Bulletin No. 39

GROUND-WATER RESOURCES OF POSEY COUNTY, INDIANA

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
Division of Water

Prepared by
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF INDIANA

DEPARTMENT OF NATURAL RESOURCES

BULLETIN NO. 39

OF THE

DIVISION OF WATER

Robert F. Jackson, Chief

GROUND-WATER RESOURCES

OF

POSEY COUNTY, INDIANA

BY

Tully M. Robison

Hydrologist, U.S. Geological Survey

Prepared by the

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

In cooperation with the

STATE OF INDIANA

DEPARTMENT OF NATURAL RESOURCES

1977

CONTENTS

ILLUSTRATIONS

(Plates in pocket)

TABLES

GROUND-WATER RESOURCES OF POSEY COUNTY, INDIANA

By

Tully M. Robison

ABSTRACT

Glacial sand and gravel deposits in and near the Wabash and Ohio River valleys are capable of yielding from 50 to more than 1,000 gallons per minute to individual wells. In the tributary valleys as much as 80 gallons per minute has been obtained from small, isolated sand and gravel deposits. In the remainder of the county, wells in sandstones of Pennsylvanian age yield from 5 to 25 gallons per minute. Natural discharge from sand and gravel into the Wabash and Ohio Rivers is estimated to be 40 million gallons per day, far exceeding the 6 million gallons per day estimated usage of ground water in the county. The shallow ground water is normally of the calcium bicarbonate type and has a dissolved-solids concentration of less than 500 parts per million. In deep bedrock wells, the water is normally of the sodium bicarbonate or sodium chloride type and has a dissolved-solids concentration of more than 500 parts per million.

INTRODUCTION

Purpose and Scope

The purpose of this report is to describe and explain the modes of occurrence of ground water in Posey County, Indiana, knowledge that is necessary to the planning of municipal, industrial, and suburban water supplies. The report describes and evaluates the principal sources of potable ground water and defines the chemical quality of the contained water and the principal factors affecting water quality.

Previous Investigations

A brief description of the ground water of the county was made by Harrell (1935). A description of the ground water in the Patoka 30-minute quadrangle, which includes most of Posey County, was made by Fuller and Clapp (1904) as part of a geologic atlas. Other notable geologic, physiographic or soil studies were made by Collett (1884), Marean (1903), Malott (1922), Fidlar (1948), Thornbury (1937 and 1950), Wier (1955), and Wier and Girdley (1962).

Cooperation and Acknowledgments

This report was prepared by the U.S. Geological Survey in cooperation with the State of Indiana, Department of Natural Resources, Division of Water. The author is grateful to the U.S. Corps of Engineers, the Indiana State Highway Commission, and the following agencies of the Department of Natural Resources: The Geological Survey, the Division of Oil and Gas, and the Division of Water.

Physiography

Posey County is in the southwestern part of the State (fig. 1). The western and southern boundaries of the county are formed by the past or the present courses of the Wabash and Ohio Rivers, respectively. It is bounded on the north by Gibson County and on the east by Vanderburgh County. The county lies entirely within the "Wabash lowlands" physiographic region of Malott (1922).

The highest elevations in the county are south of St. Wendel and are in excess of 580 feet (datum mean sea level). The normal pool elevation below Dam No. 49 is 320 feet, giving a total relief of about 260 feet. The maximum local relief is about 185 feet, near Camp Pahoka on the Wabash River.

Almost four-fifths of the county's 402 square miles of area are drained by the Wabash River. The remainder is drained by the Ohio River.

Industrial and Urban Development and Water Usage

The county is primarily agricultural but is becoming increasingly industrialized. The production, processing, storage, and shipment of oil and oil products are the most important industrial activities. A diversified industrial area is developing along the Ohio River southwest of Mount Vernon. This area has the advantage of both railroad and water transportation, low frequency of flooding, and nearness to the most heavily populated area in the county. The land presently being utilized is in the area covered by lake and stream deposits shown on plate 1, and consequently, most water must be obtained either from the river or from Mount Vernon. As shown on the plate, large supplies of ground water can be obtained from sand and gravel deposits along the river downstream from Mount Vernon. However, flooding would be more frequent here than on higher ground. A lesser commercial and industrial area is developing to the east of the city. This is in the "transitional-deposits" area shown on the plate. Here, well yields of as much as a few hundred gallons per minute are obtainable from sand and gravel deposits. Lack of water transportation is a limiting factor here.

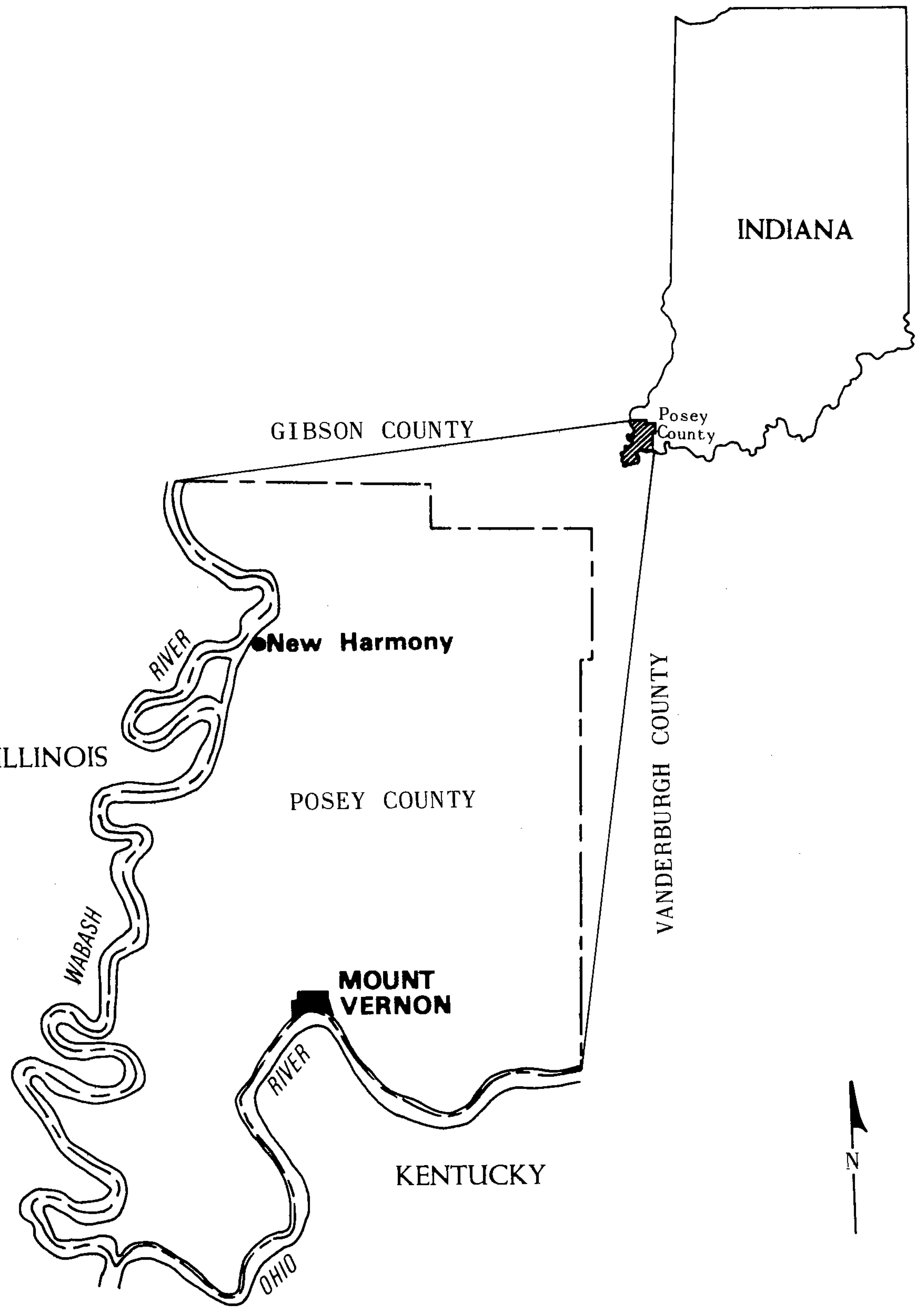


Figure 1.-- Location of Posey County.

Mount Vernon is also the center for a vigorous suburban growth. The city itself is supplied by surface water from the Ohio River. The output of the municipal plant is about 1.2 mgd (million gallons per day). The suburban areas are largely dependent upon self-supplied ground water.

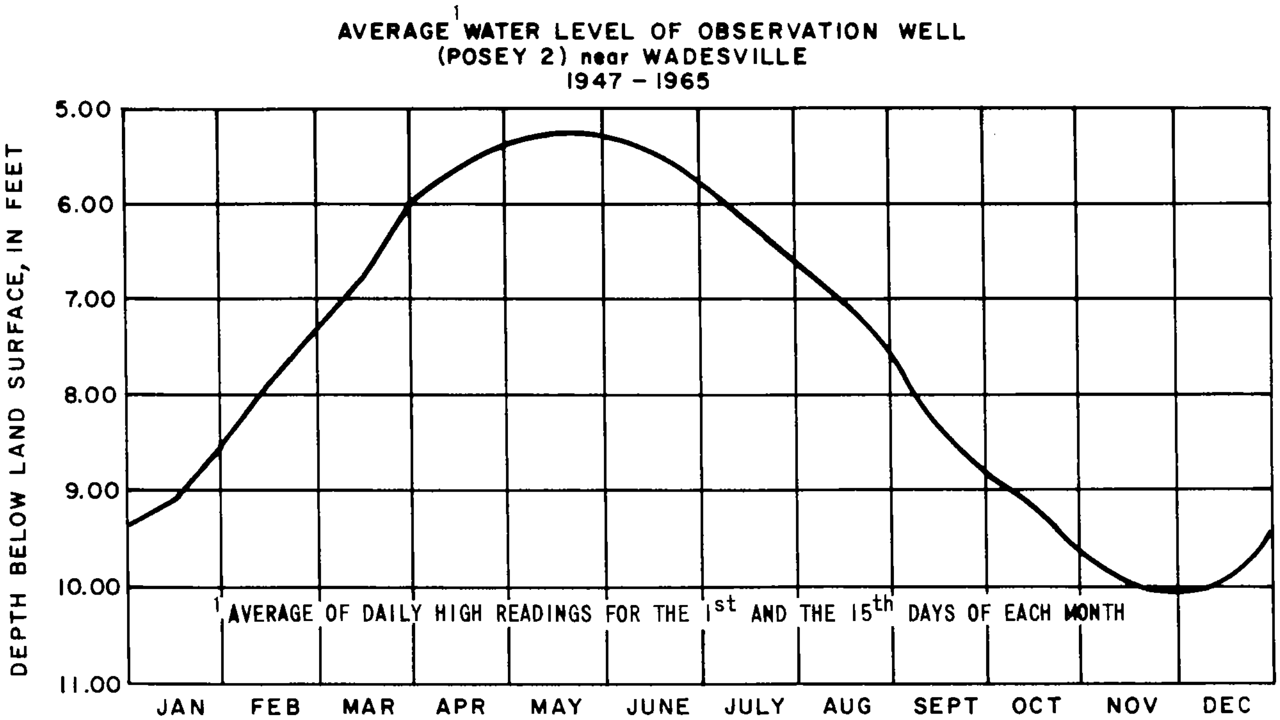
The largest use of water is for water-flooding of oil-bearing rocks. In this process the oil is forced away from the water-input area toward a pumping oil well. This activity uses an estimated 4 mgd, mostly ground water. About half of this water is fresh; the other half is brine recovered from produced oil. Other oil operations consume about 0.3 mgd of self-supplied ground water.

Three communities, in addition to Mount Vernon, have public water-supply systems. New Harmony, Poseyville, and Cynthiana have ground-water supplies whose combined output is about 0.2 mgd. Total self-supplied domestic use is estimated at about 1.3 mgd, almost entirely ground water.

Occurrence and Movement of Ground Water

Much of the rain that falls upon Posey County runs off rapidly to the streams because of the hilly terrain. However, a part is retained by the soil. Much of this retained water is evaporated or transpired by plants. During periods of precipitation accompanied by low plant activity, chiefly the winter and spring months, water in excess of the soil requirements seeps downward to a zone of saturation in the underlying rocks. The water in this zone moves slowly from higher elevations to points of discharge, such as wells, springs, and streams at lower elevations. If the recharge to the rocks is greater than the discharge from the rocks, hydraulic pressure will increase throughout the rock system causing the water levels of wells in the system to rise. Conversely, if discharge exceeds recharge the water levels will fall. Although the rainfall pattern has some effect on the water-level curve in figure 2, the principal effect is the interception and transpiration of water by plant life. The general shape of the water-level curve is typical of wells in this area that are unaffected by pumpage.

Water-bearing rocks (aquifers) are of two types: unconfined or confined. In the unconfined or water-table aquifer, the upper part of the aquifer is open to the atmosphere. Water percolates downward through the unsaturated upper part to the water table (wells D and F on fig. 3). A confined aquifer is fully saturated and is bounded, top and bottom, by saturated, less-permeable material (wells A, B, C, and E on fig. 3). As there is no unsaturated zone-saturated zone contact, there is no water table in the confined aquifer. In current technical usage the terms "confined" and "artesian" are synonymous. Therefore, a well drilled through alternating saturated rocks having contrasting permeabilities (a condition common in both the consolidated and unconsolidated rocks of Posey County) usually can be said to be artesian. Contrary to popular thinking, the only requirement for a well to be classed as artesian is that its water level stand above the top of the aquifer.



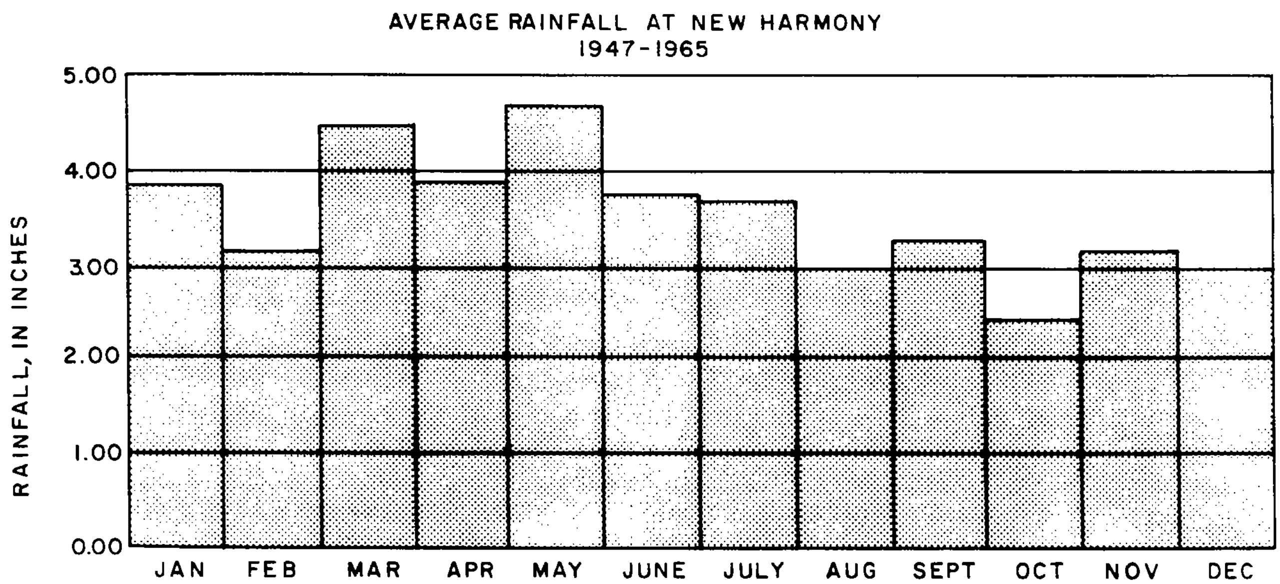


Figure 2.— Average water levels in a well near Wadesville and average rainfall at New Harmony, Ind.

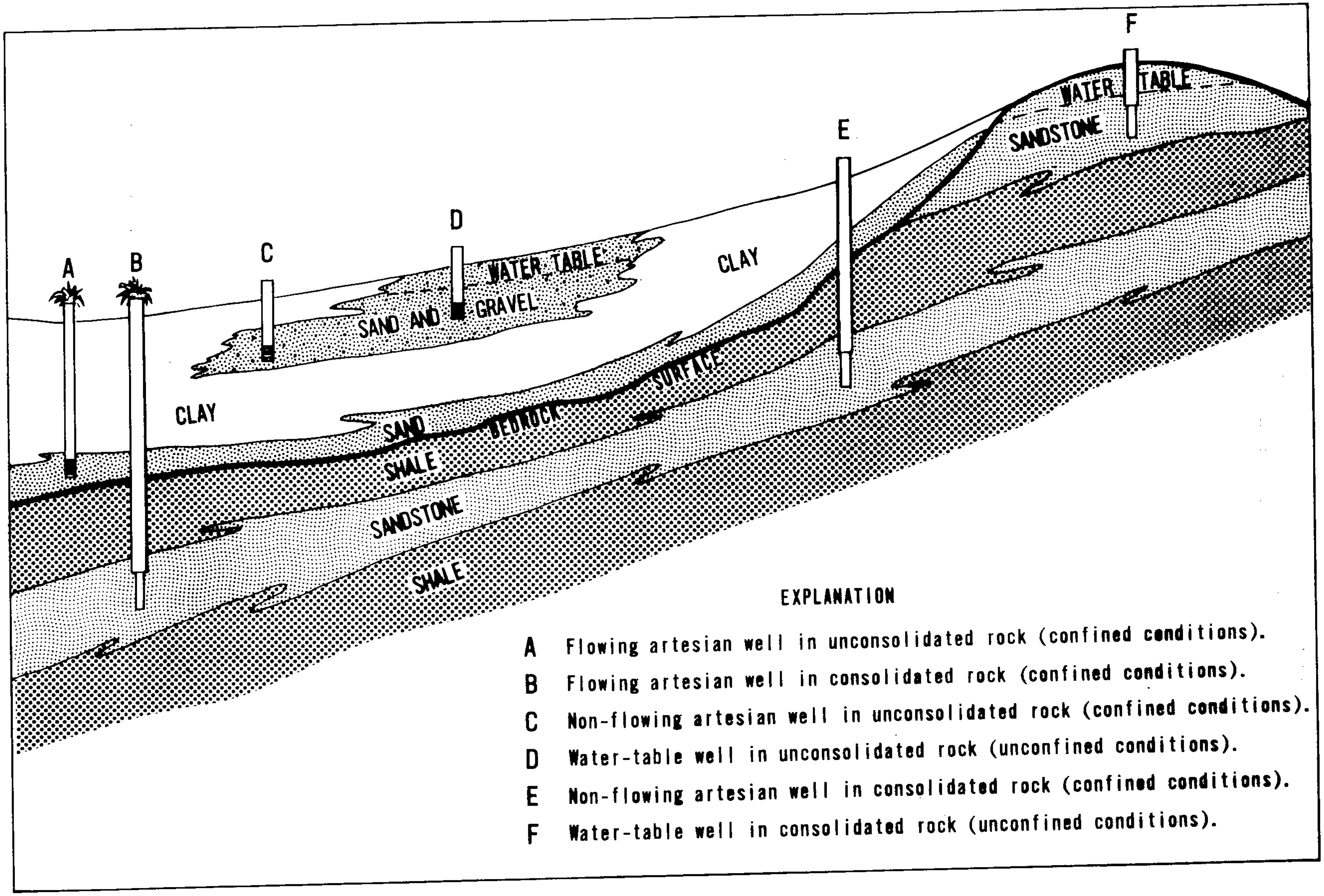


Figure 3.-- Typical hydrogeologic settings of wells in Posey County, Ind.

Springs are found in all parts of the county under many different geohydrologic conditions. However, the largest springs, which yield as much as several gallons per minute, are found at the Wabash River bluffs. They are most likely to occur where loess, sand dunes, or slope-wash deposits are in contact with the flood-plain deposits or with bedrock. While contrasting vertical permeabilities of the deposits (that is, more permeable upper deposits in contact with less permeable lower deposits) may be an important factor, the author believes that the abrupt change of slope characteristically found at such contacts is the more important factor. In one place, a spring flowed from the steep side of a sand dune into a depression in saturated sand in which an organic muck was forming. Stock-watering is the most important use of springs in the county.

HYDROGEOLOGY OF THE CONSOLIDATED ROCKS

Structure

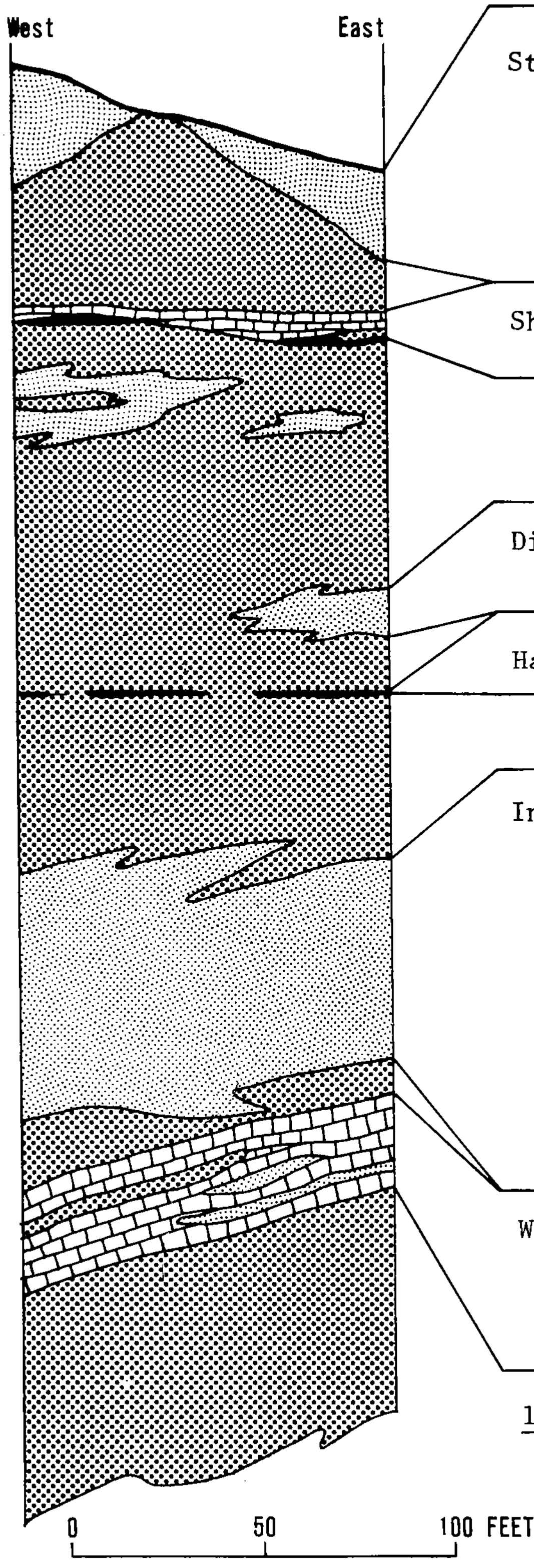
Where unfaulted, the consolidated rocks of the county dip generally to the west at an average rate of about 20 feet per mile. There are several NE-SW trending faults in the southern and western parts of the county. Parts of some of the southern faults are shown on plate 3. However, most of the larger faults are along the Wabash River and in the "point" area formed by the confluence of the Wabash and Ohio Rivers. In fact, the intensity of faulting made the mapping of the bedrock aquifers unfeasible in these areas. The unusual reversal of dip shown on the west-central part of the plate may be due to faulting, but there is insufficient evidence for confirmation.

Stratigraphy, Lithology, and Water-Bearing Characteristics

The consolidated rocks at depths that are feasible for freshwater wells are of Pennsylvanian age and are composed of alternating beds of sandstone, siltstone, shale, limestone, coal, and clay. The principal water-bearing consolidated rocks are the sandstones, although a few wells are producing from other rock types. The aquifers will be discussed by their rock type.

The stratigraphic position of the various aquifers is shown on figure 4. The rocks shown on the figure comprise all or part of the Shelburn, Patoka[1], and Bond[1] Formations. Not shown on the figure are the rocks of the overlying Mattoon Formation[1]. This formation has been preserved by faulting in the Mumford Hills, north of Griffin. Also not shown is the New Harmony Sandstone[1] of the Bond Formation[1]. There is not sufficient information for geohydrologic evaluation or positive geological indentification of these rocks.

[1]The following terms used in this report are of local usage and are not recognized by the U.S. Geological Survey: Bond Formation, Mattoon Formation, Patoka Formation, St. Wendel Sandstone, Dicksburg Hills Sandstone, Hazelton Bridge Coal, Parker Coal, and New Harmony Sandstone.



St. Wendel Sandstone aquifer--Supplies many wells at Stewartsville and St. Wendel. Eroded away or otherwise not present or nonwater-bearing in many localities. Yields calcium bicarbonate water of moderate mineralization.

Shoal Creek Limestone (Parker Coal[1/] beneath)--Good marker bed.

Dicksburg Hills Sandstone aquifer--Not present or nonwater-bearing in most localities.

Hazelton Bridge Coal[1/] --Fair marker bed.

Inglefield Sandstone aquifer--Principal consolidated aquifer; present and water-bearing over most of the county. Median estimated coefficient of transmissibility = 110 gpd/ft; median estimated field coefficient of permeability = 2.2; estimated eight-hour specific capacity = 0.2 gpd/ft drawdown. Where elevation of top of formation is above 300 ft., calcium bicarbonate water prevails; below this elevation, sodium bicarbonate water having adequate to excessive fluoride and excessive dissolved solids prevails.

West Franklin Limestone--Excellent marker bed. A few wells derive water from solution channels in the limestone. Few wells in the county obtain water below this limestone.

[1/] local usage

Figure 4.--Generalized stratigraphic section showing the relationships of the various aquifers and their hydrologic characteristics, Posey County, Indiana.

Sandstone Aquifers

A sandstone, by definition, consists largely of "sandsize" particles (1/16 to 2 millimeters in diameter). In most sandstones these particles consist primarily of quartz grains. A typical sandstone also contains varying amounts of the smaller clay and silt particles and the larger granules and gravel. The relative proportions of the particle sizes, the arrangement of the particles, and the presence or absence of cement determines the permeability of the rock material; that is, its ability to transmit water.

The Inglefield Sandstone aquifer is the principal consolidated rock aquifer in the county. This sandstone is massive and extensive. It crops out in the vicinity of West Franklin and subcrops beneath lake sediments in the bedrock valleys of Big Creek and Black River (pl. 3). It is usually white to gray in drill cuttings and white, gray, buff, or tan in weathered outcrop. The drillers in the area generally refer to this aquifer as the "white water sand." This aquifer is about 50 feet thick in the east part of the county and about 65 feet thick in the west. In general, wells in this aquifer have yields that are more than adequate for domestic needs. The best water-bearing zones are reported to be in the lower part of the aquifer. The yields by area, based on drillers' reported yields, are shown on plate 3. Elevation contours on the top of the aquifer are shown on the plate. To estimate the depth to the aquifer at any given locality, subtract the elevation of the top of the aquifer at that point from the corresponding ground-surface elevation.

The second most important consolidated aquifer is the St. Wendel Sandstone aquifer, which is found only in the areas of high bedrock elevation. Elsewhere, it has been eroded away. The thickness of the aquifer varies greatly because of erosion and erratic deposition. Even where present, the sandstone may not yield adequate domestic supplies. The areas in which this sandstone is known to be present and water bearing are shown on figure 5. The sandstone varies from thin-bedded to massive and its color, from white or gray to chocolate brown.

The least promising of the sandstone aquifers is the Dicksburg Hills Sandstone aquifer. Throughout much of the county, this sandstone is missing or is too thin or too impermeable to be of use. The sandstone or its equivalent is described as "shaly sandstone" or "sandy shale" in many drillers' logs.

The Merom Sandstone (not shown on fig. 4) of the Mattoon Formation[1] is found in the Mumford Hills, an approximately 3-square mile area north of Griffin, Ind. This sandstone may be supplying the several deep wells in the area, or these wells may derive their water from the New Harmony Sandstone[1] (not shown on fig. 4) of the underlying Bond Formation[1]. Neither of these aquifers can be evaluated because of lack of information.

[1]Local usage.

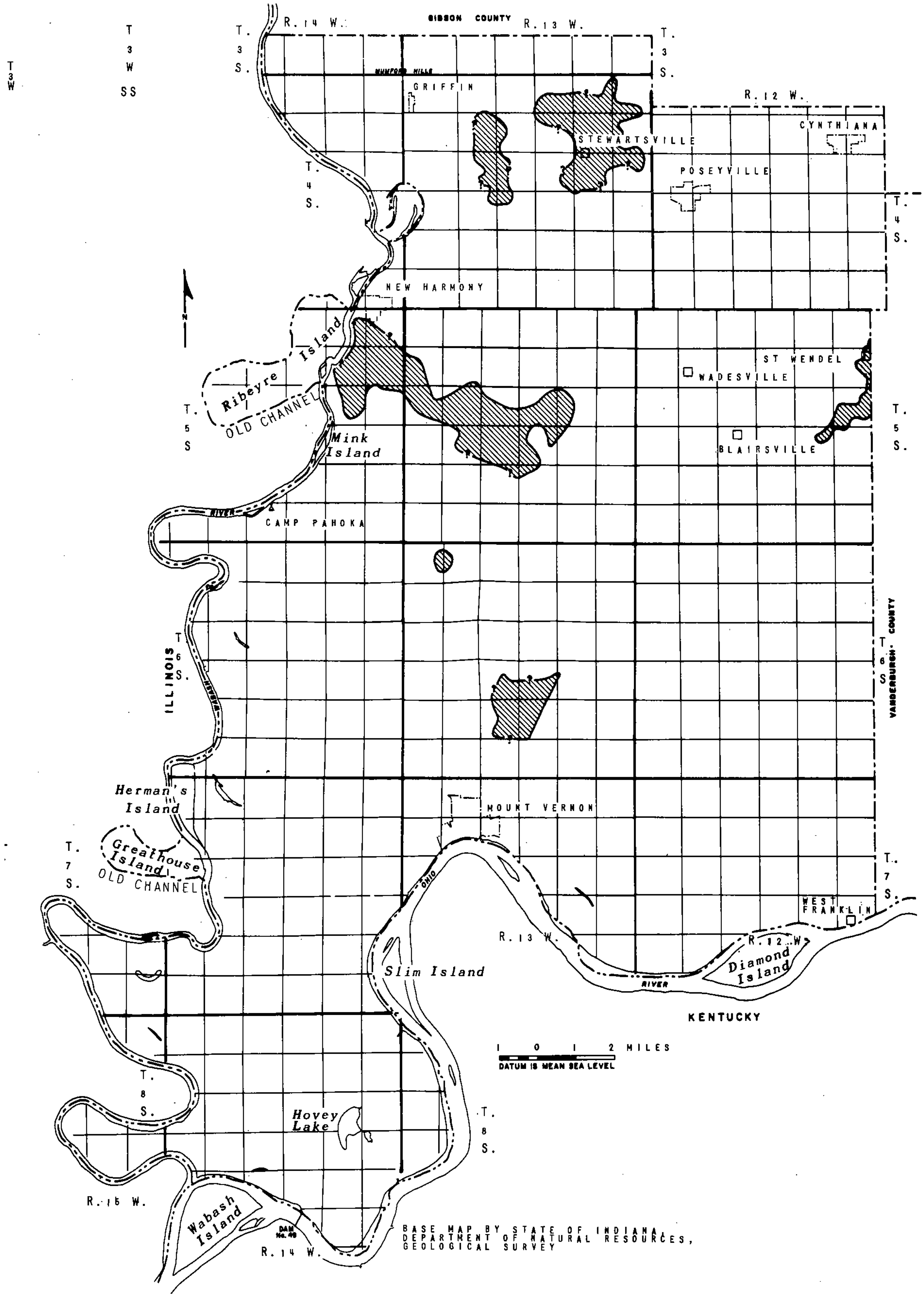


Figure 5.-- Areas in which the St. Wendel Sandstone aquifer is known to be present and water-bearing.

Limestone Aquifers

The limestones in the county are dense and poorly permeable. However, small amounts of water can pass between the bedding planes and joints. Under some conditions percolating ground water may widen these crevices by solution of the limestone, thus greatly increasing the ability of the formation to transmit water. However, there are only a few wells in the county that are known to be producing water from limestone. The reported yields of these wells are 5 gpm (gallons per minute) or less.

Shale and Coal Aquifers

A few wells produce water from shale or coal or both. As is the case with limestones, these rocks can only yield water from bedding planes, joints, or other crevices. In Posey County, shale or coal will not normally yield enough water for a domestic supply. The maximum reported yield from a well in these rocks is 6 gpm.

HYDROGEOLOGY OF THE UNCONSOLIDATED ROCKS

Thousands of years ago, in Pleistocene time, the northwestern half of the county was covered by a thick ice sheet. As the ice melted, rock particles ranging from flour-size to boulders were released from the ice, forming a dense, poorly sorted rock called "till". The large volume of water released by the melting ice formed torrential streams which, in places, sorted the rock particles, carrying away the fine particles and leaving the coarse ones. These sand and gravel deposits were called "drift ridges" by Fuller and Clapp (1904).

A later ice sheet, the southern end of which lay about 80 miles north of the county, was so extensive that its melt water affected the Ohio River as well as the Wabash River. The water levels in these rivers rose so high that the backwater formed lakes in the tributary streams. As shown on plate 1, the tributary valleys filled with clayey and silty lake deposits, whereas the Ohio and Wabash Rivers filled with "valley-train deposits" consisting primarily of sand and gravel. At about the same time, wind-blown deposits, such as sand dunes and loess, were being deposited over much of the county.

From the time of the retreat of the last ice sheet to the present, the Ohio and Wabash Rivers have carved the valley-train deposits into a series of terraces. However, the rivers are for the most part still bottomed upon these deposits and in many places a considerable thickness remains below the bottoms of the rivers. The rivers periodically flood the terraces, leaving each time a veneer of clay, silt, or sand. The cumulative flood deposits on the uppermost terraces have destroyed all traces of former river courses (meander scars). Meander scars are prominent features on the lowermost parts of the flood plains. The most recently abandoned meanders contain water, forming lakes and sloughs. These lakes and sloughs are replenished with each flood. Between floods, they serve as sources of recharge for the underlying unconsolidated aquifers.

Loess Deposits

These deposits are largely composed of wind-blown silt and are best developed on the Wabash bluffs. They are also interbedded with till and lake deposits as well as being found as a thin mantle over the unglaciated parts of the county. Although the loess deposits are well-sorted and uncemented, two factors favorable to permeability, the openings between the silt grains are too small to permit easy passage of water. Therefore, loess is not considered to be an aquifer. Although unproven, it seems logical that these deposits would have a ground-water infiltration capacity superior to a clay soil but inferior to a sandy soil. The loess in the glaciated area is calcareous and should impart hardness to infiltrating water.

Till Deposits

Being composed of poorly sorted clay to boulder-size material, these ice-laid deposits are not considered to be aquifers. However, they have contributed sand and gravel to the streams eroding them. Most of the sand and gravel pockets in the small upland bedrock valleys are till-derived. To a lesser extent, this is true of the sand and gravel deposits in the larger drains. The ground-water infiltration capacity of the till can be assumed to be poor, but superior to that of a clay soil. The till has normally been leached of its calcareous material to a depth of 7 feet or more, but where sufficiently thick will impart hardness to water.

Lakes and Stream Deposits

The lake deposits consist of clay, silt, and fine sand. In places, these deposits are interbedded with till or sand and gravel. The fine sand has some potential as an aquifer, but would require large expenditures for moderate well yields (perhaps 25 to 75 gpm). During periods when the glacial lakes drained, the streams that had previously occupied the valley appeared again. Along the courses of the streams, some of the fine materials were removed and the coarse materials were left behind. These fine to coarse sands, some gravelly, are thin, narrow, and difficult to locate in the upper reaches of the valleys. In the lower reaches of the streams, the deposits are thicker and easier to locate. If the drillers' designations and the thicknesses are accurate, well yields of as much as a few hundred gallons per minute are possible. Some reported locations are shown on plate 2. The only sizeable supply from such deposits is at

Poseyville, where the town wells are pumped at 80 gpm each. No industrial supplies are known to have been developed from these deposits in the industrial area southwest of Mount Vernon.

Valley-Train Deposits

This assemblage of fine sands to coarse gravels comprises the best aquifer in the area. Potential yields in the water-table aquifer vary greatly because of local variations in thickness and character of material. However, generalized comparisons can be made between the Wabash valley-train deposits and those of the Ohio. The Wabash deposits tend to be more sandy. Typically, there is a thin surficial layer of soil or clay, underlain by fine sand, which is in turn underlain by gravelly sand or sand and gravel. In many localities, however, this pattern of progressive coarseness is not found. The geologic section of the Ohio valley-train deposits shown on figure 6 is not typical. In a more typical section, the clay is much thinner. In most areas, there is an abrupt transition from the clay to various mixtures of sand and gravel. In general, the coarsest and cleanest gravels are found in the deepest part of the section. In the "point" area, there is a complex mixture of the two types of deposition. In each of these depositional types, a properly constructed well should yield from several hundred to more than 1,000 gpm in most localities. The estimated coefficients of transmissibility (see Glossary) shown on plate 2 were obtained by assigning field coefficients of permeability on the basis of lithologic descriptions on well logs. The values used were those of Keech and Dreeszen (1959). Interpolations of saturated thickness were made from plate 4. Although this technique is subject to considerable error, the coarse estimates will probably be useful to water-resource planners and managers. By similar techniques, the direct discharges to the Wabash and Ohio Rivers from these deposits were estimated to be 25 and 15 mgd, respectively. Present usage is very small compared to this quantity. The total amount of recoverable stored water in this aquifer is estimated to be 500 billion gallons.

Transitional Deposits

These deposits represent a transition between the lake deposits and the valley-train deposits. In the area east of Mount Vernon, the first 50 feet or so of these deposits are normally composed of clay and silt. Approximately the next 50 feet may be composed of interbedded clay, silt, and fine sand. Below 100 feet, fine to medium sand or sand and gravel may occur. In the area west of Mount Vernon, the upper interval is sandier and there is no sharp division between the transitional deposits and "Wabash-type" valley-train deposits. These deposits are capable of yielding from 50 to a few hundred gpm to properly constructed wells. Explorations for industrial water supplies in the area east of Mount Vernon have shown that a few test holes are usually needed to find an adequate supply because of the extreme variability of the transitional deposits. Confined conditions are prevalent.

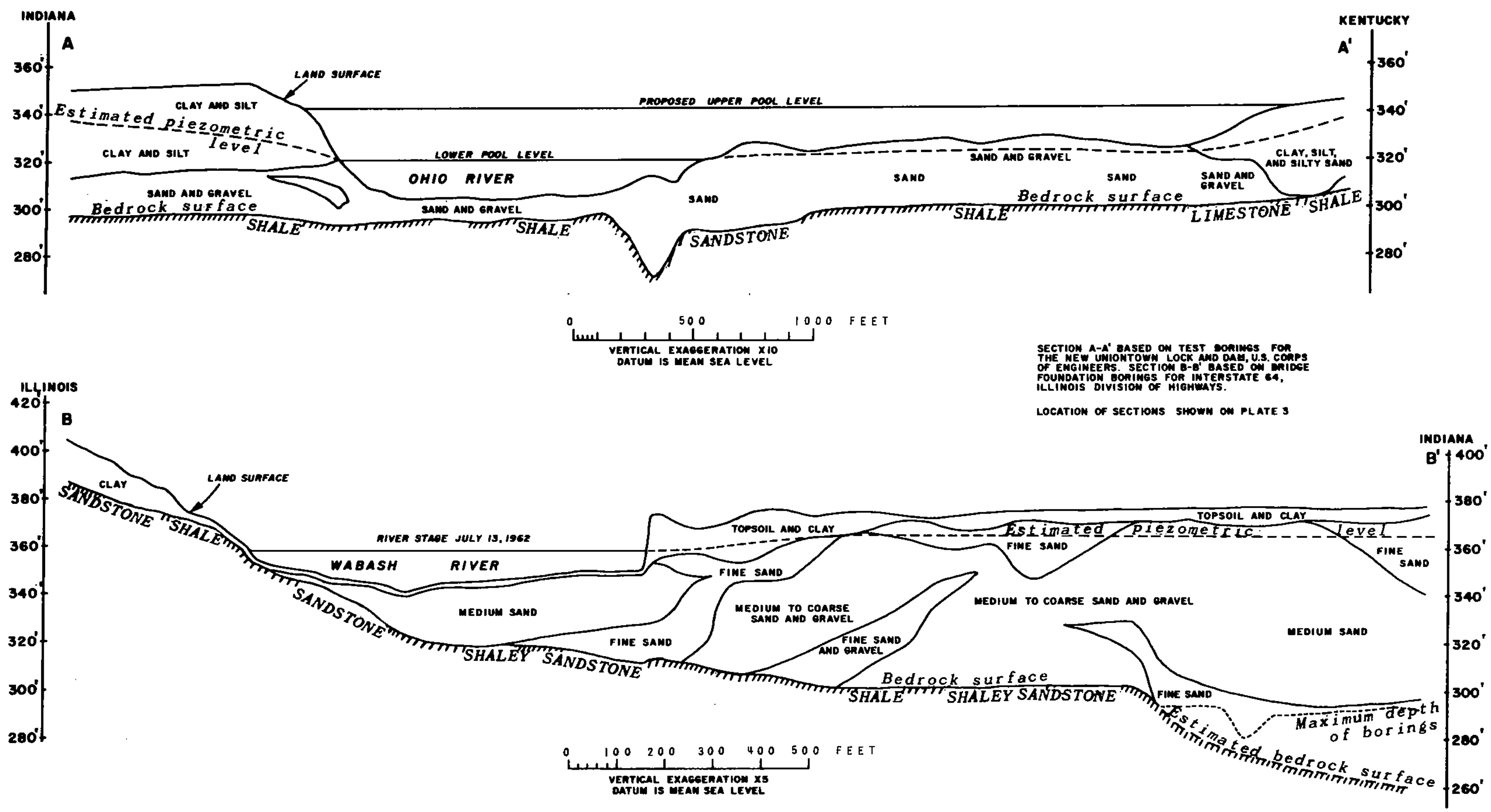


Figure 6.-- Geologic sections of the Ohio and Wabash River valleys, Posey County, Indiana.

Dune Deposits

These deposits of wind-blown sand are chiefly found on the recessed parts of the Wabash bluffs (pl. 1). The predominantly fine sand is described as a "red sand" by drillers and is typically buff on outcrop. This sand is virtually unused as an aquifer in the northwest and west-central areas. Here, the Inglefield or St. Wendel Sandstone aquifers are normally available, yielding superior water at lower completion cost. However, west of Mount Vernon the sandstone aquifers are not available because of faulting. In this area, several domestic wells tap the dune sand. Although the thickness of the sand exceeds 60 feet in places, about half of this is unsaturated. Under optimum conditions, the yield of a well in this aquifer would probably be less than 50 gpm.

CHEMICAL QUALITY OF GROUND WATER

The chemical quality of water is one of the critical factors influencing its utility. An abundance of a dissolved constituent can inhibit, or even prohibit, the use of the water for certain purposes. Terms such as "excessive," "deficient," "high," and "low," which are used in the following discussion, refer to concentrations of certain dissolved constituents and are based on limits recommended by the U.S. Public Health Service (1962). These standards and other usages such as "hard" and "soft" are discussed in table 1. The statistical analyses are based on field determinations made by the Indianapolis office of the U.S. Geological Survey and on chemical analyses analyses made by the Indiana State Board of Health and the Columbus, Ohio, laboratory of the U.S. Geological Survey. Those of the Indiana State Board of Health have been published (1960), and those of the Columbus, Ohio, laboratory are given in table 2.

Hardness

Posey County is almost completely covered by a mantle of unconsolidated materials. These materials contain varying amounts of calcium and magnesium carbonates. When rainwater containing carbon dioxide from the atmosphere and from soil-bacteria activity comes into contact with these minerals, calcium and magnesium ions are taken into solution, causing the water to become moderately hard to very hard (See "Hardness as $CaCO_3$," in table 1.). As the water passes from the unconsolidated rock into the consolidated rocks, a water-softening process begins. In this process calcium and magnesium ions are replaced by sodium ions from ion-exchange minerals. The softening is most complete at the lower elevations. This is due to at least two factors: (1) Progressive depletion of exchangeable sodium in the rocks in the line of flow of the water; that is, the uppermost rocks had contact with the hardest water, and the lower rocks had contact only with partially softened water. (2) At elevations below stream level, and especially below the level of the bedrock valleys, water movement is more sluggish;

Table 1.--Significance of selected dissolved-mineral constituents and properties of ground water

Constituent or property
Iron (Fe)
Manganese (Mn)
Calcium (Ca) and magnesium (Mg)
Sodium (Na)
Potassium (K)
Bicarbonate (HCO_3) and carbonate (CO_3)
Sulfate (SO_4)
Chloride (Cl)
Fluoride (F)
Nitrate (NO_3)
Dissolved solids
Hardness as $CaCO_3$
Hydrogen-ion concentration (pH)

Significance
Excessive amounts cause: "red water"; yellowish- or reddish-brown laundry and fixture stains; slimy iron-bacteria growth in wells, pipes and tanks; bitter taste. The U.S. Public Health Service (1962, p. 7) recommends that iron should not exceed 0.3 ppm on the basis of taste and laundry use.
Similar to iron. Causes dark stains. U.S. Public Health Service (1962, p. 7) recommends that the manganese concentration should not exceed 0.05 ppm.
Principal cause of hardness. (See "Hardness", p. 15)
High concentrations may cause water to be unsuitable for agriculture. See Hem (1959, p. 247-250).
Chemically similar to sodium.
Principal alkaline factors in water. (See "Hardness", p.15)
In combination with calcium forms hard scale in boilers. In high concentrations imparts bitter taste to water. U.S. Public Health Service (1962, p. 7) recommends that the sulfate concentration should not exceed 250 ppm.
In high concentrations chloride increases the corrosiveness of water and imparts a salty taste. The U.S. Public Health Service (1962, p. 7) recommends a maximum concentration of 250 ppm, based upon taste.
In low concentrations fluoride reduces tooth decay. In higher concentrations tooth mottling or bone damage may occur (U.S. Public Health Service, 1962, p. 41). The U.S. Public Health Service (1962, p. 8) recommendations are based on the annual average of maximum daily air temperatures. For Posey County the recommended limits are: minimum, 0.7 ppm; optimum, 0.9 ppm; maximum, 1.2 ppm.
A high nitrate concentration may cause methemoglobinemia (blue-baby disease) in infants. The U.S. Public Health Service (1962, p. 50) recommends a limit of 45 ppm.
U.S. Public Health Service (1962, p. 7) recommends a limit of 500 ppm.
Consumes soap by formation of scum. Primarily due to calcium and magnesium. When these constituents are combined with bicarbonate they cause temporary or carbonate hardness. A widely used hardness scale is: 0-60 ppm, soft; 61 to 120 ppm, moderately hard; 121 to 180 ppm, hard; more than 180 ppm, very hard (Durfor and Becker, 1964, p. 27).
Measure of alkalinity-acidity: 0 to 7 denotes decreasing acidity; 7 neutrality; 7 to 14 increasing alkalinity.

Table 2.--Chemical analyses of ground water in Posey County, Indiana
(Results in parts per million except as indicated; analyses by the U.S. Geological Survey)

Anal. no.	Well location	Date of collection	Depth of well (feet)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)
	Unconsolidated rock aquifers of Quaternary age									
1	SE 1/4 NE 1/4 Sec. 33, T. 3 S., R. 14 W.	10-12-66	80	--	15	0.48	0.06	112	31	207
2	NW 1/4 SE 1/4 Sec. 33, T. 3 S., R. 14 W.	10-12-66	80	--	12	.71	.06	101	26	47
3	NE 1/4 SW 1/4 Sec. 23, T. 5 S., R. 14 W.	10-28-65	28	60	20	---	---	94	29	38
4	SE 1/4 NE 1/4 Sec. 35, T. 5 S., R. 14 W.	10-28-65	64	56	22	---	---	101	52	8.5
5	NE 1/4 NE 1/4 Sec. 17, T. 7 S., R. 12 W.	10-27-65	40	59	14	---	---	40	18	5.4
6	NE 1/4 SE 1/4 Sec. 4, T. 7 S., R. 13 W.	4-20-55	111	59	26	.92	.66	111	51	26
7	NE 1/4 SW 1/4 Sec. 14, T. 8 S., R. 14 W.	10-27-65	51	57	6.9	---	---	32	7.6	8.5
	Shale aquifer of Pennsylvanian age									
8	NW 1/4 NW 1/4 Sec. 7, T. 7 S., R. 13 W.	10-27-65	100	58	28	---	---	79	38	6.8
	St. Wendel Sandstone aquifer of Pennsylvanian age									
9	SE 1/4 NE 1/4 Sec. 12, T. 5 S., R. 12 W.	2-24-66	63	55	34	0.53	0.90	27	16	56
10	SE 1/4 NW 1/4 Sec. 20, T. 5 S., R. 13 W.	12-17-65	90	66	26	6.5	.05	74	41	8
	Inglefield Sandstone aquifer of Pennsylvanian age									
11	SE 1/4 SW 1/4 Sec. 23, T. 4 S., R. 13 W.	2-24-66	322	54	8.1	0.17	0.15	1.4	0.0	272
12	NW 1/4 SE 1/4 Sec. 19, T. 5 S., R. 12 W.	10-28-65	244	58	12	---	---	1.6	.4	252
13	SE 1/4 NW 1/4 Sec. 36, T. 5 S., R. 13 W.	10-28-65	96	56	30	---	---	84	4.4	36
14	NE 1/4 NE 1/4 Sec. 24, T. 5 S., R. 14 W.	10-28-65	255	58	9	---	---	1.5	.3	400
15	NE 1/4 NE 1/4 Sec. 30, T. 6 S., R. 12 W.	10-28-65	250	62	9.8	---	---	1.4	.5	304
16	NW 1/4 SE 1/4 Sec. 28, T. 6 S., R. 13 W.	10-27-65	318	58	8.3	---	---	4.3	.9	988

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (Calculated)	Hardness as $CaCO_3$	Noncarbonate hardness	Specific conductance (micromhos per centimeter at 25°C.)	pH	Remarks
1.6	308	0	44	385	0.1	7.7	955	407	155	1,740	7.2	Water-flood supply well.
.9	330	0	35	106	.1	1.5	492	359	88	878	7.3	Do.
2.1	370	0	23	75	.2	.8	466	354	50	815	7.3	Do.
.2	556	0	9.6	7	.3	.2	474	466	10	818	7.2	
1.1	188	0	24	3	.3	.2	200	174	20	341	7.7	
.7	635	0	12	5	.3	2.5	549	487	0	924	7.4	Industrial well.
1.8	68	0	52	15	.0	6.6	164	111	56	293	6.8	
0.4	424	0	16	4	0.4	3.2	384	353	6	657	7.4	
0.6	64	0	63	62	0.1	54	345	134	81	555	6.2	
.4	442	0	1.6	4	.2	.2	379	353	0	639	7.1	
0.7	606	10	2.4	68	0.8	0.4	662	4	0	1,130	8.7	Elevation top of aquifer, 203 ft.
.9	505	20	9.2	71	.6	.6	616	6	0	1,020	8.7	Elevation top of aquifer, 235 ft.
1.1	360	0	1.2	3	.3	2.2	342	228	0	540	7.0	Elevation top of aquifer, 309 ft.
1.0	712	18	.4	186	1.3	1.0	969	5	0	1,670	8.6	Elevation top of aquifer, 175 ft.
.9	608	14	1.2	91	1.1	.5	724	6	0	1,240	8.6	Elevation top of aquifer, 250 ft.
3.0	1,540	0	12	640	2.6	2.4	2,420	14	0	4,050	8.2	Elevation top of aquifer, 175 ft.

consequently, the ion-exchange minerals have had contact with less water and, therefore, have had contact with fewer calcium and magnesium ions.

As is shown in the table that follows, there is a rather sharp decline in hardness of water obtained from the Inglefield Sandstone aquifer where the elevation of the top of the formation is below 300 feet.

Environment	Number of analyses	Minimum hardness (ppm)	Maximum hardness (ppm)	Median hardness (ppm)	Average hardness (ppm)
Unconsolidated rocks	21	111	546	359	352
St. Wendel Sandstone aquifer	6	134	440	290	283
Inglefield Sandstone aquifer--elev. of top, above 300 ft.	6	87	228	166	155
Inglefield Sandstone aquifer--elev. of top, below 300 ft.	18	4	76	12	15

Bicarbonate, Carbonate, and pH

Most natural water contains a combination of dissolved carbon dioxide and carbonate or bicarbonate. This combination is the principal control of pH (Hem, 1959, p. 46). Bicarbonate and carbonate ions are present in most water because of the abundance of carbonate minerals and because carbon dioxide, which enters into equilibria with them in water solution, is readily available. The relation of bicarbonate, carbonate, and pH is shown in the table on the following page.

Environment	Constituents and pH	Number of analyses	Minimum concn. or pH	Maximum concn. or pH	Median concn. or pH	Average concn. or pH
			Chemical constituents are in parts per million.			
Unconsolidated rocks	HCO_3	21	68	700	410	404
	CO_3	21	0	0	0	0
	pH	14	6.8	7.7	7.2	[a]7.1
St. Wendel Sandstone aquifer	HCO_3	6	64	576	373	344
	CO_3	6	0	0	0	0
	pH	6	6.2	7.1	6.6	[a]6.6
Inglefield Sandstone aquifer--elev. of top, above 300 ft.	HCO_3	6	293	466	422	401
	CO_3	6	0	0	0	0
	pH	6	7.0	8.2	7.4	[a]7.4
Inglefield Sandstone aquifer--elev. of top, 200-300 ft.	HCO_3	12	298	952	576	590
	CO_3	12	0	86	26	30
	[b]pH	5	8.2	8.7	8.6	[a]8.5
Inglefield Sandstone aquifer-- elev. of top, below 200 ft.	HCO_3	7	542	1,540	712	879
	CO_3	7	0	52	41	32

[a]Average hydrogen-ion concentration expressed as pH.

[b]For all elevations below 300 ft. in the Inglefield Sandstone aquifer.

Sulfate

Sulfate concentrations in the ground water are normally well below the 250-ppm maximum concentration recommended for drinking water by the U.S. Public Health Service (1962, p. 7), average concentrations being 29 ppm in the water from the unconsolidated rocks (36 ppm on the Wabash and Ohio flood plains; 8 ppm elsewhere), 25 ppm in water from the St. Wendel Sandstone aquifer, and 11 ppm in water from the Inglefield Sandstone aquifer. A single exception was found in section 2 of T. 7 S., R. 13 W., where a 72-foot well in limestone, coal, and shale yielded water having a sulfate concentration of 392 ppm.

Fluoride

In the calcium-rich, hard water of the unconsolidated rocks, St. Wendel Sandstone aquifer, and higher elevations of the Inglefield Sandstone aquifer, fluoride concentrations are normally below the concentration recommended for drinking water by the U.S. Public Health Service (1962, p. 8). This is chiefly because of the low solubility of calcium fluoride. As shown in the accompanying table, soft water from the lower elevations of the Inglefield Sandstone aquifer tends to have fluoride concentration in the adequate to excessive range, with respect to fluoride protection of teeth. (See table 1.)

Water type	Number of analyses	Average hardness (ppm)	Fluoride (ppm)			
			Minimum	Maximum	Median	Average
Hard	15	319	0.0	0.4	0.2	0.2
Soft	5	7	.6	2.6	1.1	1.3

Chloride

High chloride concentrations in ground water can be due to either man-made or natural causes. Both conditions seem to be present in Posey County. Where high chloride concentrations are found in water from the unconsolidated deposits, they are most likely caused by oil and gas operations--specifically because of spillage of brine and leakage of brine from "evaporation pits," brine tanks, and improperly cased or plugged wells.

A field partial analysis of water from a ditch adjacent to an evaporation pit in section 10 of T. 7 S., R. 13 W. (about 2 miles southwest of Mount Vernon) showed a chloride concentration of 408 ppm. The chloride concentration of the water in the pit was estimated to be 40,000 ppm. Analyses 1 and 2 in table 2 indicate hard water (hardness of 407 and 359 ppm, respectively) and water containing high concentrations of iron (0.48 and 0.71 ppm) and manganese (0.06 and 0.06 ppm) in the oil-producing area northwest of Griffin. Analysis 3 indicates that the water in the area opposite Mink Island has a lower dissolved-solids concentration than that northwest of Griffin. Field analyses made 4 months previously of water samples from the same wells from which the samples for analyses 2 and 3 were taken showed a chloride concentration decrease from 545 ppm in the Griffin well and an increase from 40 ppm in the Mink Island well. Firm conclusions can't be drawn from such meager data, but both a problem and the need for a detailed study are indicated.

High chloride concentrations in water from the consolidated rocks are probably due to natural causes. In the area north of Mount Vernon, between the faults, water having excessive chloride concentration has been found in the Inglefield Sandstone aquifer at elevations approaching 300 feet. Restriction of freshwater circulation due to the faults may be the causative factor. Heavy domestic pumpage may be aggravating the condition. Shallow oil shows have also been reported in this area. In no other area in the county has this aquifer been reported to yield salty water, although at the lower aquifer elevations the 250 ppm chloride limit may be approached. Salty water has been reported, but not confirmed, in sections 12 and 13 of T. 7 S., R. 12 W., (north of West Franklin) in an undefined aquifer that lies about 200 feet below the Inglefield at an elevation of about 250 feet. Such occurrences of salty water in the consolidated rocks above the level of the deeper bedrock channels (pl. 4) indicate that salty water from the consolidated rocks may be seeping into the unconsolidated deposits in the deeper bedrock channels. This salty water is not brine, however, and even a moderate circulation of freshwater should prevent the occurrence of excessive chloride concentrations in the unconsolidated deposits.

Nitrate

The only known occurrence of high nitrate concentration is in water from a shallow well in the St. Wendel Sandstone aquifer in the community of St. Wendel. (See analysis 9 in table 2.) Whether this high concentration is attributable to local contamination of the aquifer, due to the high density of septic tanks in the community, or to improper construction of the subject well is not known. In either case, the problem could be solved by drilling a properly constructed well to the deeper Inglefield Sandstone aquifer.

Iron

The solubility of iron in water is favorably influenced by such factors as low pH and low concentrations of hydrogen sulfide, carbonate, and oxygen. These conditions prevail in the confined lake deposits and transitional deposits. In water from these deposits the average iron concentration is 2.1 ppm, and the median concentration is 1.0 ppm. Water from the unconfined valley-train deposits has an average iron concentration of 0.3 ppm (median 0.3). Most wells in the St. Wendel Sandstone and the Inglefield Sandstone aquifers produce water having an acceptable iron concentration. Water from the sand dunes west of Mount Vernon and from isolated sand and gravel pockets in the till areas tend to have an excessive iron concentration.

Dissolved Solids

As shown in the table that follows, average dissolved-solids concentration of water from aquifers in the county at elevations above 300 ft., is near or less than the concentration for drinking water recommended by the U.S. Public Health Service in table 1. However, at lower elevations in the Inglefield Sandstone aquifer, the recommended limit is exceeded. The higher dissolved solids at the lower elevations are due chiefly to higher concentrations of sodium, bicarbonate, and chloride.

Environment	Number of analyses	Dissolved-solids concentration (parts per million)			
		Minimum	Maximum	Median	Average
Unconsolidated rocks	21	164	955	422	443
St. Wendel Sandstone aquifer	6	204	516	362	367
Inglefield Sandstone aquifer--elev. of top, over 300 ft.	6	328	432	381	379
Inglefield Sandstone aquifer--elev. of top, 200-300 ft.	12	454	1,270	661	727
Inglefield Sandstone aquifer--elev. of top, below 200 ft.	7	655	2,420	969	1,248

SUMMARY AND CONCLUSIONS

The best aquifer in the county consists of Quaternary valley-train deposits in the Wabash and Ohio River valleys. Well yields in excess of 1,000 gpm can be obtained from this aquifer. The total potential yield of this aquifer greatly exceeds present usage. Much of the aquifer coincides with the lower flood plains, which are subject to frequent flooding, thereby detracting from the aquifer's utility where land occupancy is required. The flooding serves as a source of recharge, enhancing the potential yield. Other Quaternary unconsolidated rocks, such as lake and stream deposits and dune deposits, generally yield less than 50 gpm. Aquifers transitional between these and the valley-train deposits yield as much as a few hundred gallons per minute to wells.

The unconsolidated rock aquifers normally yield calcium bicarbonate water having a dissolved-solids concentration of less than 500 ppm. The water in all but the valley-train deposits tends to contain excessive iron. Preliminary information indicates some pollution of unconsolidated aquifers in the vicinity of oil and gas operations as the result of brine leakage. Detailed studies should be made to determine the extent of the problem and to recommend remedial or preventive measures where necessary and feasible.

In more than half of the county, the principal aquifers consist of consolidated rocks of Pennsylvanian age. Of these, the Inglefield Sandstone aquifer is the most important, and the St. Wendel Sandstone aquifer is of secondary importance. Most reported yields from these aquifers are in the 5 to 25 gpm range. Water from the St. Wendel Sandstone and the Inglefield Sandstone aquifers at elevations above 300 feet is typically of the calcium bicarbonate type and has a dissolved-solids concentration of less than 500 ppm. At elevations below 300 feet in the latter aquifer, the water is more likely to be of the sodium bicarbonate type and to contain excessive dissolved-solids, excessive fluoride, and, in places, excessive chloride concentrations.

GLOSSARY

Permeability, field coefficient of--Measure of a material's capacity to transmit water; expressed as rate of flow of water in gallons per day through a cross sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot at the prevailing water temperature.

Specific capacity--Yield of a well in gallons per minute per foot of drawdown for a given period of continuous pumping.

Transmissibility, coefficient of--Rate of flow of water (gallons per day), at the prevailing water temperature, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 1 foot per foot.

SELECTED REFERENCES

Collett, John, 1884, Geology of Posey County: Indiana Dept. Geology and Nat. History, Ann. Rept. 13, Pt. I, p. 45-70.

Durfor, C. N., and Becker, Edith, 1964, Public Water Supplies of the 100 largest cities in the United States, 1962: U.S. Geol. Survey Water-Supply Paper 1812, 364 p.

Fidlar, M. M., 1948, Physiography of the lower Wabash valley: Indiana Div. Geology Bull. 2, 112 p., 5 pls., 3 figs.

Fuller, M. L., and Clapp, F. G., 1904, Description of the Patoka quadrangle, Indiana-Illinois: U.S. Geol. Survey Geol. Atlas, Folio 105, 12 p., 13 figs., 2 maps.

Gallaher, J. T., 1964, Geology and hydrology of alluvial deposits along the Ohio River between the Uniontown area and Wickliffe, Kentucky: U.S. Geol. Survey Hydrol. Inv. Atlas HA-129, 2 pls.

Gallaher, J. T., and Price, W. E., Jr., 1966, Hydrology of the alluvial deposits in the Ohio River valley in Kentucky: U.S. Geol. Survey Water-Supply Paper 1818, 80 p., 22 figs.

Harrell, Marshall, 1935, Ground water in Indiana: Indiana Dept. Conserv., Pub. 133, 504 p., 8 pls. including geologic map.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p.

Indiana State Board of Health, 1960, Data on Indiana public water supplies: Indiana State Board Health Bull. No. S. E. 10, 83 p.

Keech, C. F., and Dreeszen, V. H., 1959, Geology and ground-water resources of Clay County, Nebraska: U.S. Geol. Survey Water-Supply Paper 1468, 157 p., 17 figs., 4 pls.

Malott, C. A., 1922, The Physiography of Indiana, in Handbook of Indiana geology: Indiana Dept. Conserv., Pub. 21, pt. 2, p. 59-256.

Marean, H. W., 1903, Soil survey of Posey County, Indiana: U.S. Dept. Agriculture, Bur. Soils, 20 p., 1 fig., 1 map.

Pryor, W. A., 1956, Groundwater Geology of White County, Illinois: Illinois Geol. Survey Rept. Inv. 196, 50 p., 4 pls., 21 figs.

Thornbury, W. D., 1937, Glacial geology of southern and south-central Indiana: Indiana Div. Geology, 138 p., 21 figs.

______1950, Glacial sluiceways and lacustrine plains of southern Indiana: Indiana Div. Geology Bull. 4, 21 p., 2 pls., 3 figs.

U.S. Public Health Service, 1962, Public Health Service drinking-water standards, revised 1962: U.S. Public Health Service Pub. 956, 61 p.

Wier, C. E., 1955, Correlation of the upper part of Pennsylvanian rocks in southwestern Indiana: Bloomington, Indiana Univ., Ph.D thesis (unpublished), 110 p., 3 pls., 7 figs.

Wier, C. E., and Girdley, G. A., 1962, Distribution of the Inglefield and Dicksburg Hills Sandstone Members in Posey and Vanderburgh Counties, Indiana: Indiana Acad. Sci. Proc., 72, p. 212-217.

EXPLANATION

Predominant lithology and water-bearing properties

THICK LOESS AND TILL DEPOSITS MANTLING BEDROCK HILLS. WITH THE EXCEPTION OF MINOR SAND AND GRAVEL BODIES, NOT CONSIDERED TO BE WATER-BEARING

THIN LOESS DEPOSITS MANTLING BEDROCK HILLS, NONWATER-BEARING

LAKE AND STREAM DEPOSITS. CLAYS, SILTS AND SANDS INTERBEDDED WITH TILL, LOESS OR SAND AND GRAVEL. POTENTIAL YIELDS EXTREMELY VARIABLE WITH LOCALITY, RANGING FROM VIRTUALLY NIL TO A FEW HUNDRED GALLONS/MINUTE

VALLEY-TRAIN DEPOSITS. SAND AND/OR GRAVEL DEPOSITS HAVING POTENTIAL YIELDS OF FROM SEVERAL HUNDRED TO WELL OVER 1,000 GALLONS/MINUTE

TRANSITIONAL DEPOSITS. UPPER INTERVALS MOSTLY FINE MATERIAL, LOWER INTERVALS MAY CONTAIN SAND AND GRAVEL BEDS. YIELDS OF A FEW HUNDRED GALLONS/MINUTE OBTAINABLE IN MANY LOCALITIES

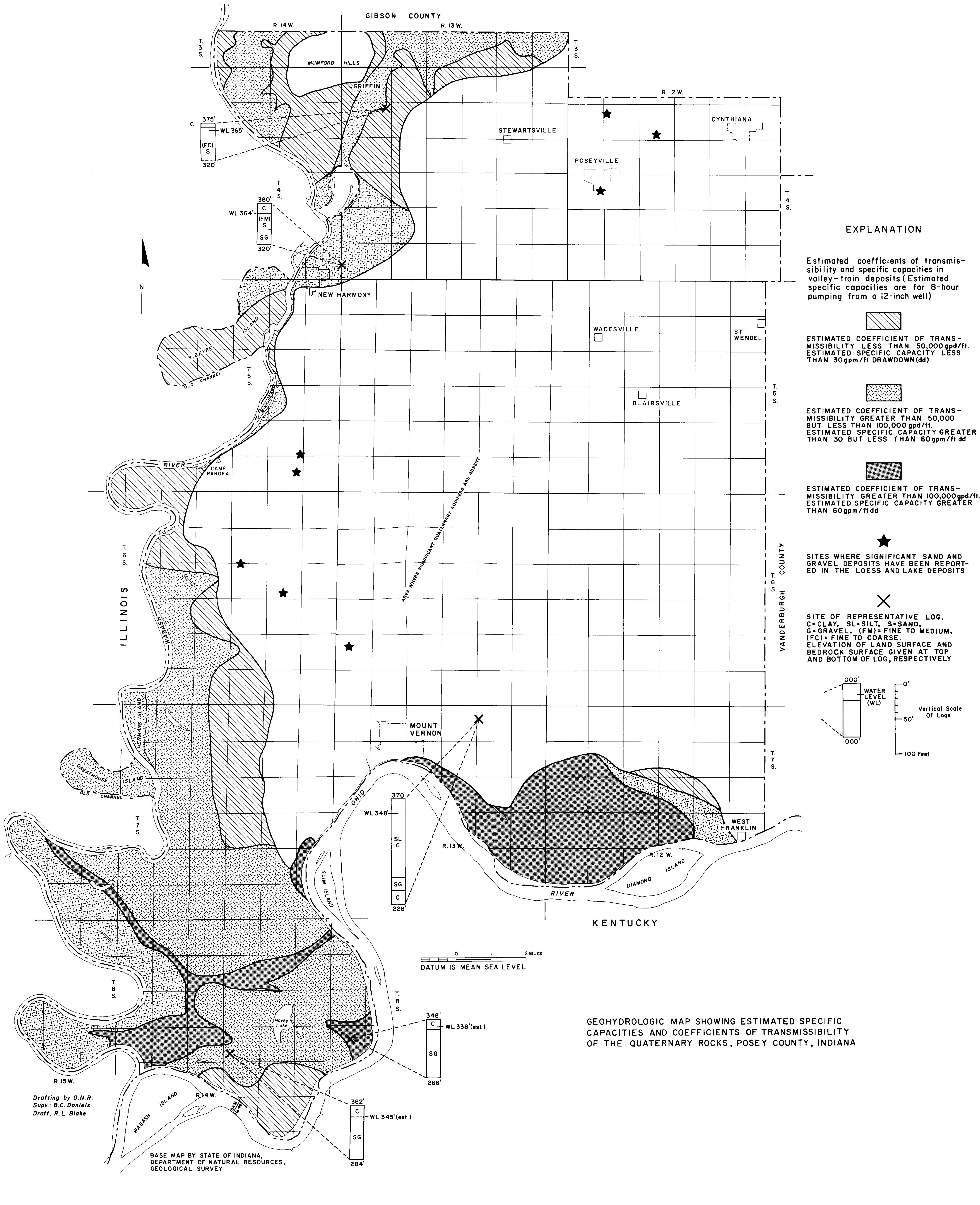
DUNE DEPOSITS. CONSIST MOSTLY OF FINE SAND. ESTIMATED MAXIMUM YIELD 50 GALLONS/MINUTE OR LESS

GEOLOGY MODIFIED FROM
M.L. FULLER AND F.G. CLAPP (1904)

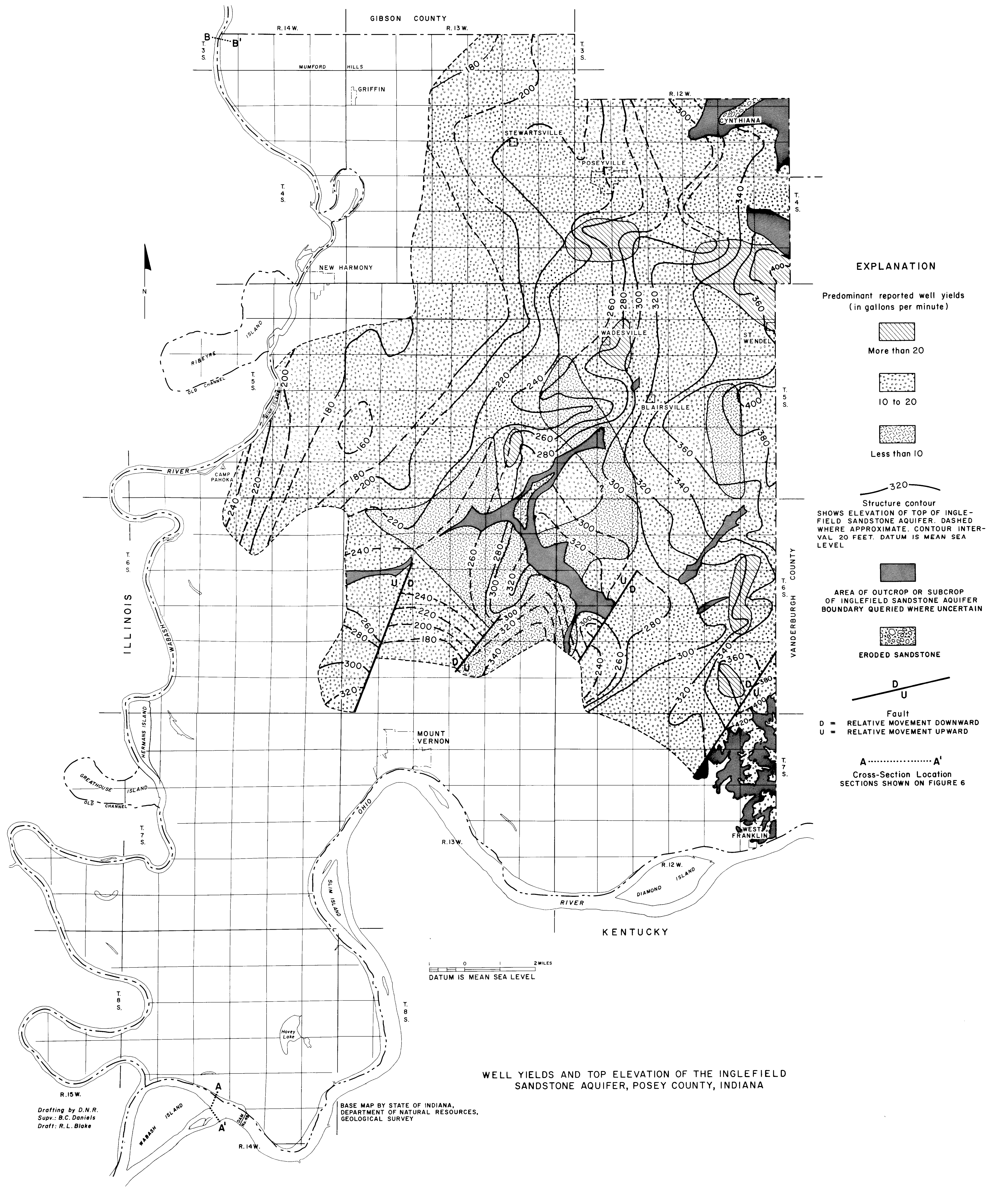
UNCONSOLIDATED GEOLOGY OF POSEY COUNTY, INDIANA

Drafting by D.N.R.
Supv.: B.C. Daniels
Draft: R.L. Blake

BASE MAP BY STATE OF INDIANA,
DEPARTMENT OF NATURAL RESOURCES,
GEOLOGICAL SURVEY



GEOHYDROLOGIC MAP SHOWING ESTIMATED SPECIFIC CAPACITIES AND COEFFICIENTS OF TRANSMISSIBILITY OF THE QUATERNARY ROCKS, POSEY COUNTY, INDIANA



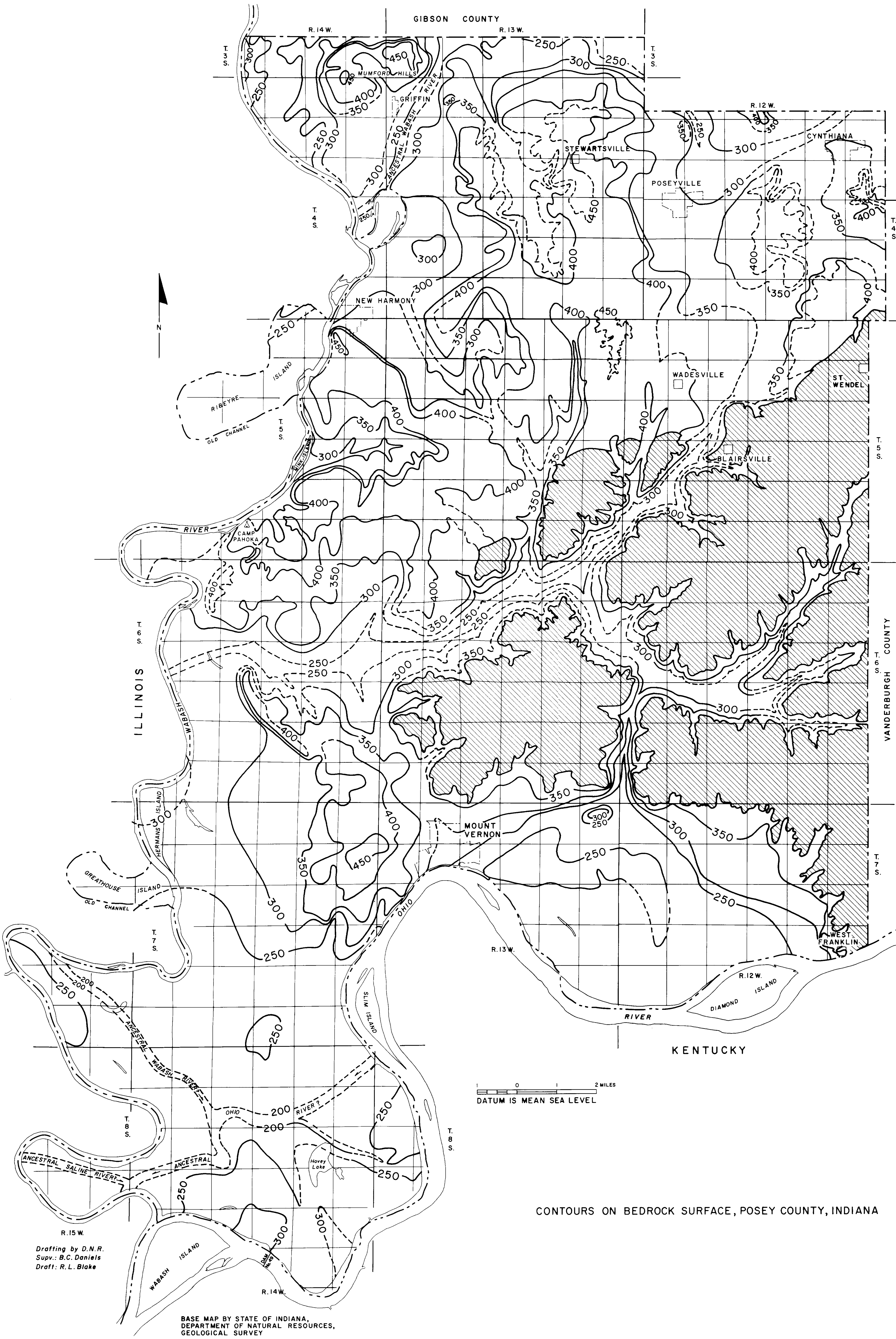
WELL YIELDS AND TOP ELEVATION OF THE INGLEFIELD SANDSTONE AQUIFER, POSEY COUNTY, INDIANA

Drafting by D.N.R.
Supv.: B.C. Daniels
Draft: R.L. Blake

BASE MAP BY STATE OF INDIANA, DEPARTMENT OF NATURAL RESOURCES, GEOLOGICAL SURVEY

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



EXPLANATION

BEDROCK COVERED WITH THIN LOESS DEPOSITS. NOT CONTOURED

250

Bedrock Contour

ELEVATION OF BEDROCK SURFACE. DASHED WHERE APPROXIMATE. CONTOUR INTERVAL 50 FEET. DATUM IS MEAN SEA LEVEL

CONTOURS ON BEDROCK SURFACE, POSEY COUNTY, INDIANA

Drafting by D.N.R.
Supv.: B.C. Daniels
Draft: R.L. Blake

BASE MAP BY STATE OF INDIANA, DEPARTMENT OF NATURAL RESOURCES, GEOLOGICAL SURVEY