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GEOHYDROLOGY AND GROUND-WATER POTENTIAL OF PORTER AND LAPORTE COUNTIES, INDIANA

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GEOHYDROLOGY AND GROUND-WATER POTENTIAL OF

PORTER AND LAPORTE COUNTIES, INDIANA

By J. S. Rosenshein and J. D Hunn

ABSTRACT

The principal sources of ground water in Porter and La Porte Counties are the unconsolidated rocks of Quaternary age. These rocks form a single but complex hydrologic system consisting of four units, that is locally more than 400 feet thick. The potential ground-water yield of the area is estimated to be 900 mgd (million gallons per day), of which about 12 mgd id being pumped.

Unit 4 consists of clay till that contains discontinuous zones of sand and gravel. These zones are a potential source of water for small to moderate supplies, particularly in the northern part of Porter County and the northwestern part of La Porte County.

Unit 3, a sand and gravel, is the principal aquifer in the area. This unit is about 15 per cent artesian and about 85 per cent water-table. Recharge is derived from local precipitation. Recharge to the artesian part and in Porter County to much of the water-table part of the aquifer must percolate through the overlying till (unit 2). This recharge is estimated to average 300,000 gpd (gallons per day) per square mile, or about 100 mgd. Recharge to that portion of the water-table part of the aquifer which is exposed at the surface is estimated to average 1.2 mgd per square mile. The potential yield of this part of the aquifer is estimated to be 700 mgd.

Natural discharge from the unit takes place by effluent seepage to streams, evapotranspiration, upward leakage through the overlying till, and downward movement to the underlying rock units. An estimated 38,000 million gallons was discharged by evapotranspiration from the water-table part during the 1960 growing season. Pumpage from unit 3 is about 9.3 mgd, or about 78 per cent of the ground water pumped.

Unit 2, a silt till, is the confirming layer for the artesian part of the principal aquifer. The unit may have as much as 2 million acre-feet of water in storage. Production from the unit is limited to relatively thin, discontinuous, intertill sand and gravel zones and is not a significant part of the ground water pumped in the area.

Unit 1, a sand with local zones of sand and gravel, is chiefly a water-table aquifer. Recharge is derived from local precipitation and probably amounts to less than 600,000 gpd per square mile. Ditching and industrial and urban development during the past 60 years have decreased recharge. Natural discharge takes place by evapotranspiration and by effluent seepage to streams, ditches, and Lake Michigan. Estimated pumpage from the unit is 1.6 mgd, or about 13 per cent of the ground water pumped. Under present hydrologic conditions the potential yield of the unit may be as much as 60 to 70 mgd. Development of this potential may be impeded by the unit's susceptibility to contamination.

INTRODUCTION

Purpose and Scope

A ground-water investigation is currently in progress in northwestern Indiana by the U. S, Geological Survey, in cooperation with the Division of Water, Indiana Department of Natural Resources, as part of the state-wide investigation of the ground-water resources of Indiana. The purpose of this report is to define the aquifers and determine their geohydrology, to estimate their current and potential yields, and to identify the problems relating to their development. This report is the second in a series of interpretive reports scheduled for the area. It presents an evaluation of the ground-water resources of Porter and LaPorte Counties and provides information to serve as a guide for sound development and responsible management of the ground-water resources of these counties.

Porter and LaPorte Counties (fig.1) are adjacent to the heavily industrialized area of Lake County. The growth of industry and population should increase sharply within the next few decades as a result of the general economic development of the Great Lakes region. Increased growth has already taken place in the northern part of Porter County with the recent construction of a steel plant. The eventual construction of an additional steel plant and a deep-water port in the area should also greatly spur economic development and population growth. Because of these factors the demand for water for industrial, urban, and rural nonfarm use will increase. The available ground-water resources in this area could supply much of this demand.

Conclusions

The principal sources of ground water in Porter and LaPorte Counties are the unconsolidated rocks of Quaternary age. The underlying bedrock is only a minor source. The unconsolidated rocks form a single but complex hydrologic system composed of four units. This system has a potential yield of 900 mgd, (million gallons per day) of which about 12 mgd or about one per cent is currently being withdrawn. Although the available ground water should be more than adequate to satisfy the needs of the counties for the next few decades, the increased demands will produce hydrologic problems such as those of contamination, drainage and well spacing which are common to highly urbanized areas. Therefore, in order to tap a major part of the potential yield, sound practices of development and responsible management of water resources will be required.

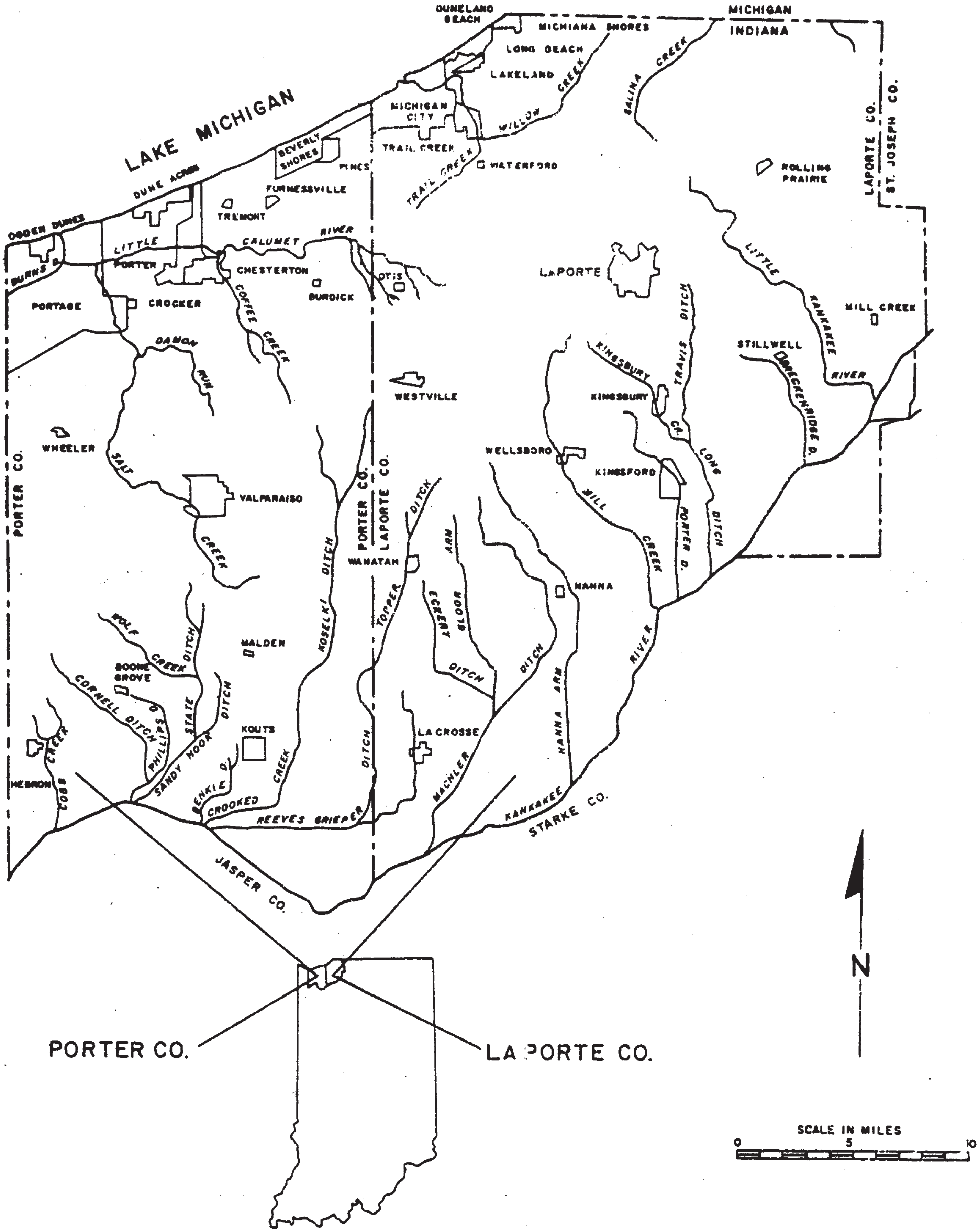

Fig. I Map of Indiana showing the area covered by this report.

Well-Numbering System

Each well referred to in this report is assigned a number that indicates its location according to the official rectangular public-land survey. A comprehensive description of this well-numbering system is given for Porter County by Rosenshein (1962a, p. 4), and for LaPorte County by Rosenshein and Hunn (1962, p. 4).

Acknowledgments

The authors thank all persons who contributed time, information, and assistance during the preparation of this report. The investigation was under the immediate supervision of C. M. Roberts, district geologist of the Ground Water Branch, U. S. Geological Survey. R. J. Vig, formerly of the U. S. Geological Survey, assisted in the geologic reconnaissance. Well drillers supplied logs and other information.

The authors also thank the following government agencies which provided information: Geological Survey and Divisions of Oil and Gas and Water, Indiana Department of Natural Resources; Indiana State Highway Department; Indiana Toll Road Commission; and Indiana State Board of Health.

This report has been prepared as a part of the statewide investigation of the ground-water resources of Indiana, conducted by the U. S. Geological Survey in cooperation with the Indiana Department of Natural Resources, Division of Water.

CLIMATE AND GEOGRAPHY

Porter and LaPorte counties have a climate characteristic of the northern midcontinent region. The average annual precipitation is about 39 inches at Valparaiso and about 50 inches at LaPorte. The average annual air temperature is about 50° F. at both Valparaiso and LaPorte.

The Valparaiso morainal system is the chief topographic feature of the area. It extends from southwest to northeast across the two counties. A principal drainage divide follows the crest of this morainal system and separates the St. Lawrence River basin from the Mississippi River basin. This divide has been altered somewhat by ditching. The maps in this report show the drainage pattern of the principal streams and ditches. Points of highest elevation are in the morainal system in LaPorte County. The lowest elevation in the two counties is the shore line of Lake Michigan. Maximum relief is about 370 feet.

GEOHYDROLOGY OF THE PRINCIPAL WATER-BEARING UNITS

General Aspects

The principal sources of ground water occur in the unconsolidated rocks of Quaternary age, which are locally more than 400 feet thick and were deposited chiefly as a result of glaciation during Pleistocene time. These rocks form a single but complex hydrologic system from which about 12 mgd is currently being withdrawn.

The geology of the unconsolidated rocks is described to some extent by Blatchley (1897) and Leverett and Taylor (1915). The soils formed on these rocks have been mapped by Bushnell and Barrett (1918) and Ulrich, Leighty, and Shearin (1944). Generalized descriptions of the ground-water resources of these rocks are published in reports by Leverett (1899) and Harrell (1935). A preliminary evaluation of the ground-water resources of Porter County is published in a report by Rosenshein (1962a) and that of La Porte County in a report by Rosenshein and Hunn (1962). Rosenshein (1962b) subdivided the rocks into the four lithologic units used in this report. The units are discussed in ascending order. The stratigraphy, character and distribution, and geohydrologic properties of the units are summarized in table 1. The areal extent of those units that are exposed at the surface is shown on plate 1.

The underlying dolomite, dolomitic limestone, and shale of Devonian and Mississippian ages are potential sources of only small quantities of water (Rosenshein and Hunn, 1965) of uncertain quality. The underlying Ordovician and Silurian rocks are not used as a source of supply in Porter and La Porte Counties and the water they contain generally has more than 5,000 ppm (parts per million) dissolved solids (Rosenshein, 1962a, p. 6; Rosenshein and Hunn, 1962, p. 6).

Unit 4

Water-bearing characteristics.--This unit is a clay till that contains discontinuous zones of sand and gravel. The till underlies about 80 percent of the area. The vertical permeability (definition, p. 20) of the till is probably similar to that estimated by Rosenshein (1963 p. 15) for that part of the same unit underlying Lake County--0.003 gpd (gallons per day) per square foot. The porosity (definition, p. 20) of the till may be as much as 30 to 40 percent (Rosenshein and Hunn, 1965), and the unit may have as much as 12 million acre-feet of water in storage.

Development and potential.--The intertill sand and gravel zones are used locally as a source of water. Wells tapping these zones discharge an estimated 0.7 mgd, or about six percent of the ground water used in the counties. Of this amount 0.6 mgd is pumped for domestic and farm use and 0.1 mgd for industrial and commercial use. Wells tapping these zones have been reported to flow from 10 to as much as 270 gpm (gallons per minute) with water levels rising from several feet to more than 30 feet above the land surface. The permeability of these zones ranges from less than 100 to about 800 gpd per square foot. Locally the sand and gravel may be as much as 50 feet thick. The potential of these zones for development is limited, however, by their restricted area extent and by the small vertical permeability of the enclosing till which largely determines the rate of recharge. Recharge is derived chiefly from local precipitation that percolates downward through the overlying units. Some recharge may be derived from the underlying bedrock. Highly mineralized water in some of the intertill sand and gravel zones may be caused by recharge from this source. Fluctuations of water levels in two observation wells that tap these intertill zones are shown on figure 2. Available water analyses are summarized on table 2, p. 12.

Table 1.--Stratigraphic section and summary of water-bearing properties of rocks of Quaternary age, Porter and La Porte Counties, Indiana

System	Series	Strati-graphic unit	Thickness (feet)		Character and distribution	Geohydrologic properties and significance	Remarks
			Range	Average			
Quaternary	Recent and Pleistocene	Unit 1	0-125+	----	Sand, generally fine to medium, somewhat silty, slightly to moderately calcareous, grains generally subrounded; interbedded with zones of beach gravel, silt, and clay; locally organically rich; contains small areas of relatively thick, thinly laminated silt and clay; underlies about 125 square miles of northern part of area.	Second most utilized aquifer in the area; potential source of water supplies requiring yields of less than 50 to more than 500 gpm; contributes to base flow of streams. Estimate of average hydraulic properties: permeability, about 450 gpd per square foot; coefficient of storage, about 0.12.	Geohydrology and topographic expression modified as result of industrial and urban growth in northern part of county.
		Unit 2	1-150+	40	Till; silt, clayey and sandy, grading into sandy, silty clay along western edge of area; moderately to highly calcareous, pebbly, and cobbly; generally olive-gray in lower part, yellowish-gray to pale- to dark-yellowish-gray in upper part; contains discontinuous lenses of sand and gravel of small areal extent; underlies about 350 square miles of area.	Discontinuous sand and gravel lenses utilized locally as a source of water for some domestic and farm supplies; mantles artesian and water-table parts of unit 3; contributes to base flow of streams; locally forms spring horizons where intertill sand and gravel crop out and at contact of unit with overlying unit 1.	Forms dissected ground moraine and terminal moraines; hydrology altered by drainage of upper part of unit.
		Unit 3	0-230	100	Sand, generally medium to coarse, somewhat pebbly, silty and clayey, calcareous, and sand and gravel; grains subrounded to rounded; composed of fragments of shale, quartz, dolomite, limestone, and igneous and metamorphic rocks; locally contains thick clays of limited areal extent; underlies about 880 square miles of area.	Principal aquifer; potential source of water supplies requiring yields of less than 50 to more than 3,000 gpm; locally forms spring horizons; contributes to base flow of streams. Estimated average permeability; Porter County - 600 gpd per square foot, La Porte County - 800 gpd per square foot. Estimated average coefficient of storage; 0.003 for artesian part, 0.12 for water-table part.	
		Unit 4	0-230	65	Till; clay, silty, sandy, pebbly, slightly to moderately calcareous, locally hard and compact, olive-gray to greenish-gray; contains some relatively thin, discontinuous, intertill sand and gravel zones in northern part of area; underlies about 845 square miles of area; not exposed at the surface.	Intertill sand and gravel zones utilized locally as source of water by some domestic and farm supplies.	

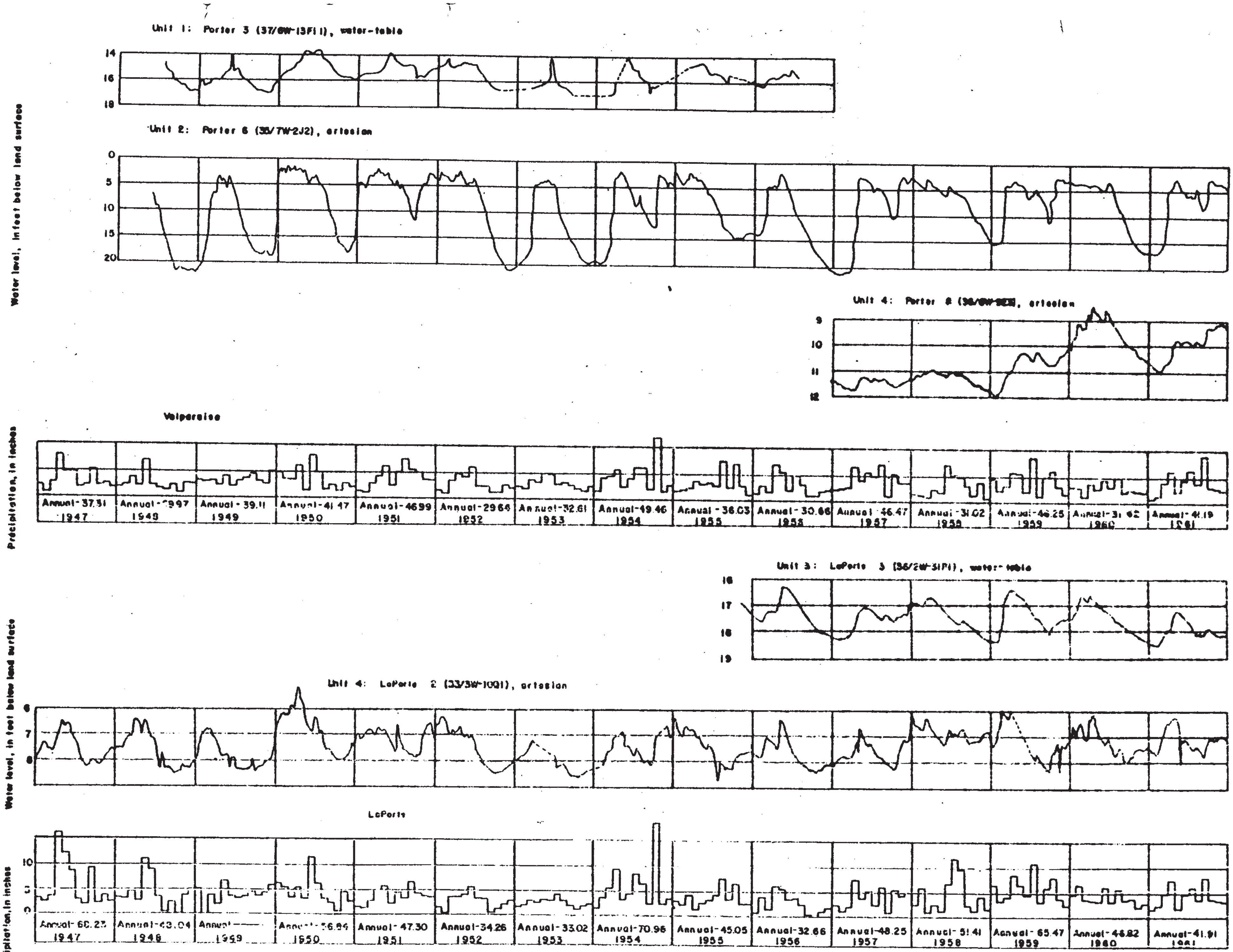

FIGURE 2.--Fluctuations of water levels in observation wells and monthly precipitation in Porter and LaPorte Counties, Indiana

The table below summarizes the water-bearing properties

Well	Estimated coefficient of transmissibility (gpd per foot)	Thickness of aquifer penetrated(ft)	Estimated coefficient of permeability (gpd per square foot)
33/3W-10Q1	1,800	21	90
35/1W-31E1	13,300	44	300
37/4W-4N1	6,600	42	160
5H1	27,500	58	470
7B1	4,400	10	440
38/4W-26A1	8,100	15	540
36B1	1,100	8	140
36B2	7,900	10	790
36P1	13,600	25	540

of the sand and gravel zones in unit 4. The information in this table indicates the feasibility of exploring the thicker parts of the unit as a potential source for small to moderate water supplies, particularly in the northern quarter of Porter County and northern and western quarters of La Porte County.

Unit 3

Water-bearing characteristics

Unit 3 consists chiefly of sand and gravel (table 1) that locally contains thick zones of gravel, especially in La Porte County. This unit forms the principal aquifer of the area and contains an artesian and a water-table part. The artesian part of the aquifer occurs principally in the western half of Porter County, and extends in a narrow band along the northern edge of the unit in the rest of the area.

The permeability of the unit ranges from less than 100 to more than 2,000 gpd per square foot and is estimated to average 600 gpd per square foot in Porter County and 800 gpd per square foot in La Porte County. The coefficient of transmissibility (definition, p. 20) ranges from less than 10,000 to more than 150,000 gpd per foot. The unit has an estimated regional transmissibility of 45,000 gpd per foot in Porter County and 65,000 gpd per foot in La Porte County.

Rosenshein and Hunn (1965) have estimated that in an adjacent area the coefficient of storage (definition, p. 20) for the artesian part of the aquifer averages 0.003 and for the water-table part 0.12. These estimates should also be sufficiently accurate to evaluate regional characteristics of the aquifer in Porter and La Porte Counties.

Recharge and discharge

Fluctuations of the water level in the aquifer caused by seasonal variations of recharge and discharge are shown on figure 2. Recharge to the unit is derived from local precipitation as shown by the configuration of the piezometric surface (fig. 3).

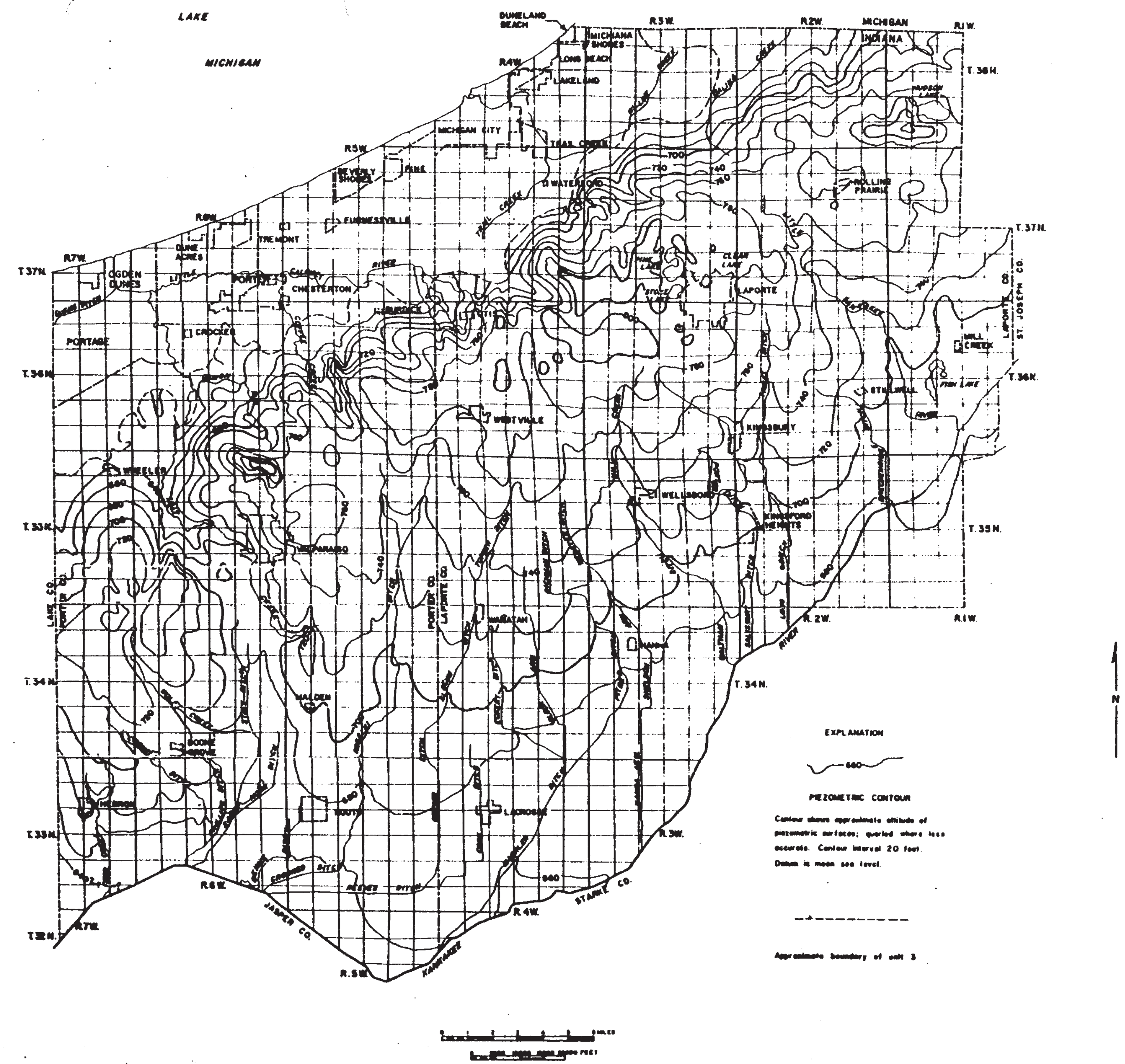

FIGURE 3.--Map showing configuration of the piezometric surface of unit 3, Porter and Laporte Counties, January 1960

Recharge to the artesian part of the aquifer, and in Porter County to much of the water-table part, must take place by slow percolation through the overlying till (unit 2, p. 15). This recharge is estimated to average 300,000 gpd per square mile.

The water-table part of the unit exposed at the land surface (plate 1) is recharged by direct percolation of precipitation through the upper part of the unit. This recharge is estimated to average 1.2 mgd per square mile.

Natural discharge from the artesian part occurs along the northern edge of the unit as upward leakage through the overlying till. Many of the numerous springs, seeps, and marshes that occur along Salt and Coffee Creeks in Porter County and in the northwestern part of La Porte County are partly the result of this upward discharge. Some discharge by evapotranspiration takes place locally where the confining layer is less than 20 feet thick. However, the quantity discharged by this means must be relatively small. Discharge to streams must also be relatively small and can take place only locally where the head in the artesian part exceeds that in the overlying till. Some discharge from both the artesian and the water-table parts also occurs as downward movement to the underlying rock units.

Natural discharge from the water-table part occurs chiefly as effluent seepage (definition, p. 20) to the ditches and streams that penetrate the unit and as direct evapotranspiration. Effluent seepage constitutes most of the discharge in the non-growing season and only a small part in the growing season. The significance of the streams and ditches as points of discharge from the unit is indicated by their effects upon the configuration of the piezometric surface (fig. 3). This discharge produces most of the stream flow from July through September.

Discharge by evapotranspiration from the water-table part in the growing season occurs chiefly where the water level is less than 20 feet below the land surface. Although no detailed evaluation of this discharge has been made, it should be similar per square mile to that estimated by Rosenshein and Hunn (1965, p. 24) for the water-table part of this unit in Lake County, and was probably about 38,000 million gallons or about 250 mgd during the 1960 growing season.

Wells tapping unit 3 discharge an estimated 9.3 mgd, accounting for about 78 percent of the ground water used in the counties. It is pumped mostly from the water-table part of the aquifer. Of this amount 2.9 mgd is pumped for domestic and farm use, 5.3 mgd for municipal use, and 1.1 mgd for industrial and commercial use. Of the amount pumped by communities for municipal use, Hebron pumps 0.1 mgd, Kingford Heights 0.1 mgd, Kouts 0.1 mgd, La Crosse 0.03 mgd, La Porte 3.3 mgd, Valparaiso 1.6 mgd, and Westville 0.1 mgd.

Quality of water

The principal constituents of the water in unit 3 are bicarbonate, calcium, and magnesium, but locally sulfate is a major constituent. Concentrations of the dissolved constituents and their significance are summarized in tables 2 and 3.

Geohydrologic control.--Much of the bicarbonate content of the water in the artesian part of this aquifer is dissolved from unit 2, a silt till which contains finely-divided calcareous particles. These particles expose a relatively large surface area per unit volume of material to react with the water. As a result, water in the artesian part of unit 3 generally contains high concentrations of bicarbonate, calcium, and magnesium derived from unit 2. Variation of bicarbonate content in the artesian part of the aquifer may be caused by differences from place to place in the amount of calcareous material in the overlying till. Percolating ground water has slowly dissolved this material since deposition of the till, and the amount of calcareous material dissolved depends on the amount of water that has passed through the till. Wherever much of the calcareous material in the till has been dissolved in the past, the concentration of bicarbonate in the water presently in the underlying aquifer should be relatively low. The factors controlling the amount of water passing through the till in a given amount of time are the thickness and permeability of the till and the difference in hydraulic head between the till and the underlying aquifer.

Bicarbonate concentration (pl. 2) is generally highest in the aquifer where the till is thickest, and generally decreases from west to east as the till becomes thinner and more permeable. Calcium and magnesium in this aquifer are associated with sulfate as well as with bicarbonate. Thickness of till apparently is not related to the concentration of sulfate, which may be derived from several sources. As a result the calcium and magnesium concentrations are not as directly related to thickness of till as is the concentration of bicarbonate. Sulfate, iron, and chloride concentrations are often relatively high in poorly drained areas where organic decay takes place.

Development and potential

Plate 3 shows estimated transmissibilities and relates these to specific capacities and possible yields obtainable from properly constructed wells. The specific capacities are those to be expected for a 12-inch diameter well after pumping for one day. The yield for a specified drawdown will be greater for a larger diameter well than for a smaller diameter well and will decrease with time of pumping. Because the aquifer is chiefly water table, the possible yields for most of the area are estimated from the specific capacities using a drawdown limited to one half the saturated thickness of the unit. Owing to these and other limitations, such as well efficiency, plate 3 gives only an approximation of the capability of the aquifer as a source of water.

Much of the unit is a possible source of water for users requiring 500 gpm or more. However, without proper well construction, actual yields may be considerably less than those indicated on plate 3. Proper construction requires careful choice of well diameter, screen diameter and length, and slot size of screen openings. Guide lines to aid in proper selection of the above factors are given by Walton (1963, p. 28-30). Wells tapping the unit require development to remove the clay, silt, and very fine sand from the immediate vicinity of the screen.

The depth to the water-bearing zone in unit 3 can be estimated from plate 4. This information may then be used in conjunction with information on plate 3 to estimate the depth to which a well must be drilled in order to develop a water supply. For supplies requiring maximum possible yield, the full thickness of the aquifer should be penetrated and as much screened as is economically and

Table 2.--Summary of water quality in the rocks of Quaternary age,

Porter and La Porte Counties, Indiana

Independent laboratories: Dearborn Chemical Co., Brookside Farms Laboratory Association, Industrial Chemicals, Inc., and Pennsylvania Railroad.
Partial analyses determined in the field office of the U. S. Geological Survey.
Total dissolved solids for all partial analyses estimated by the formula: $HCO_3 - 1/6\ HCO_3 + SO_4 + 0.4\ SO_4 + Cl + 0.6\ Cl$ (Collins, p. 260, 1928).
Constituents and properties expressed as parts per million (ppm).
Mode: most common value.

Unit	Source of Analysis	Number of samples
1	Partial analyses	52
	U. S. Geological Survey	1
	Indiana State Board of Health	1
2	Partial analyses	25
3	Partial analyses	418
	U. S. Geological Survey	7
	Indiana State Board of Health	11
	Independent laboratories	7
4	Partial analyses	58
	U. S. Geological Survey	5
	Indiana State Board of Health	8
	Independent laboratories	6

Unit		Iron (Fe)	Total alkalinity as Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Total Dissolved Solids	Hardness as Calcium Carbonate ($CaCO_3$)
1	Max.	7.5	449	180	108	653	401
	Min.	<.1	37	15	<4	120	48
	Mode	.3	152	54	9	257	136
	Avg.	.8	212	63	13	292	206
2	Max.	2.0	686	105	28	565	580
	Min.	.1	163	5	<4	226	172
	Mode	1.3	325	25	9	327	254
	Avg.	1.1	342	43	10	362	276
3	Max.	>7.5	610	545	328	1,050	792
	Min.	<.1	83	5	<4	114	72
	Mode	.2	277	61	9	352	232
	Avg.	1.3	302	93	15	391	295
4	Max.	3.5	590	430	948	1,680	832
	Min.	.1	61	1	<4	221	68
	Mode	.8	384	8	9	373	229
	Avg.	1.0	351	45	13	481	271

Table 3.--Significance of selected dissolved mineral constituents and properties of ground water [a]

Constituent or property	Significance
Iron (Fe)----------------	Oxidizes to reddish-brown sediment upon exposure to air. More than about 0.3 ppm stains laundry and utensils reddish-brown. More than 0.5 to 1.0 ppm imparts objectionable taste to water. Larger quantities favor growth of iron bacteria. Objectionable for food processing, textile processing, beverages, ice manufacturing, brewing, and other purposes.
Calcium (Ca) and Magnesium (Mg)--------------------	Cause most of the hardness and scale-forming properties of water; soap consuming. See hardness. Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and Potassium (K)--------------------	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium ratio may limit the use of water for irrigation.
Bicarbonate (HCO_3)--------	Bicarbonate in conjunction with carbonate (CO_3) produces alkalinity. Bicarbonate of calcium and magnesium decomposes in steam boilers and hot water facilities to form scale and release corrosive carbon dioxide gas.
Sulfate (SO_4)------------	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. Public Health Service drinking-water standards [b] recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)------------	Gives salty taste to drinking water when present in large amount in combination with sodium. Increases the corrosiveness of water when present in large amounts. Public Health Service drinking-water standards [b] recommend that the chloride content should not exceed 250 ppm.
Dissolved solids----------	Public Health Service drinking-water standards [b] recommend that the dissolved solids should not exceed 500 ppm. Waters containing more than 1,000 ppm of dissolved solids are unsuitable for many purposes.

Table 3.--Significance of selected dissolved mineral constituents and properties of ground water [a/]--cont.

Constituent or property	Significance
Hardness as $CaCO_3$ (Calcium and magnesium)----	Hard water increases amount of soap needed to make lather. Forms scale in boilers, water heaters, and pipes. Leaves curdy film on bathtubs and other fixtures and on materials washed in the water.

geohydrologically practicable. For domestic or farm supplies only the upper 10 to 15 feet need be penetrated and a short, small-diameter screen used.

The quantity of water potentially available for development from unit 3 depends on its rate of recharge. In part of the area this rate is controlled to a large extent by the geohydrologic properties of the overlying till, unit 2. Recharge to this part of the aquifer is currently estimated to be 100 mgd. Rosenshein (1963) has shown that the rate of recharge to the artesian part will increase as the aquifer is extensively developed. However, as the artesian part makes up only about 15 percent, or about 120 square miles, of the aquifer underlying the area, a significant increase in the rate of recharge will increase the potential of the unit by only a relatively small amount.

The potential yield of the water-table part that is exposed at the surface is estimated to be 700 mgd. Development of water supplies in this part is complicated by several factors. The saturated thickness varies seasonally by about two to five feet and locally is relatively thin. Because pumping from the water-table part results in an actual dewatering of the unit, the transmissibility decreases as water is withdrawn. Estimates of the specific capacities and possible yields (pl. 3) of this part of the aquifer have been adjusted for these factors.

The current pumpage is only about one percent of the water potentially available for use from the aquifer. The small-diameter tubular wells currently used in the area are capable of developing only a very small part of this potential. However, where economically feasible, exceptionally large-diameter vertical wells and horizontal infiltration galleries and collectors could develop a much greater quantity, particularly where the transmissibilities exceed 10,000 gpd per foot.

The use of land and the susceptibility of the aquifer to contamination are factors that also complicate possible development.. The land in much of the area is used chiefly for farming. As a result, it is continually being ditched--a practice that decreases the average saturated thickness, thereby permanently dewatering a part of the aquifer and decreasing its potential for development. Because the aquifer is readily susceptible to contamination, the user should guard against waste-disposal methods that permit downward leakage of undesirable waste products.

a/ Adapted in part from Palmquist and Hall (1961), p. 34-36.
b/ U. S. Public Health Service (1962).

Unit 2

Water-bearing characteristics

Unit 2 consists chiefly of silt till which mantles much of unit 3. The rate of recharge to the underlying aquifer depends in part on the vertical permeability of unit 2. Rosenshein (1963) estimated that the vertical permeability of the unit averages 0.007 gpd per square foot in Lake County. Although no calculations have been made for Porter and La Porte Counties, the till in this area is coarser grained and the vertical permeability is probably three to four times that estimated by Rosenshein for Lake County.

The porosity of the unit may be about 40 percent and its saturated thickness may average 20 feet. Based on these estimates the unit may have as much as 2 million acre-feet of water in storage. However, because of its low permeability, direct production from the unit is limited to relatively thin, discontinuous intertill sand and gravel zones. Pumpage from these zones is primarily for domestic and farm supplies. Total discharge of wells tapping these zones is estimated to be 0.3 mgd, or about three percent of the ground water pumped in the area. Available water analyses are summarized on table 2, p. 12.

<u>Hydrologic aspects.</u>--Unit 2 is the most extensive unit exposed at the surface in Porter County and the second most extensive in La Porte County (pl. 1). The flow of many streams and ditches is determined to a significant extent by the unit's ground-water discharge and run-off characteristics. Although this discharge has not been calculated, it is considerably less than that estimated by Rosenshein and Hunn (1965) for the unit in Lake County, where the unit covers three-quarters of the land surface.

Locally the unit is overlain in La Porte County by relatively thick deposits of windblown sand of small areal extent. Intermittent springs form at the contact of this sand and the underlying till. These springs are used locally for stock supplies.

Some perennial springs and numerous seeps occur in both counties where intertill sand and gravel zones crop out at the surface. A few of these springs are used for domestic purposes. Some wells tapping these sand and gravel zones flow, and yields as great as 60 gpm have been measured.

The hydrology of the unit has been altered to some extent within the last 60 years. Since the early 1900's, agricultural development and the increase in the rural nonfarm population have required ditching of the unit for drainage purposes. The ditching has resulted locally in: (1) reversal of the direction of flow of a few of the original streams, (2) some dewatering of the upper part of the unit, (3) more rapid runoff. These effects will be intensified with continued growth of the county's rural non-farm population.

Unit 1

Water-bearing characteristics

Unit 1 consists chiefly of sand that locally contains zones of sand and gravel. The transmissibility of the unit ranges from less than 5,000 to more than 50,000 gpd per foot. The permeability ranges from about 150 to more than 1,000 gpd per square foot and averages about 450 gpd per square foot.

The coefficient of storage of the unit in Lake County is estimated to be 0.12 (Rosenshein and Hunn, 1965). This estimate should be sufficiently accurate for evaluating regional characteristics of the aquifer.

Recharge and discharge

Fluctuations of the water level in the aquifer owing to seasonal variations in recharge and discharge are shown on figure 2. This figure shows that recharge is derived from local precipitation and is estimated by Rosenshein and Hunn (1965, p. 30) to be less than 600,000 gpd per square mile.

The hydrology of the unit has been altered since the early 1900's by ditching and industrial and urban development. This alteration has changed the natural balance between recharge and discharge. It has increased the natural discharge from the unit and decreased the natural recharge. The changes produced are similar to those described by Rosenshein and Hunn (1965) but are not as extensive.

Natural discharge from the unit occurs chiefly as effluent seepage to streams, ditches, and Lake Michigan and as direct evapotranspiration. The effluent seepage is greatest during the nongrowing season. However, during the spring and summer evapotranspiration constitutes the major part of the discharge. The quantity of water discharged by this process must be considerably greater than that discharged by effluent seepage.

The estimated discharge of wells tapping the unit is 1.6 mgd. This withdrawal accounts for about 13 percent of the ground water pumped in the counties. Of this amount 1.0 mgd is pumped for domestic use, 0.5 mgd for municipal use, and 0.1 mgd for industrial and commercial use. Of the amount pumped for municipal use, Chesterton pumps about 0.5 mgd, Dune Acres about 0.003 mgd, and Duneland Beach about 0.001 mgd.

Development and potential

Figure 4 shows the saturated thickness and possible yields obtainable from wells that tap the aquifer. The transmissibility in a specified area can be estimated by multiplying the saturated thickness by its average permeability.

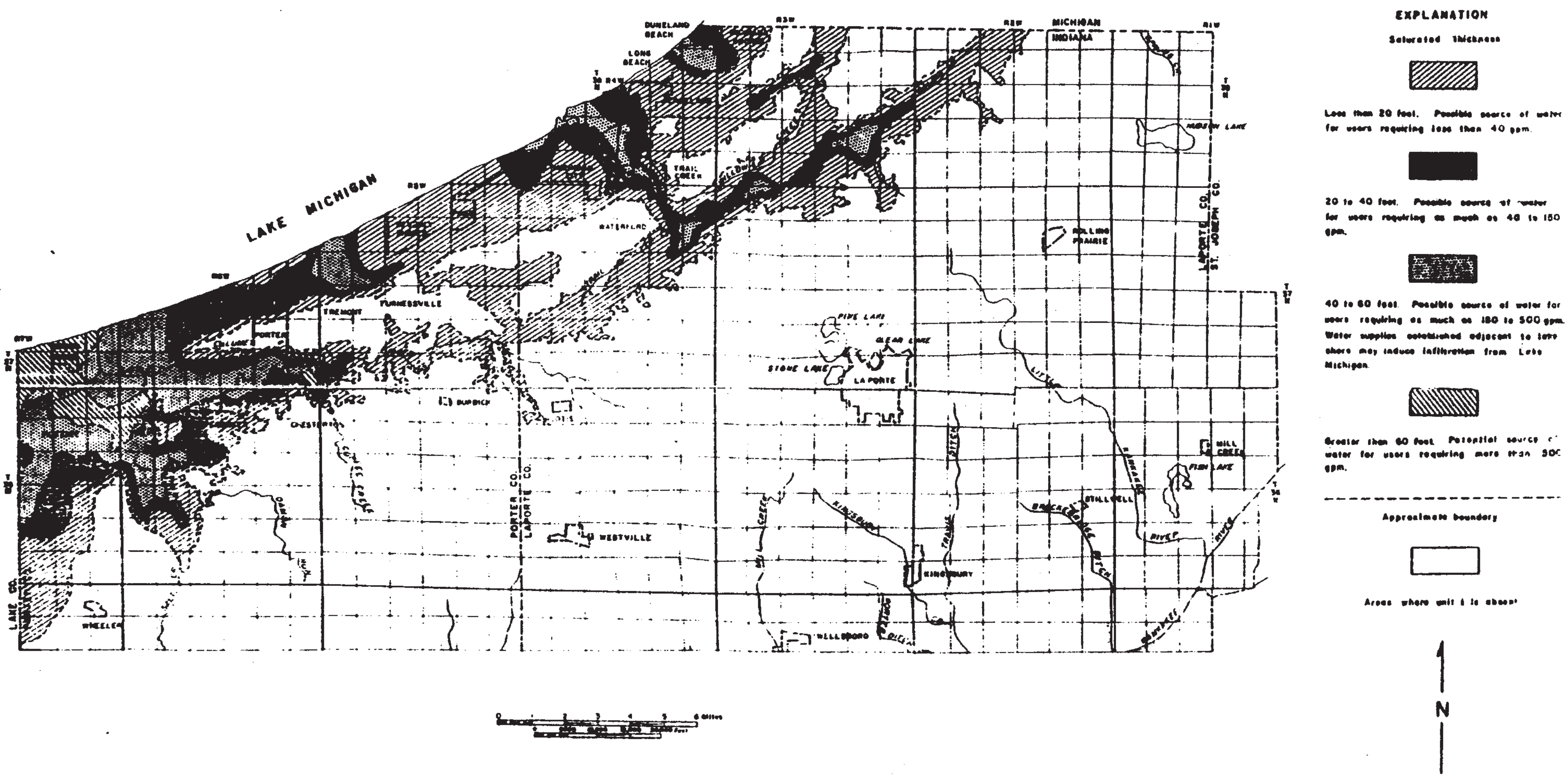

FIGURE 4 – Map showing saturated thickness and possible yields of wells, unit I, Porter and LaPorte counties

Development of the unit is complicated by factors similar to those affecting the water-table part of unit 3 (p. 14). Where the saturated thickness is less than 20 feet the unit will not be extensively developed except possibly for domestic use. To develop even a small part of the unit's potential will require types of wells different from those commonly used. Properly constructed horizontal infiltration galleries and collectors or unusually large-diameter wells could possibly obtain large quantities of water, particularly in the area adjacent to Lake Michigan.

Susceptibility to contamination may impede development of unit 1. Because of the slow movement of water through the aquifer, local areas of concentrated contamination can easily form.

A small part of the potential yield of the aquifer is being utilized. Under present conditions of recharge the potential yield may be as much as 60 to 70 mgd. This potential will decrease somewhat as industrial and urban growth increases.

SUMMARY

General summary:--The principal sources of ground water in Porter and La Porte Counties are the unconsolidated rocks of Quaternary age. The underlying bedrock is only a minor source. The unconsolidated rocks form a single but complex hydrologic system of four units. This system has a potential yield of 900 mgd, of which about 12 mgd or one percent is currently being withdrawn.

Geohydrology of rock units:--Unit 4, a clay till, contains discontinuous zones of sand and gravel that are used locally for domestic and farm supplies. The permeability of these zones ranges from less than 100 to about 800 gpd per square foot. Vertical permeability of the unit is probably about 0.003 gpd per square foot. The unit may have as much as 12 million acre-feet of water in storage.

Unit 3, a sand and gravel, is the principal aquifer underlying the area. Its coefficient of transmissibility ranges from less than 10,000 to more than 150,000 gpd per foot. The unit has an estimated regional transmissibility of 45,000 gpd per foot in Porter County and 65,000 gpd per foot in La Porte County. The regional values of the coefficient of storage are probably about 0.003 for the artesian part and 0.12 for the water-table part. Recharge to the artesian part, and in Porter County to much of the water-table part, must percolate through the overlying till (unit 2). This recharge is about 100 mgd. Extensive development of the artesian part will increase the potential of the unit by only a relatively small amount. Direct recharge to the water-table part is about 1.2 mgd per square mile and the estimated potential yield is 700 mgd. Development of this potential will require types of wells different from those commonly used in the area.

The principal dissolved constituents in the water from unit 3 are calcium, magnesium, and bicarbonate. The concentration of dissolved solids averages about 390 ppm. These constituents in the artesian part are derived mostly from the recharge percolating through unit 2 and their concentrations in the aquifer are controlled to some extent by the thickness of the confining layer.

Unit 2, a silt till, is the confining layer for the artesian part of the principal aquifer. Its vertical permeability is probably about 0.007 gpd per square foot. The unit may have as much as 2 million acre-feet of water in storage. Discontinuous sand and gravel zones within the unit are used locally for domestic and farm supplies. It is the most extensive unit exposed at the surface in Porter County and the second most extensive in La Porte County. The flow of many streams and ditches is influenced by the ground-water discharge and runoff characteristics of the unit. The hydrology of the unit has been altered by ditching during the past 60 years.

Unit 1, a sand with local zones of sand and gravel, is chiefly a water-table aquifer. Its coefficient of transmissibility ranges from less than 5,000 to more than 50,000 gpd per foot. The regional coefficient of storage is about 0.12. The hydrology of the unit has been altered during the past 60 years by industrial and urban development. Under present hydrologic conditions recharge is probably less than 600,000 gpd per square mile. The potential yield may be as much as 60 to 70 mgd. Development of this potential will require types of wells different from those commonly used and may be impeded by the unit's susceptibility to contamination.

GLOSSARY

Hydraulic Coefficients (After Ferris and others, 1962)

Permeability.--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 prevailing temperatures.

Storage.--Volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Transmissibility.--Rate of flow of water, at the prevailing water temperature, in gallons per day, 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.

Miscellaneous Terms

Effluent seepage.--Discharge of ground water to surface bodies of water.

Equivalent per million (epm).--Weight concentration of an ion divided by the combining weight of that ion. (Hem, p. 32).

Porosity.--Volume of pore space expressed as a percentage of the total volume of the rock.

Specific capacity.--Yield of a well in gallons per minute per foot of drawdown.

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STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

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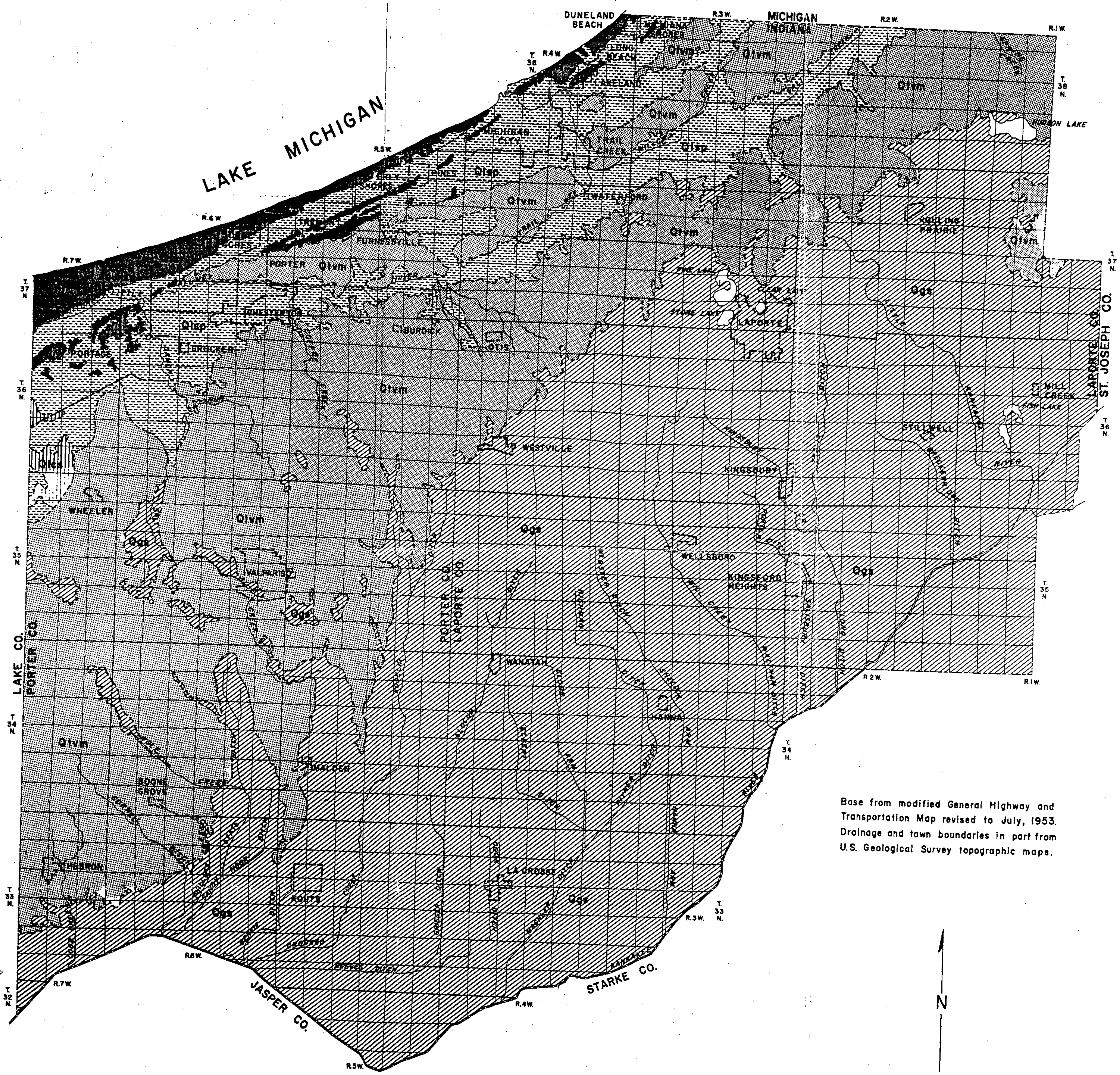

Base from modified General Highway and Transportation Map revised to July, 1953. Drainage and town boundaries in part from U.S. Geological Survey topographic maps.

EXPLANATION

QUATERNARY

Pleistocene to Recent

Qd

Sand, fine to medium, locally coarse, pebbly and organically rich. Forms beach ridges and dunes that represent former strand lines. Includes man-made land along edge of Lake Michigan.

Qlcs

Clay, silty, maroon alternating with layers of tan silt; thinly laminated. Locally contains calcareous concretions and some sand.

UNIT 1
Chiefly glaciolacustrine

Qlsp

Sand, fine to medium, silty; locally sandy, silty clay; organically rich. Forms relatively flat to slightly rolling plains between sand dunes and beach ridges.

UNIT 2
Till

Qlvm

Silt, clayey and sandy, grading into sandy, silty clay along west edge of area; pebbly and cobbly; generally buff to tan or reddish brown in outcrop. Forms dissected ground and terminal moraines. Overlain locally by windblown sand.

UNIT 3
Chiefly glaciofluvial

Qgs

Sand, medium to coarse, somewhat pebbly, silty and clayey, and sand and gravel. Locally interbedded with layers of organically rich silt and clay of relatively small areal extent. Contains small dunes.

GEOLOGIC MAP OF PORTER AND LAPORTE COUNTIES

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

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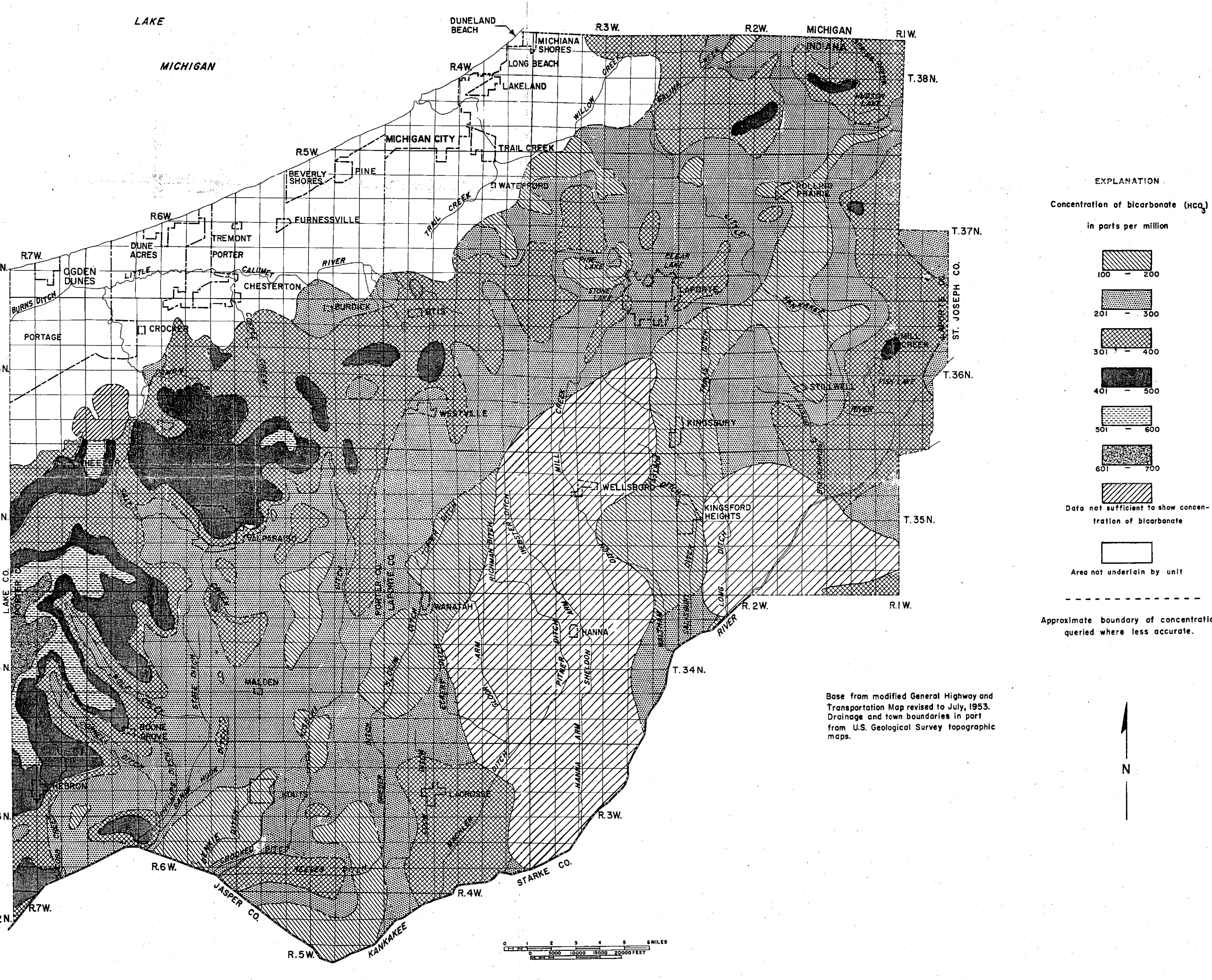

MAP OF PORTER AND LAPORTE COUNTIES, INDIANA, SHOWING DISTRIBUTION OF BICARBONATE (HCO_3) IN WATER OF UNIT 3

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
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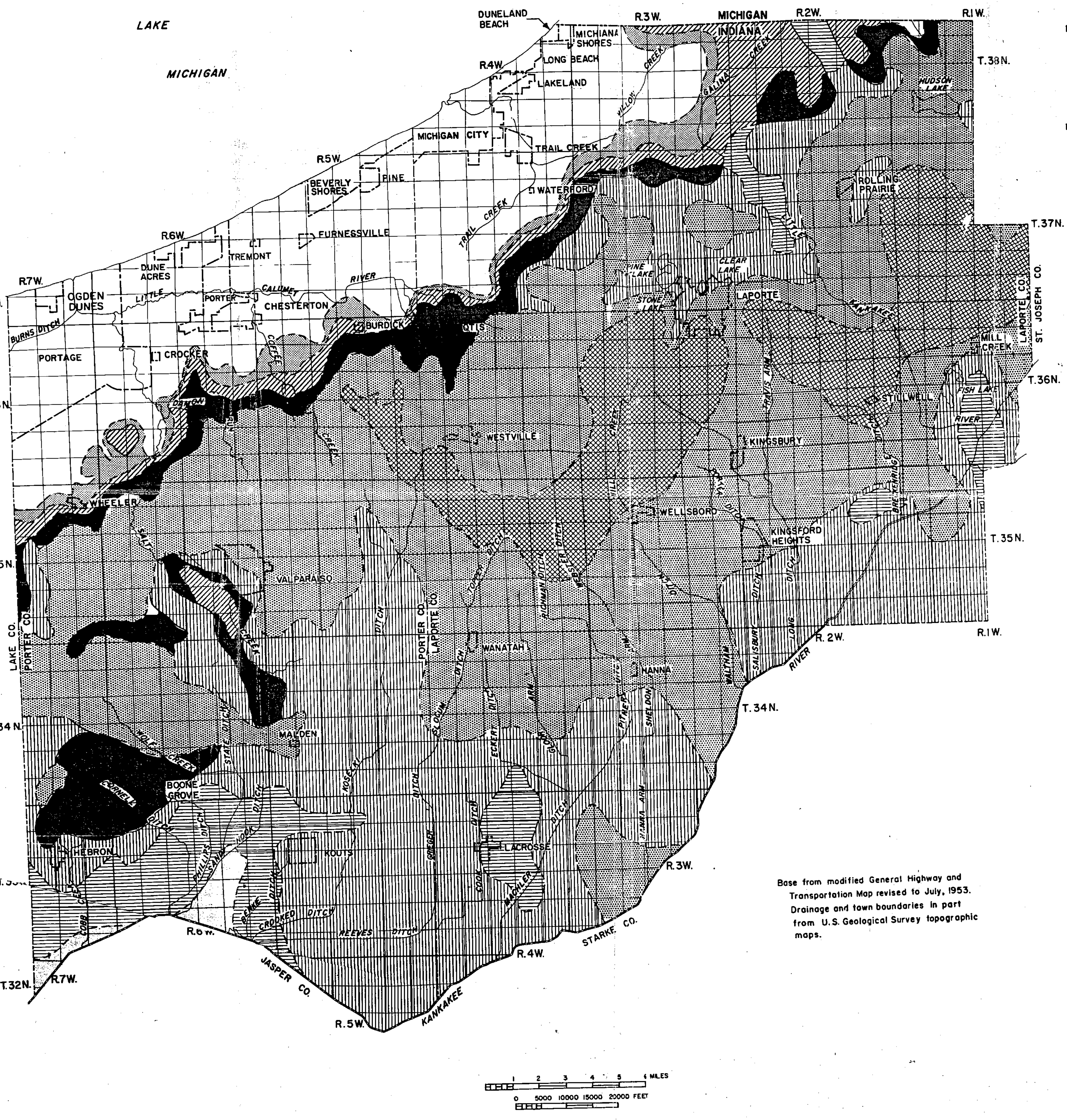
BULLETIN 32 PLATE 3



Base from modified General Highway and Transportation Map revised to July, 1953. Drainage and town boundaries in part from U.S. Geological Survey topographic maps.

EXPLANATION

Water-Table Part

Estimated transmissibilities generally less than 10,000 gpd/ft. Specific capacities of wells estimated to be less than 5 gpm per foot of drawdown. Possible source of water for users requiring less than 25 gpm.

Estimated transmissibilities generally range from 10,000 to 25,000 gpd/ft. Specific capacities of wells estimated to range from 5 to 10 gpm per foot of drawdown. Possible source of water for users requiring as much as 25 to 180 gpm.

Estimated transmissibilities generally range from 25,000 to 50,000 gpd/ft. Specific capacities of wells estimated to range from 10 to 20 gpm per foot of drawdown. Possible source of water for users requiring as much as 180 to 800 gpm.

Estimated transmissibilities generally range from 50,000 to 100,000 gpd/ft. Specific capacities of wells estimated to range from 20 to 40 gpm per foot of drawdown. Possible source of water for users requiring as much as 800 to 3,000 gpm.

Estimated transmissibilities generally greater than 100,000 gpd/ft. Specific capacities of wells estimated to be more than 40 gpm per foot of drawdown. Possible source of water for users requiring more than 3,000 gpm.

Artesian Part

Estimated transmissibilities generally less than 10,000 gpd/ft. Specific capacities of wells estimated to be generally less than 7 gpm per foot of drawdown. Possible source of water for users requiring less than 120 gpm.

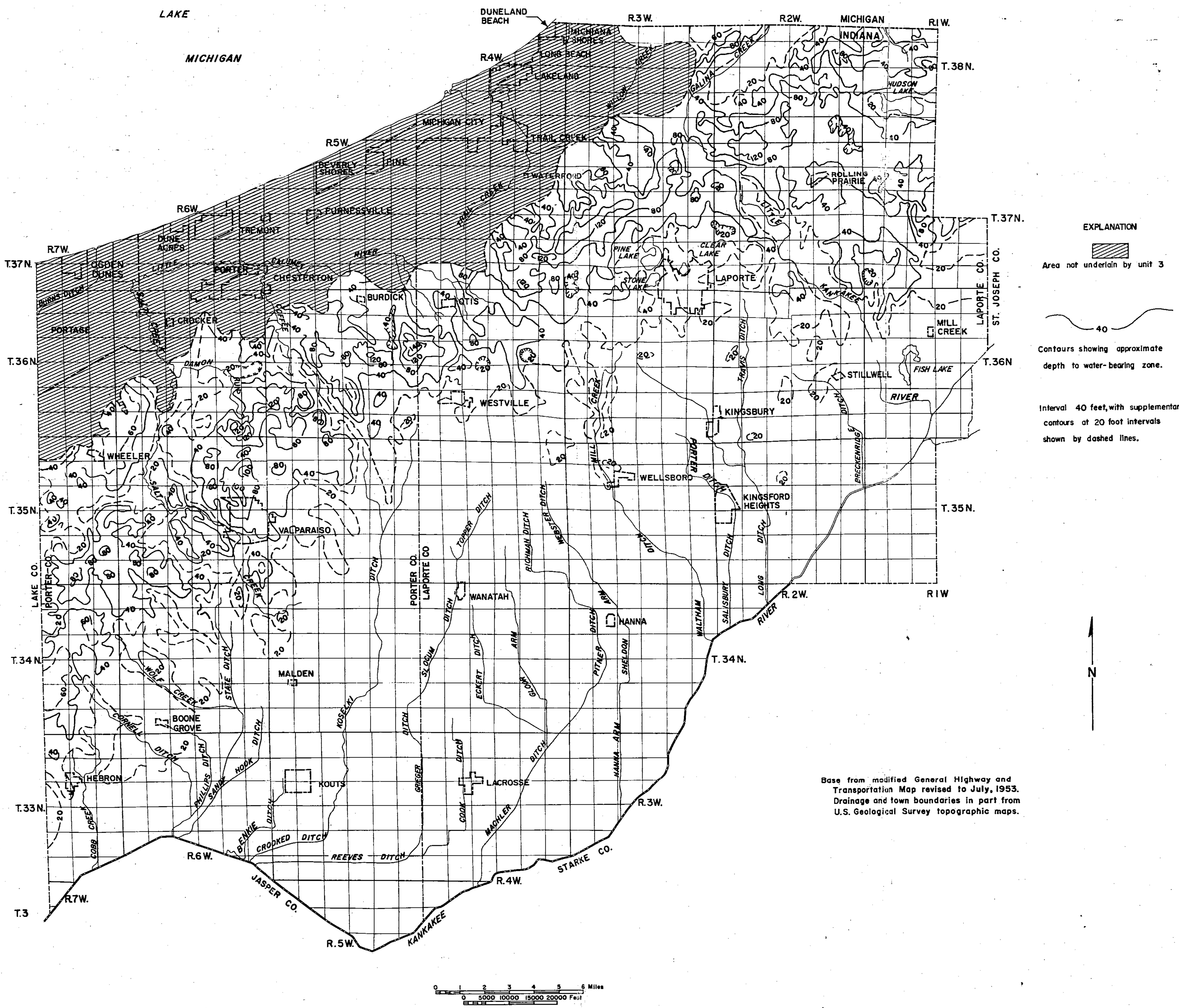
Estimated transmissibilities generally range from 10,000 to 25,000 gpd/ft. Specific capacities of wells estimated to range from 7 to 15 gpm per foot of drawdown. Possible source of water for users requiring as much as 120 to 300 gpm.

Estimated transmissibilities generally range from 25,000 to 50,000 gpd/ft. Specific capacities of wells estimated to range from 15 to 25 gpm per foot of drawdown. Possible source of water for users requiring as much as 300 to more than 1,000 gpm.

Area not underlain by unit 3

Approximate boundary

MAP OF PORTER AND LAPORTE COUNTIES, INDIANA, SHOWING CAPABILITY OF UNIT 3 AS SOURCE OF WATER



MAP OF PORTER AND LA PORTE COUNTIES, INDIANA, SHOWING APPROXIMATE DEPTH TO THE WATER-BEARING ZONE IN UNIT 3