayne Sts.	Y.M.C.A.	-	1907	51.7 CD 709.5 MSL	-
Sj 8-22	Bronson and Lafayette Sts.	Studebaker Corp.	-	1908	64 CD 722 MSL	-

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield: Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 8-7	102	10	-	-	-	-	+4.5	Prior to 1911	-	-	-	-	-	-	H2
Sj 8-8	150	-	50	10	Sand and gravel	150	-	-	-	-	-	-	-	-	H12
Sj 8-9	122	10	60 110	10 12	Gravel	122	4	Prior to 1911	-	-	-	-	-	-	H24
Sj 8-10	182	-	53	94	Sand and gravel	147	29	do.	-	-	-	-	-	-	H14
Sj 8-11	114	-	55	59	do.	114?	+11.3	do.	-	-	-	-	-	-	H1
Sj 8-14	121	-	42	75	do.	118	+15.87	do.	-	-	-	-	-	-	H1
Sj 8-18	111	-	73	38	do.	-	1.6	do.	-	-	-	-	-	-	H12
Sj 8-20	145	-	133	12	Gravel	145	19	1903	-	-	-	-	-	-	H12
Sj 8-21	100	-	0	100	Sand	100	12.7	1907	-	-	-	-	-	-	H12
Sj 8-22	100	-	0 90	60 10	Gravel Sand and gravel	100	20	1908	-	-	-	-	-	-	H11

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 8-23	Chapin and Ford Sts.	Oliver Chilled Plow Works	-	-	62 CD 720 MSL	-
Sj 8-24	Western Ave. and Jackson St.	Singer Mfg. Co.	-	1908	59 CD 717 MSL	-
Sj 8-25	Near Becks Lake	City of South Bend	-	-	51 CD 709 MSL	Test
Sj 8-26	-	South Bend Brewing Co.	-	1907	54 CD 712 MSL	-
Sj 8-27	Wilber and Elmwood Sts.	Muessel Brewing Co.	-	1908	43 CD 701 MSL	-
Sj 8-28	Springbrook Park	-	-	-	31 CD 689 MSL	-
Sj 8-29	East Jefferson St.	Clement Studebaker	-	1911	78 CD 736 MSL	-
Sj 8-30	Notre Dame	Notre Dame University	-	-	85.0 CD 743 MSL	-
Sj 8-31	St. Mary's Academy	St. Mary's Academy	-	-	10.2 CD 668.6 MSL	-
Sj 8-34	Mishawaka	Kamm and Schellinger Brewery	-	-	35 CD 693 MSL	-

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer			Depth to bedrock (feet)	Water level		Yield		Drawdown		Hardness (gr./gal.)	Temperature (°F)	Notes
			Depth to top of bed (feet)	Thickness (feet)	Material		Above (+) or below land surface (feet)	Date	Yield (g.p.m.)	Date	Amount (feet)	Rate (g.p.m.)			
Sj 8-23	40	240	0	40	Sand and gravel	-	12	Prior to 1911	-	-	-	-	-	-	H11 (7)
Sj 8-24	110	-	44	66	Sand	-	10	1908	-	-	-	-	-	-	H10
Sj 8-25	129	-	34	95	Sand and gravel	-	+6	Prior to 1911	-	-	-	-	-	-	H9
Sj 8-26	124	-	-	-	-	-	5	1907	-	-	-	-	-	-	H3
Sj 8-27	-	-	-	-	-	-	9	1908	-	-	-	-	-	-	H2
Sj 8-28	--	-	-	-	-	-	+1	Prior to 1911	-	-	-	-	-	-	I18
Sj 8-29	151	-	146	5	Gravel	-	-	-	-	-	-	-	-	-	I7
Sj 8-30	151	2	40	111	Sand and gravel	-	23	Prior to 1911	-	-	-	-	-	-	C36
Sj 8-31	123	6	30 119	85 4	do.	-	+1.8	do.	-	-	-	-	-	-	C35
Sj 8-34	725	-	160	5	Gravel	165	-	-	-	-	-	-	-	-	I16 (8)

Well No.	Location	Owner	Driller	Date Completed	Altitude of land surface (feet)	Use
Sj 8-35	Mishawaka, George St. and Prospect Drive	City of Mishawaka	-	-	62 CD 720 MSL	Test
Sj 8-36	Indiana Ave. and Joseph St., Mishawaka	-	-	Prior to 1911	56 CD 714 MSL	do.
Sj 8-38	Power House, Mishawaka	-	-	do.	19 CD 677 MSL	do.

Well No.	Depth (feet)	Diameter (inches)	Principal Aquifer: Depth to top of bed (feet)	Principal Aquifer: Thickness (feet)	Principal Aquifer: Material	Depth to bedrock (feet)	Water level: Above (+) or below land surface (feet)	Water level: Date	Yield (g.p.m.)	Yield: Date	Drawdown: Amount (feet)	Drawdown: Rate (g.p.m.)	Hardness (gr./gal.)	Temperature (°F)	Notes
Sj 8-35	302	-	0 100 145 224	53 25 75 78	Sand and gravel	(9)	7	Prior to 1911	-	-	-	-	-	-	I14
Sj 8-36	62	-	0 40.5	40 21.5	do.	62	-	-	-	-	-	-	-	-	I15
Sj 8-38	133	-	0	25	do.	55	-	-	-	-	-	-	-	-	-

NOTES

1. Records of wells from Artingstall report (1).
2. To replace 17A.
3. Well used for pumping test.
4. Well records from report of Burns and McDonnell (3).
5. Used for pumping test. Well 2 at South Station.
6. Well records from Burdick report (2).
7. Open dug well.
8. See well Sj 116-1-1.
9. Did not strike bedrock.

APPENDIX B

Logs of deep wells penetrating the bedrock formations of St. Joseph County.

See plate 2 for location

All logs except that for well G-Sj H11-1 were furnished by Division of Geology, Indiana Department of Conservation. The geologic names given are those used by the driller, except where noted.

G-Sj D14-1. Stuart Godfrey - No. 1, Karl Gadbury, 644 ft. from north line, 561 ft. from west line, NE$\frac{1}{4}$NW$\frac{1}{4}$, sec. 14, T. 38 N., R. 3 E. Completed August 22, 1945. Elevation 803 ft. Total depth 815 feet. Dry hole.

Material	Depth to bottom of stratum (feet)
Drift	470
Shale, blue	472
C. W. lime	476
Lime; shale	482
Lime, black; shale	483
Sand	487
Sand and gravel	497
Sand, dark brown at	497
Shale, dark brown, hard	548
Lime, gray, hard	560
Lime, gray; shale, soft	567
Lime, gray, brown	573
Traverse lime, hard	588
Coarse brown and black	593
Lime, hard, gray, buff	594
Gray and black	598
Traverse-calcite	711
Traverse washes in solution	740
Monroe dolomite, hard	765
Monroe dolomite, brown	780
Monroe, show of oil	785
Monroe dolomite, brown and gray	815

G-Sj E20-1. M. C. Pletcher - No. 1, Notre Dame University, 100 ft. from south line, 960 feet from east line, SW¼SW¼, sec. 20, T. 38 N., R. 4 E. Completed September 28, 1944. Dry hole. Drillers log.

Material	Depth to bottom of stratum (feet)
Unknown	450
Shale, brown	518
Traverse	527½
Water at 560	
Lime	978
Shale, gray	1008
Lower Monroe; set casing	1011½
Oil show at 1013½ to 1030	
Water, salt at 1045	
Total depth	1045
Plugged back to	1030

CASING RECORD:

5-3/16" casing 1011½'

G-Sj E20-2. Worden, Emma, No. 1, 250 ft. from north line, 250 ft. from east line, $NW\frac{1}{4}NE\frac{1}{4}$, sec. 20, T. 38 N., R. 4 E. Completed May 2, 1941, by John H. McLean. Elevation 779 ft. Plugged May 2, 1941.

Material	Depth to bottom of stratum (feet)
Sand	144
Gravel	146
Shale	152
Shale, green	180
Shale, green, sandy	400
Shale, dark, Antrim	434
Shale, dark, Antrim	500
Shale, black, hard	548
Shale, gray	554
Lime shell	568
Lime shell and shale	587
Lime, brown; top of Traverse	598
Lime, dark gray	611
Lime, light gray	619
Lime, light brown	627
Lime, light gray	642

CASING RECORD:

8"	casing	150'
6-5/8"	"	180'
5-3/16"	"	483'

G-Sj E29-1. Sones, Harry, No. 1, 330 ft. from south line, 330 ft. from east line, $NE\frac{1}{4}SE\frac{1}{4}$, sec. 29, T. 38 N., R. 4 E. Completed June 24, 1940, by Robert Allen Crude Oils. Dry Hole. Plugged July 11, 1940.

Material	Depth to bottom of stratum (feet)
Drift	224
Shale, blue	243
Soapstone and water	253
Shale, blue	374
Shale, brown; gas 475-490'	500
Shale, gray	519
Shale, gray, and iron	525
Traverse lime - no fossils	530
Sand, brown and white-secondary Traverse	531
Sand, brown and white; oil-dead	533
Sand, brown and white; oil-semi dead	536
Sand, light brown	538
Sand, darker brown, coarser and some oil	547
White water sand; some fresh water-no salt	574

CASING RECORD:

8"	casing	228'
5"	"	510'7"

G-Sj E33-1. M. C. Pletcher - No. 1, Mrs. Clara Plass, 540 ft. from south line, 450 ft. from west line, SW$\frac{1}{4}$NW$\frac{1}{4}$, sec. 33, T. 38 N., R. 4 E. Completed March 1, 1945. Elevation 765 ft. Dry hole. Driller's log.

Material	Depth to bottom of stratum (feet)
Mud, gray	175
Lime, gray	185
Shale, gray; water	190
Shale, gray	232
Lime, dense	242
Shale, green	275
Shale and shells	292
Shale, green	330
Shale, green, and shells	382
Shale, light brown	411
Shale, gray	414
Shale, dark brown	488
Shale, gray	492
Lime, brown	504
Lime, gray	516
Gypsum, white	519
Traverse - little oil show	523
Total depth	551

WATER SANDS:

Shale, water 185 - 190'

CASING RECORD:

8$\frac{1}{4}$"	drive pipe	127'
6$\frac{1}{2}$"	casing	196'
5$\frac{1}{4}$"	casing	492'

G-Sj G8-1. Kush, Joseph - No. 1, 210 ft. from north line, 260 ft. from east line, NE$\frac{1}{4}$NW$\frac{1}{4}$, sec. 8, T. 37 N., R. 1 E. Completed September 27, 1939, by Clapsaddle and Harris, et al. Dry hole. Plugged October 19, 1939.

Material	Depth to bottom of stratum (feet)
Drift	167
Green shale	228
Lime shale	245
Shale and shells	267
Brown shale	400
Gray shale	412
Lime	538
Blue lime	545
Brown lime	565
Gray lime	580
Lime	624
Gray shale	631
Black lime, hard	651
Lime	660
Gray shale	667
Blue lime	673
Dark lime	720
White lime	727
Lime	773
Lime, shells and crevices	803
Lime	848
White lime	874
Lime	923
Gray lime	959
White lime	1034
Lime	1086
White lime	1102
Green shale	1120
Shale and shells	1160
Green shale and shells	1211
Lime	1246
Shale and shells	1291
Green shale, soft	1347
Shale	1403
Light brown shale	1484
Gray shale; top Trenton	1497
Hard Trenton lime	1513
Trenton sand	1532
Trenton lime	1625

CASING RECORD:

10"	casing	167'
8¼"	"	677'
6 5/8"	"	1112'

G-Sj H11-1. Oliver Chilled Plow Works, South Bend, Indiana. Elevation 725 ft. Total depth 1676 feet.

Material	Depth to bottom of stratum (feet)	Correlations A. C. Lane	C. E. Wright
Sand	25		
Gravel	45	137-350 St. Clair of Ohio	137-350 Huron
Clay	75		
Sand	100		
Gravel	137		
"Blue shale", calcareous clay shale; dark drab	280		
Gas at 280 feet			
Strong smell of oil from 200 to 350 feet			
Bituminous argillaceous shale; dark brown "Red shale"	350	350-381 Traverse or Hamilton	350-610 Hamilton
Argillaceous limestone;bluish drab	425		
Salt water at 387 feet		381-540 Dundee or upper Helderberg	
Limestone, light gray to drab	455		
Crinoidal shaly limestone	475	540-900 Monroe or lower Helderberg	
Limestone, light drab	540		
Dolomitic limestone, drab	555		
Gypsum and dolomite, drab and white mixed	610		610-796 Corniferous
Salt water at 610 feet			
Dolomite, light drab	670		
Salt water at 670 feet			
Dolomitic limestone gray	680		
Dolomite, light gray	710		
Dolomitic limestone, light gray	733		
Dolomite, drab	780		
Dolomitic limestone, light gray	796		796-1300 Helderberg
Dolomitic limestone, bluish gray	900	900-1120 Niagara	
Dolomitic limestone greyish white	940		
Dolomitic limestone	960		
Dolomite, greyish white	1180	1120-1180 Clinton and Medina	
Argillaceous dolomite bluish drab gray and white	1300		1300-1600 Salina?
Argillaceous shale, dark bluish drab	1350	1180-1360 Hudson River	
Argillaceous shale, drak brown to black	1585		
Dolomitic limestone	1670	1360-1600 Utica 1600-1670 Trenton	1600-1670 Niagara?

From
Michigan Geological Survey, volume 5, Plate LXIV, 1881-1893.

G-Sj I27-1. M. C. Pletcher - No. 1, Clayton and Bertha Weiss, 130 ft. from south line, 1190 ft. from west line, SW$\frac{1}{4}$SW$\frac{1}{4}$, sec. 27, T. 37 N., R. 3 E. Completed July 19, 1945. Elevation 856 ft. Dry hole.

Material	Depth to bottom of stratum (feet)
Drift to rock	250
Lime	254
Oil, some	255
Salt water, little	256
Sand, gravel	400
Shale, gray	420
Shale, gray to green	435
Shale, green to light brown	445
Shale, light brown	455
Shale, light brown	465
Shale, light brown to dark brown	475
Shale, very dark brown	485
Shale, light brown	490
Shale, brown to very dark	495
Shale, very dark some gas; some green oil	505
Shale, brown, hard	515
Shale, to lime, brown	520
Lime, tight	525
Lime, tight and hard	560

CASING RECORD:

8"	casing	250'
6"	"	400'
5-3/16"	"	520'

G-Sj K25-1. Hay, W. F., and Rettie, No. 1, 100 ft. from north line, 200 feet from east line, in $NE\frac{1}{4}SE\frac{1}{4}$, sec. 25, T. 36 N., R. 1 W. Completed January 30, 1942, by P. F. Williams and C. R. Lonzo. Elevation 619 ft. Dry hole.

Material	Depth to bottom of stratum (feet)
Sand, gravel, quicksand, coarse water sand	190
Gravel	195
Gravel, sand, coarse	200
Sand and gravel, fine	205
Sand and gravel, coarse	218
Sand, light brown, water	225
Shale, brown	230
Shale, dark brown	234
Shale, dark brown, mixed	237
Shale, light brown	240
Shale, brown-black	242
Shale, light brown	246
Shale, black	250
Shale, black, mixed	256
Shale, black, limestone, gray, mixed, enter Devonian	259
Shale, black, limestone, gray, mixed	263
Shale, black, limestone, gray, mixed	270
Lime, black and light, mixed, finer	273
Lime, black and light, mixed, lime and dolomite	275
Lime, light and dark mixed	277
Lime, medium free, light show oil	279
Lime, medium fine, show oil	280
Lime, light fine, show oil	281
Lime, light, coarse, show oil	282
Lime, light dark mixed, coarse	283
Lime, medium light and dark, mixed	284
Lime, light, fine	287
Lime, medium light, fine	289
Lime, light brown, fine	$289\frac{1}{2}$
Lime, light brown, fine	290
Lime, light and fine	291
Lime, light brown, fine	293
Lime, light brown, fine	296
Lime, light and fine into sulfur water, stagnant black and heavy.	300

CASING RECORD:

$8\frac{1}{4}$"	casing	180'
$6\frac{1}{4}$"	"	187'
5 3/16"	"	284'

G-Sj L28-1. Pearse, Delbert A, et al, No. 1, 330 ft. from north line, 330 ft. from west line, NE$\frac{1}{4}$NW$\frac{1}{4}$, sec. 28, T. 36 N., R. 1 E. Completed December 24, 1941, by the Ohio Oil Co. Elevation 729 ft. Dry hole.

Material	Depth to bottom of stratum (feet)
Sand, clay and gravel	202
Shale, gray, green, brown	205
Shale, brown, light brown	210
Shale, green, gray	219
Shale, dark brown, solid, Antrim, 219 ft.	286
Dolomite, fine sucrose, Traverse formation 286 ft.	287$\frac{1}{2}$
Shale, light gray dolomite, hard	295
Shale, with quartz grains	296
Dolomite, calcareous, brown	307
Dolomite, with quartz grains	310
Dolomite, light buff, dead oil	313
Limestone, light buff	315
Dolomite, calcareous, light buff	319
Limestone, light buff, Traverse limestone, 319 feet	386
Limestone, brown, gray, Detroit River 386 ft.	413
Dolomite, brown	448
Dolomite, light gray	455
Dolomite, some sandy, Bass Island 448 ft.	460
Dolomite, gray-white, Guelph 460 ft.	571
Dolomite	937
Dolomite, milky to brown chert, Brassfield 937 ft.	970
Dolomite, no chert	990
Dolomite, chert, white	1055
Dolomite, green shale streak, Richmond 1055 ft.	1197
Shale, green-gray	1210
Shale, green-gray, soft, Maysville 1197 ft.	1278
Shale, brown, light brown, Eden 1278 ft.	1397
Dolomite, buff to brown, Galena 1379 ft. some dead oil	1514

CASING RECORD:

7" Casing 223'

APPENDIX C

Chemical analyses of water from the South Bend municipal

Water-supply wells and from St. Joseph River.

Analyses made by the

Indiana State Board of Health and others

Chemical analyses of water of South Bend municipal water supply.
St. Joseph County, Indiana.

	Total solids ppm	Total hardness as $CaCO_3$ ppm	Total hardness as $CaCO_3$ gr./gal.	Alkalinity as $CaCO_3$ ppm	Chloride ppm	Nitrate ppm	Total iron ppm	pH	Temperature, °F.	Well No.	Analyst a/
North Station											
Nov. 11, 1911	496	358	20.8	-	0.6	-	-	-	-	2	1
Jan. 9, 1934	-	284	16.6	236	11	-	0.8	7.4	-	2	1
Dec. 14, 1935	-	290	16.9	240	10	-	.7	7.4	-	2	1
Dec. 6, 1936	-	306	17.9	288	10	-	.8	7.3	-	2	1
Mar. 5, 1938	-	270	15.8	268	13	-	.7	7.4	-	2	1
Feb. 8, 1939	-	335	19.6	256	5	-	1.0	7.5	-	2	1
Nov. 21, 1941	-	268	15.7	244	11	-	.7	7.7	-	2	1
May 21, 1942	-	324	18.9	244	10	-	.8	7.6	-	2	1
Sept. 19, 1942	-	320	18.7	238	10	-	1.0	7.5	-	2	1
Mar. 27, 1943	-	316	18.5	240	12	-	.8	7.9	-	2	1
Oct. 21, 1944	-	452	26.4	204	3	-	.6	8.0	-	2	1
Jan. 11, 1945	368	342	20.0	243	9	-	.9	7.6	-	3	2
Feb. 28, 1945	342	332	19.4	240	8	0.5	.2	-	-	2	1
Mar. 28, 1945	360	304	17.8	234	8	0.7	.3	-	-	2	1
Apr. 28, 1945	296	248	14.5	188	8	0.0	.3	-	-	2	1
June 5, 1945	402	366	21.4	242	7	0.4	.5	-	-	2	1
June 20, 1945	326	324	18.9	238	6	1.0	.1	-	-	2	1
June 20, 1945	365	342	20.0	238	6	1.0	.3	-	-	2	1
July 12, 1945	340	371	21.7	244	8	0.8	.5	-	-	2	1
Aug. 23, 1945	427	368	21.5	244	7	0.4	.3	-	53	2	1
Sept. 28, 1945	436	384	22.4	244	6	0.4	.6	-	53	2	1
Nov. 1, 1945	381	332	19.4	244	6	0.4	.5	-	52	2	1
Jan. 10, 1946	394	298	17.4	244	-	0.2	.4	-	53	2	1
Mar. 1, 1946	380	301	17.6	218	8	0.4	.5	-	52	2	1
May 3, 1946	322	292	17.1	240	7	0.5	.4	-	52	2	1
July 31, 1946	314	258	15.1	188	10	0.1	.5	-	52	2	3
July 31, 1946	395	345	20.2	-	10	0.5	.48	-	52	2	1
Oct. 25, 1946	434	352	20.6	260	10	0.16	.5	-	52	2	1
Dec. 10, 1946	390	318	18.6	260	8	0.16	.3	-	52.5	2	1
Mar. 28, 1947	382	307	18.0	192	12	0.4	.5	-	52	2	1
Average	378	323	18.9	238	8.5	0.45	.55	7.6	52		

a/ See notes at end of tables.

Date	Total solids ppm	Total hardness as $CaCO_3$ ppm	Total hardness as $CaCO_3$ gr./gal.	Alkalinity as $CaCO_3$ ppm	Chloride ppm	Nitrate ppm	Total iron ppm	pH	Temperature °F.	Well No.	Analyst
Central Station											
Nov. 11, 1911	900	414	24.2	-	16.4	-	-	-	-	-	1
Dec. 12, 1935	-	434	25.4	300	37	-	-	7.2	-	-	1
Dec. 6, 1936	-	398	23.3	288	26	-	-	7.3	-	-	1
Feb. 8, 1939	-	476	27.8	310	26	-	-	7.5	-	-	1
Oct. 21, 1944	-	432	25.2	232	2	-	-	7.9	-	-	1
Jan. 11, 1945	480	420	24.6	284	19	-	0.1	7.4	-	1	2
Feb. 28, 1945	543	452	26.4	282	19	0.5	.1	-	-	1	1
June 5, 1945	519	443	25.9	298	16	.5	.2	-	-	1	1
June 20, 1945	471	428	25.0	278	25	.8	.1	-	-	1	1
June 20, 1945	463	428	25.0	278	21	.8	.1	-	-	1	1
July 12, 1945	542	436	25.5	272	18	.7	.1	-	-	1	1
Aug. 23, 1945	479	424	24.8	268	18	.8	.1	-	57	1	1
Sept.28, 1945	511	480	28.0	268	19	.6	.1	-	57	1	1
Nov. 1, 1945	511	410	23.9	270	21	.5	.1	-	56	1	1
Jan. 10, 1946	510	416	24.3	278	-	.4	.1	-	55.5	1	1
Mar. 1, 1946	494	405	23.7	274	18	.5	.1	-	55.5	1	1
May 3, 1946	500	411	24.0	282	20	.6	.3	-	56	1	1
July 31, 1946	378	344	20.5	276	16	.3	.2	-	55.5	1	1
July 31, 1946	463	375	21.9	-	16	2.6	.9	-	-	3	3
Oct. 25, 1946	524	411	24.0	301	20	.6	.2	-	56	1	1
Dec. 10, 1946	532	407	23.8	296	18	.16	.1	-	55.5	1	1
Mar. 28, 1947	488	369	21.6	242	20	.5	.2	-	55	1	1
Average	518	418	24.4	279	20	.7	.2	7.4	56		

Date	Total solids ppm	Total hardness as $CaCO_3$ ppm	Total hardness as $CaCO_3$ gr./gal.	Alkalinity as $CaCO_3$ ppm	Chloride ppm	Nitrate ppm	Total iron ppm	pH	Temperature °F.	Well No.	Analyst
Oliver Park Station											
Jan. 9, 1934	-	500	29.2	286	9	-	0.0	7.4	-		1
Dec. 14, 1935	-	504	29.4	288	5	-	.0	7.2	-		1
Dec. 6, 1936	-	508	29.6	288	7	-	.0	7.3	-		1
Mar. 5, 1938	-	484	28.3	290	5	-	.0	7.2	-		1
Feb. 8, 1939	-	596	34.8	300	7	-	.0	7.5	-		1
Nov. 21, 1941	-	432	25.2	230	7	-	-	7.4	-		1
Sept. 19, 1942	-	576	33.7	282	2	-	-	7.6	-		1
Oct. 21, 1944	-	600	35.0	228	2	-	.1	8.0	-		1
Jan. 11, 1945	608	534	31.2	288	6	-	.1	7.3	-		2
Feb. 28, 1945	741	620	36.2	392	8	6.0	.0	-	-		1
Mar. 28, 1945	709	628	36.7	270	5	4.0	.0	-	-		1
Apr. 28, 1945	653	540	31.4	286	7	0.7	.0	-	-		1
June 5, 1945	726	636	37.1	292	6	3.0	.1	-	-		1
June 20, 1945	680	635	37.0	290	7	4.0	.1	-	-		1
June 20, 1945	670	640	37.2	290	7	4.0	.0	-	-		1
July 12, 1945	732	636	37.1	292	7	4.0	.1	-	-		1
Aug. 23, 1945	730	681	39.7	290	6	4.0	.05	-	54		1
Sept. 28, 1945	647	669	39.0	286	7	4.0	.05	-	54		1
Nov. 1, 1945	780	589	34.3	286	8	4.5	.05	-	54		1
Jan. 10, 1946	713	570	33.2	290	-	4.0	.1	-	54		1
Mar. 1, 1946	732	560	32.7	294	7	4.0	.0	-	53		1
May 3, 1946	718	561	32.8	290	6	5.0	.1	-	54		1
July 31, 1946	512	512	30.0	264	5	4.7	.1	-	54		1
July 31, 1946	732	525	30.6	-	6	20	.13	-	54		3
Oct. 25, 1946	724	566	33.0	309	8	5.0	.1	-	54		1
Dec. 10, 1946	714	572	33.4	312	8	3.0	.05	-	54		1
Mar. 28, 1947	668	493	28.8	216	8	5.0	.05	-	53		1
Average	694	569	33.3	285	6.4	4.9	.05	7.4	54		

Date	Total solids ppm	Total hardness as $CaCO_3$ ppm	Total hardness as $CaCO_3$ gr./gal.	Alkalinity as $CaCO_3$ ppm	Chloride ppm	Nitrate ppm	Total iron ppm	pH	Temperature °F.	Well No.	Analyst
South Station											
Jan. 9, 1934	-	274	16.0	250	7	-	-	7.4	-	-	1
Dec. 14, 1935	-	254	14.7	240	5	-	-	7.4	-	-	1
Dec. 6, 1936	-	256	14.9	232	5	-	-	7.3	-	-	1
Mar. 5, 1938	-	244	14.3	240	5	-	-	7.4	-	-	1
Nov. 21, 1941	-	232	13.6	240	7	-	-	7.4	-	-	1
Sept. 19, 1942	-	296	17.3	262	3	-	-	7.5	-	-	1
Oct. 2, 1944	-	304	17.8	218	1	-	-	8.2	-	-	1
Jan. 11, 1945	300	280	16.4	230	5	22	0.05	7.6	-	2-3	2
Feb. 28, 1945	500	300	17.5	226	5	4.0	.1	-	-	-	1
Mar. 28, 1945	316	300	17.5	232	5	4.0	.1	-	-	2	1
April 28, 1945	298	228	13.3	200	7	1.0	.1	-	-	2	1
June 5, 1945	323	299	17.5	232	6	1.0	.1	-	-	2	1
June 20, 1945	281	304	17.8	226	7	4.0	.1	-	-	2	1
June 20, 1945	313	304	17.8	226	7	4.0	.0	-	-	2	1
July 12, 1945	314	299	17.5	230	5	4.0	.1	-	-	-	1
Aug. 23, 1945	313	366	21.4	290	4	4.0	.1	-	52	1	1
Sept. 28, 1945	350	336	19.6	226	7	4.0	.1	-	53	2	1
Nov. 1, 1945	352	301	17.5	282	5	4.5	.2	-	52	1	1
Jan. 10, 1946	322	280	16.4	232	-	3.5	.1	-	52	2	1
Mar. 1, 1946	343	285	16.6	266	5	4.0	.0	-	52	1	1
May 3, 1946	323	280	16.4	226	6	5.0	.1	-	52	2	1
July 31, 1946	214	243	14.2	232	4	5.7	.1	-	52	2	1
July 31, 1946	313	285	16.6	-	6.5	20	.17	-	52	2	3
Oct. 25, 1946	336	283	16.5	264	7	6.0	.1	-	52	2	1
Dec. 10, 1946	344	283	16.5	264	10	0.5	.05	-	52	2	1
Mar. 28, 1947	292	221	12.8	180	10	4.0	.05	-	52	2	1
Average	323	310	18.2	238	6	5.5	.1	7.5	52		

Date	Total solids ppm	Total hardness as $CaCO_3$ ppm	Total hardness as $CaCO_3$ gr./gal.	Alkalinity as $CaCO_3$ ppm	Chloride ppm	Nitrate ppm	Total iron ppm	pH	Temperature °F.	Well No.	Analyst
Coquillard Station											
Jan. 11, 1945	278	259	15.1	256	4	-	1.4	7.6	-	1	2
Feb. 28, 1945	290	272	15.9	250	5	0.5	0.9	-	-	1	1
Mar. 28, 1945	266	260	15.2	240	5	.5	.9	-	-	1	1
Apr. 28, 1945	254	216	12.6	216	7	.0	1.0	-	-	1	1
June 5, 1945	288	286	16.7	258	6	.4	1.2	-	-	1	1
June 20, 1945	267	272	15.9	252	8	.4	1.2	-	-	1	1
June 20, 1945	256	272	15.9	254	7	4.0	.0	-	-	1	1
July 12, 1945	273	278	16.2	258	6	.4	.9	-	-	1	1
Aug. 23, 1945	273	272	15.9	254	8	.4	.9	-	53	1	1
Sept. 28, 1945	288	283	16.5	254	6	.4	.9	-	54	1	1
Nov. 1, 1945	272	251	14.7	256	6	.2	.9	-	53	1	1
Jan. 10, 1946	241	234	13.7	256	-	.3	.8	-	53	1	1
Mar. 1, 1946	246	216	12.6	246	4	.3	.8	-	53	1	1
May 3, 1946	264	258	15.1	254	4	.3	1.0	-	53.5	1	1
July 31, 1946	187	232	13.6	270	5	.1	.6	-	53	1	1
July 31, 1946	272	278	16.2	-	7	.5	.58	-	53	1	2
Oct. 25, 1946	288	252	14.7	274	6	.12	.9	-	53	1	1
Dec. 10, 1946	278	252	14.7	276	4	.08	.6	-	53	1	1
Mar. 28, 1947	250	206	12.0	202	5	.3	.9	-	52	1	1
Average	262	254	14.8	251	6	.5	.9	7.6	53		

Date	Total solids ppm	Total hardness as $CaCO_3$ ppm	Total hardness as $CaCO_3$ gr./gal.	Alkalinity as $CaCO_3$ ppm	Chloride ppm	Nitrate ppm	Total iron ppm	pH	Temperature °F.	Well No.	Analyst
St. Joseph River											
Feb. 28, 1945	339	272	15.9	184	2	2.5	0.3	-	-		1
Mar. 28, 1945	334	276	16.1	196	8	2.0	.3	-	-		1
Apr. 28, 1945	324	272	15.9	186	5	0.3	.3	-	-		1
June 5, 1945	316	278	16.2	196	3	2.0	.4	-	-		1
July 12, 1945	303	272	15.9	198	7	1.3	.2	-	-		1
Aug. 23, 1945	310	428	25.0	270	14	.6	.1	-	75		1
Sept. 28, 1945	335	370	21.6	198	7	1.0	.2	-	66		1
Nov. 1, 1945	319	249	14.5	202	6	.3	.1	-	57		1
Jan. 10, 1946	283	219	12.8	178	-	.2	.3	-	37		1
Mar. 1, 1946	360	230	13.4	186	4	1.5	.3	-	40		1
May 3, 1946	309	236	13.8	200	4	.6	.4	-	61		1
July 31, 1946	309	216	12.6	190	5	.5	.5	-	78		1
Oct. 25, 1946	330	252	14.7	218	12	.4	.3	-	59		1
Dec. 10, 1946	338	251	14.7	220	7	.5	.1	-	41.5		1
Mar. 28, 1947	340	213	12.5	144	7	1.4	1.5	-	37		1
Average	321	268	15.7	195	6.5	1.0	.3				

Analysts:
1. Indiana State Board of Health
2. Infilco, Inc., Chicago, Illinois
3. U. S. Geological Survey

APPENDIX D

BIBLIOGRAPHY

1. Artingstall, William, Report to the Board of Water Commissioners on an increased water supply for the City of South Bend, Indiana: Unpublished report, 52 pp., 8 exhibits, Sept. 1921.

2. Burdick, C. B., A report of an increased water supply for the City of South Bend, Indiana: Univ. Illinois, unpublished thesis, 67 pp., 21 exhibits, 1911.

3. Burns and McDonnell Engineering Company, Report on water works improvements for South Bend, Indiana: Unpublished report, Feb. 1928.

4. Capps, S. R., The underground water of north-central Indiana: U. S. Geol. Survey Water-Supply Paper 254, pp. 205-214, 1910.

5. Consoer, Townsend, and Associates, City of South Bend, Indiana, Water Department, Report on Waterworks: Unpublished report, 80 pp., 4 plates, 4 drawings, Mar. 1945.

6. Cooper, H. H., Jr., and Jacob, C. E., A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., vol. 27, no. 4, pp. 526-534, Aug. 1946.

7. Hammond, A. J., The deep well water supply of South Bend: Municipal Engineering, vol. 38, pp. 156-160, Jan.-June 1910.

8. Harrell, Marshall, Ground water in Indiana: Ind. Dept. of Conservation, Div. of Geology, Publication 133, pp. 442-445, 1935.

9. Jacob, C. E., Notes on determining permeability by pumping tests under water table conditions: U. S. Geol. Survey, mimeographed, June 1944.

10. Jacob, C. E., Partial penetration of pumping well, adjustments for: U. S. Geol. Survey Water Resources Bulletin, pp. 169-175, Aug. 10, 1945.

11. Jacob, C. E., Drawdown test to determine effective radius of artesian well: Am. Soc. Civil Eng. Proc., vol. 72, No. 5, pp. 629-646, 1946.

12. Klaer, F. H., Jr. and Kazmann, R. G., A quantitative study of the well fields of the Mill Creek Valley Water Supply Project, Butler County, Ohio: U. S. Geol. Survey, duplicated report, p. 47, July 1943.

13. Leverett, Frank, Water resources of Indiana and Ohio: U. S. Geol. Survey 18th Ann. Rept., pt. 4, pp. 438-439, 1897.

14. Leverett, Frank, Wells of northern Indiana: U. S. Geol. Survey Water-Supply Paper 21, pp. 11, 21-22, 1899.

15. Leverett, Frank, The Illinois glacial lobe: U. S. Geol. Survey Monograph 38, 817 pp., 1899.

16. Leverett, Frank, and Taylor, F. B., The Pleistocene of Indiana and Michigan: U. S. Geol. Survey Monograph 53, 529 pp., 1915.

17. Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, 321 pp., 1923.

18. Meinzer, O. E., and others, Hydrology, Physics of the Earth series, vol. IX, pp. 385-477, 1942.

19. Montgomery, H. T., The Kankakee Valley: Indiana Acad. Sci. Proc., 1898, pp. 277-282, 1899.

20. Montgomery, H. T., The glacial phenomena as exhibited in northern Indiana and southern Michigan and the resulting waterways: Northern Indiana Hist. Soc. Pub. No. 2, 20 pp., 1899.

21. Montgomery, H. T., The geological history of Saint Joseph County, Indiana: Northern Indiana Hist. Soc., Pub. No. 2 rev. ed., 19 pp., 1929.

22. Schaefer, E. J., White, G. W., and VanTuyl, D. W., The ground-water resources of the glacial deposits in the vicinity of Canton, Ohio: Ohio Water Resources Board Bull. 3, pp. 39-44, 1946.

23. Theis, C. V., The relation between the lowering of the piezometric surface and the rate and duration of discharge from a well using ground water storage: Am. Geophys. Union Trans., 1935, p. 519-524, 1935.

24. Tolman, C. F., Ground water, McGraw Hill Book Co., Inc., New York, 593 pp., 1937.

25. U. S. Dept. Agr., Weather Bureau, Climatic summary of the United States section 66, Northern Indiana, pp. 6612-6613, 1930.

26. U. S. Dept. Commerce, Weather Bureau, Climatological data, Indiana section, published currently.

27. Wenzel, L. K., Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods: U. S. Geol. Survey Water-Supply Paper 887, 192 pp., 1942.

28. __________, Preliminary test of the South Bend Waterworks December 25, 1873, and report of engineer Birkinbine and description of the works, The Tribune Printing Company, South Bend, Indiana, 8 pp., 1873.

29. __________, Soil Survey of St. Joseph County, Indiana: U. S. Dept. agr., Bur. Plant Industry (in cooperation with Purdue Univ. Agr. Exper. Sta.). (Map in course of publication, 1946.)

30. __________, Annual report of the Board of Trustees of the South Bend Water Department to the City Council for the year 1894, 40 pp., 1895.

Additional information on the South Bend municipal water-supply system is given in the Annual Reports of Departments, South Bend, Indiana, 1905-1925.

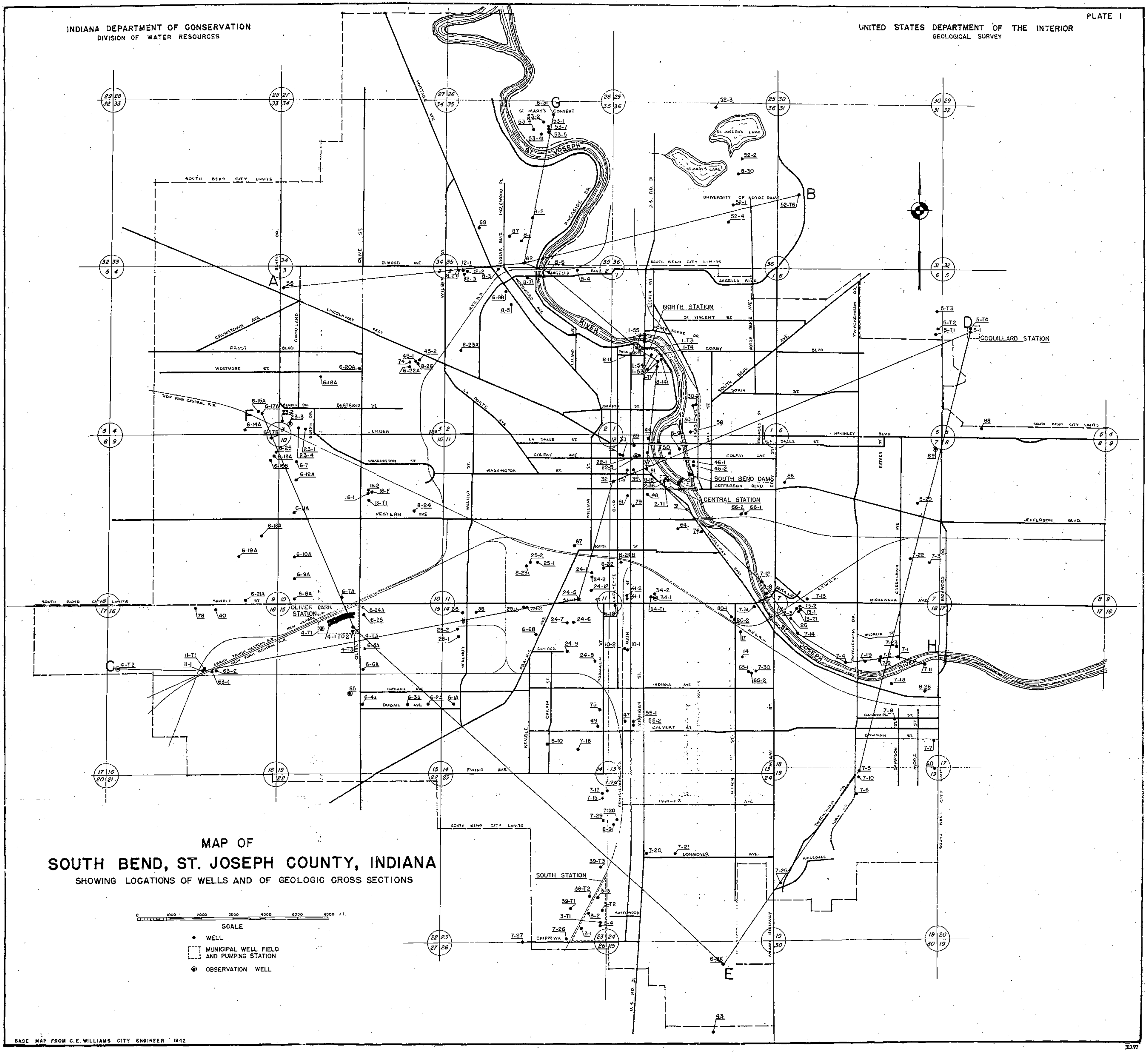
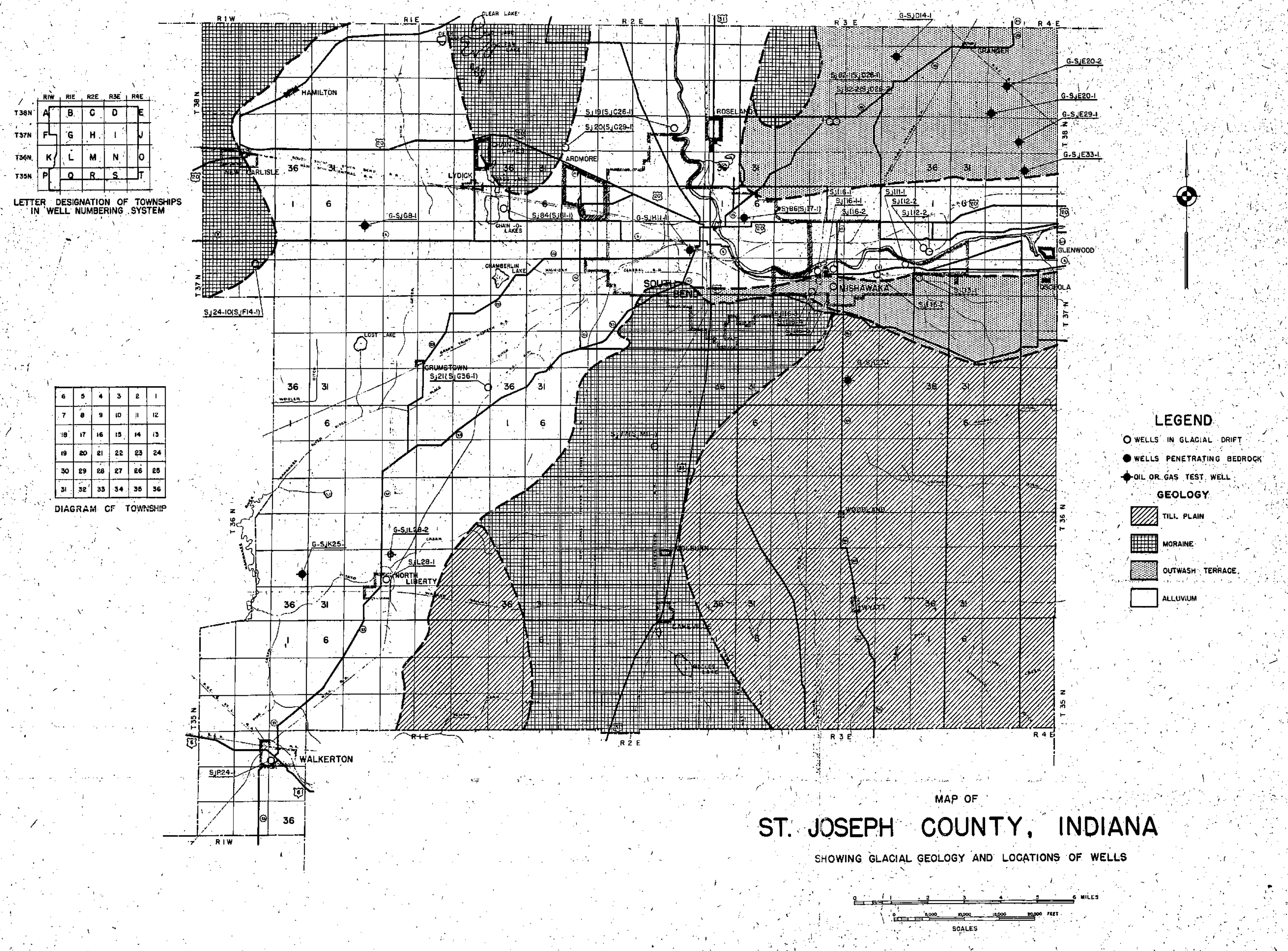


PLATE I
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
MAP OF
SOUTH BEND, ST. JOSEPH COUNTY, INDIANA
SHOWING LOCATIONS OF WELLS AND OF GEOLOGIC CROSS SECTIONS
0 1000 2000 3000 4000 5000 6000 FT.
SCALE
WELL
MUNICIPAL WELL FIELD AND PUMPING STATION
OBSERVATION WELL
NORTH STATION
COQUILLARD STATION
SOUTH BEND DAM
CENTRAL STATION
OLIVER PARK STATION
SOUTH STATION
ST. JOSEPH RIVER
ST. MARY'S CONVENT
ST. JOSEPH'S LAKE
ST. MARY'S LAKE
UNIVERSITY OF NOTRE DAME
SOUTH BEND CITY LIMITS
BASE MAP FROM C.E. WILLIAMS CITY ENGINEER 1942

INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE 2



MAP OF
ST. JOSEPH COUNTY, INDIANA
SHOWING GLACIAL GEOLOGY AND LOCATIONS OF WELLS

GEOLOGY AFTER CAPPS AND LEVERETT
BASE FROM INDIANA STATE HIGHWAY COUNTY MAP

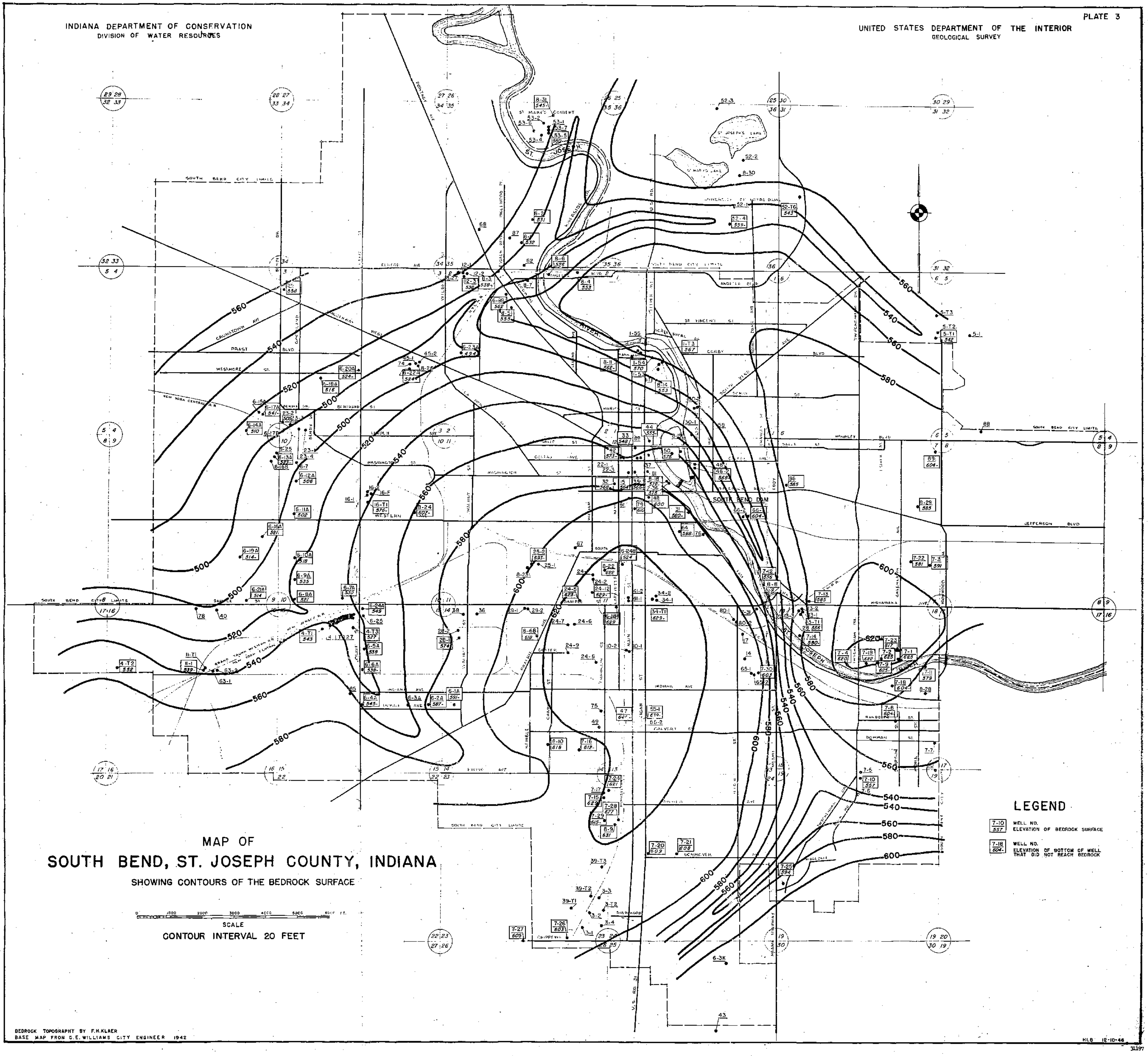
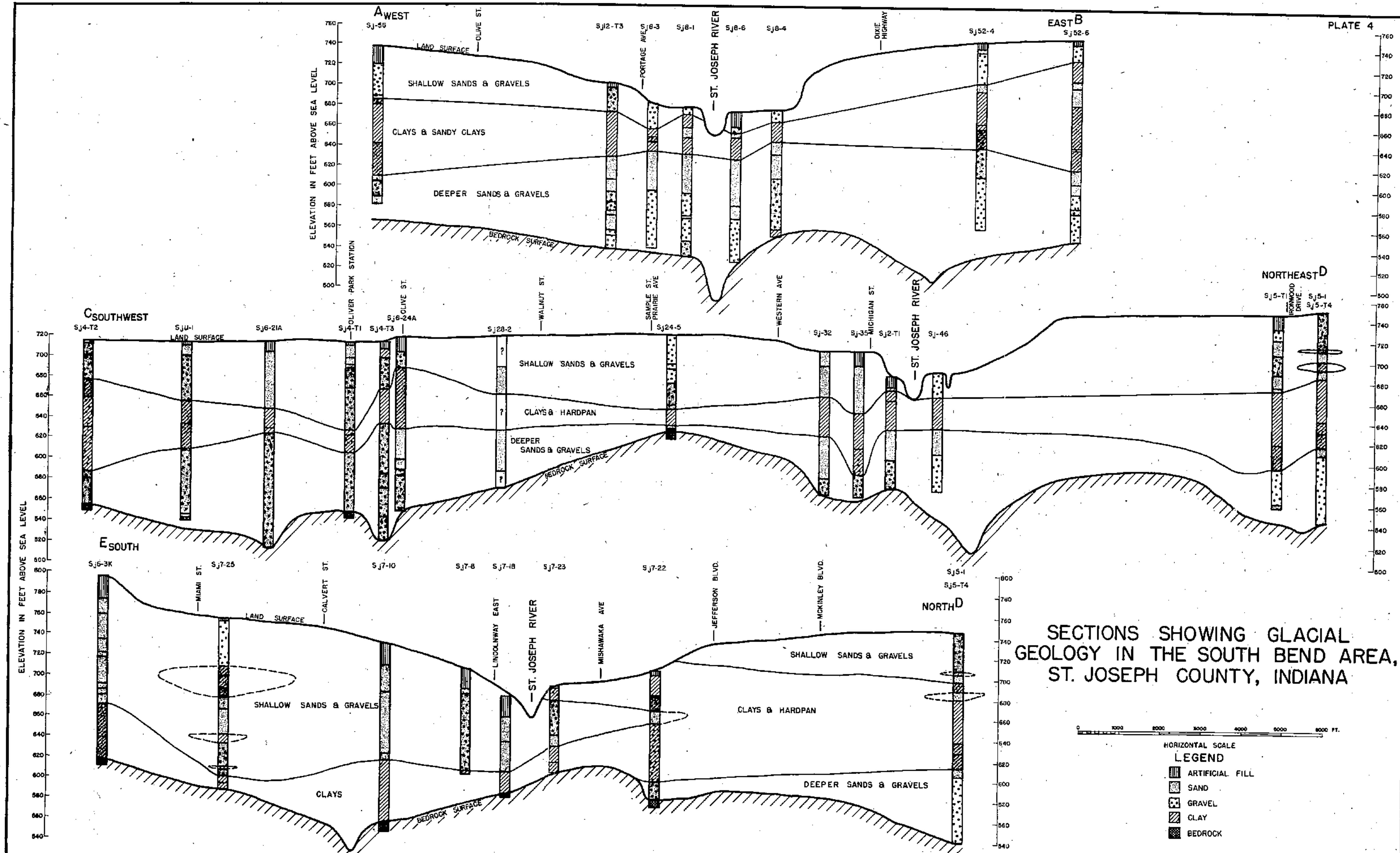


PLATE 3
INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
MAP OF
SOUTH BEND, ST. JOSEPH COUNTY, INDIANA
SHOWING CONTOURS OF THE BEDROCK SURFACE
SCALE
CONTOUR INTERVAL 20 FEET
LEGEND
WELL NO.
ELEVATION OF BEDROCK SURFACE
WELL NO.
ELEVATION OF BOTTOM OF WELL THAT DID NOT REACH BEDROCK
SOUTH BEND CITY LIMITS
SOUTH BEND DAM
ST. JOSEPH RIVER
ST. MARY'S CONVENT
ST. JOSEPH LAKE
ST. MARYS LAKE
UNIVERSITY OF NOTRE DAME
JEFFERSON BLVD
MISHAWAKA AVE
INDIANA AVE
WESTERN
WASHINGTON
COLFAX AVE
LINCOLN
ANGELA BLVD
ST. VINCENT ST
CORBY
MCKINLEY
EWING AVE
CALVERT ST
RANDOLPH
BOWMAN ST
CHIPPEWA
SHIRLWOOD
U.S. RD. 31
BEDROCK TOPOGRAPHY BY F.H.KLAER
BASE MAP FROM C.E.WILLIAMS CITY ENGINEER 1942
HLB 12-10-46

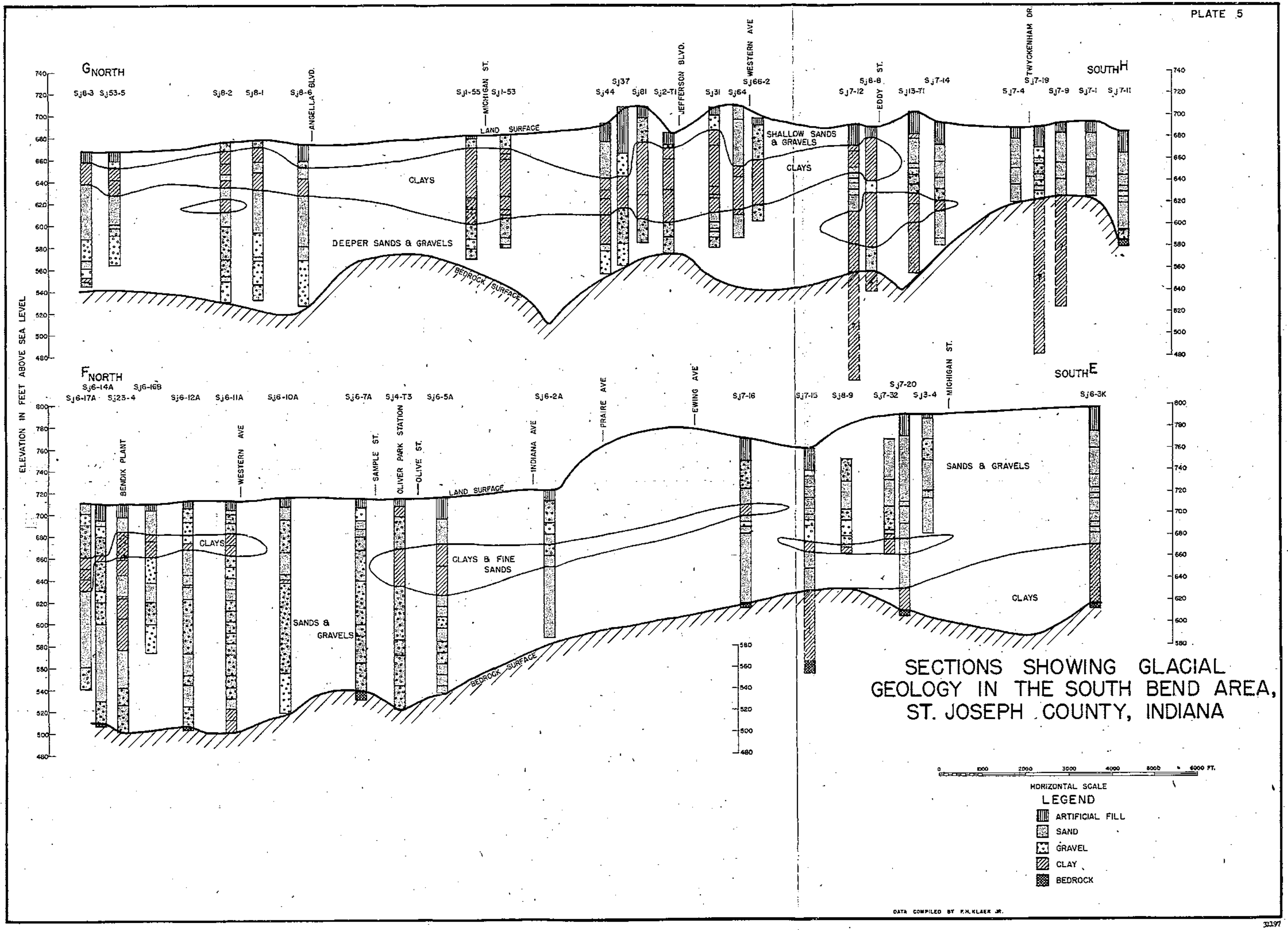
PLATE 4



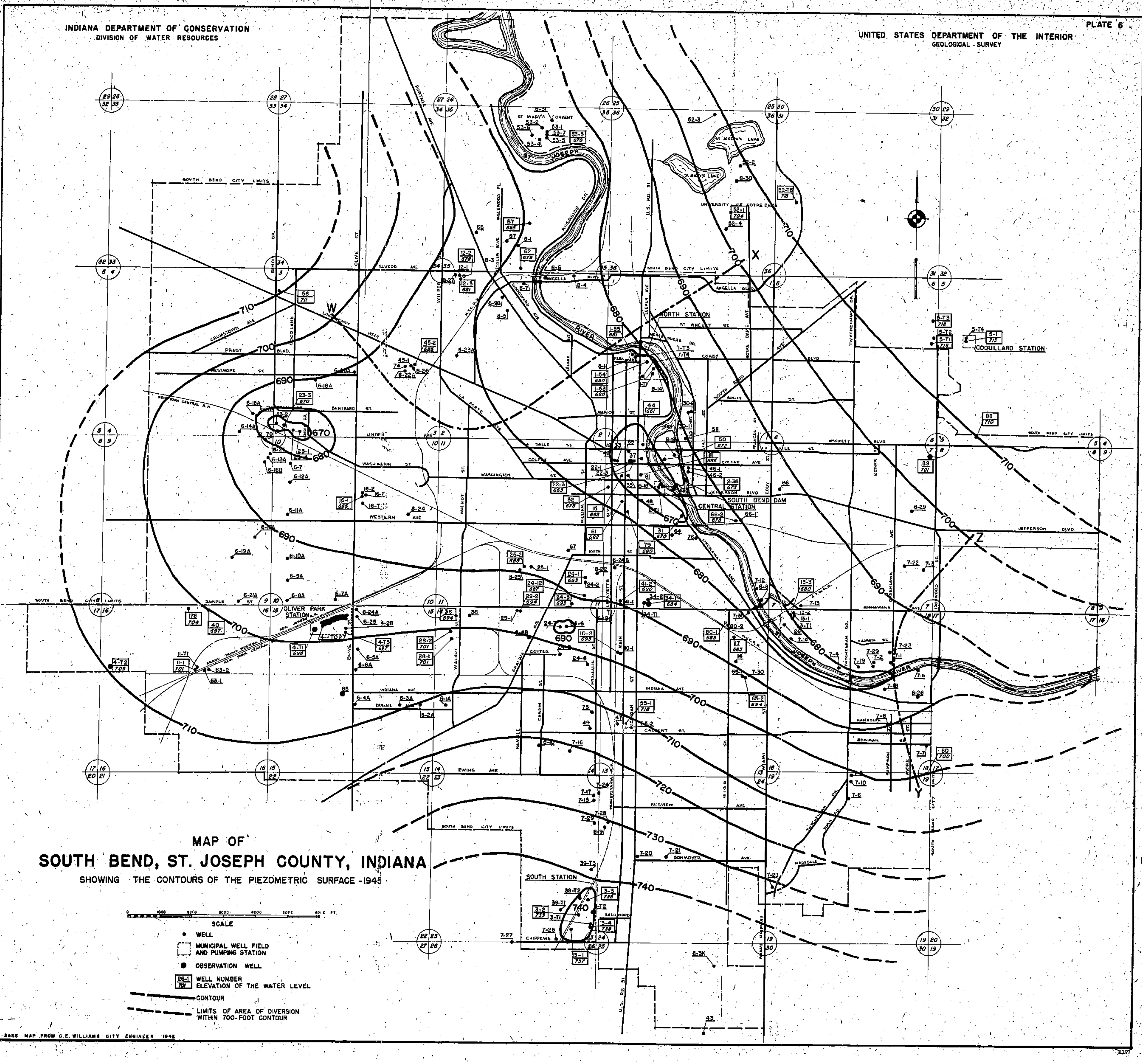
SECTIONS SHOWING GLACIAL GEOLOGY IN THE SOUTH BEND AREA, ST. JOSEPH COUNTY, INDIANA

DATA COMPILED BY F.H. KLAER JR.

PLATE 5



SECTIONS SHOWING GLACIAL GEOLOGY IN THE SOUTH BEND AREA, ST. JOSEPH COUNTY, INDIANA



INDIANA DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
PLATE 6
MAP OF
SOUTH BEND, ST. JOSEPH COUNTY, INDIANA
SHOWING THE CONTOURS OF THE PIEZOMETRIC SURFACE - 1945
SCALE
WELL
MUNICIPAL WELL FIELD AND PUMPING STATION
OBSERVATION WELL
WELL NUMBER
ELEVATION OF THE WATER LEVEL
CONTOUR
LIMITS OF AREA OF DIVERSION WITHIN 700-FOOT CONTOUR
BASE MAP FROM C.E. WILLIAMS CITY ENGINEER 1942
SOUTH BEND CITY LIMITS
NORTH STATION
CENTRAL STATION
SOUTH BEND DAM
COQUILLARD STATION
OLIVER PARK STATION
SOUTH STATION
ST. MARY'S CONVENT
UNIVERSITY OF NOTRE DAME
ST. JOSEPH'S LAKE
ST. MARY'S LAKE
ST. JOSEPH RIVER