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. [b/] Public Health Service drinking-water standards 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.

Hydrologic aspects.--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.

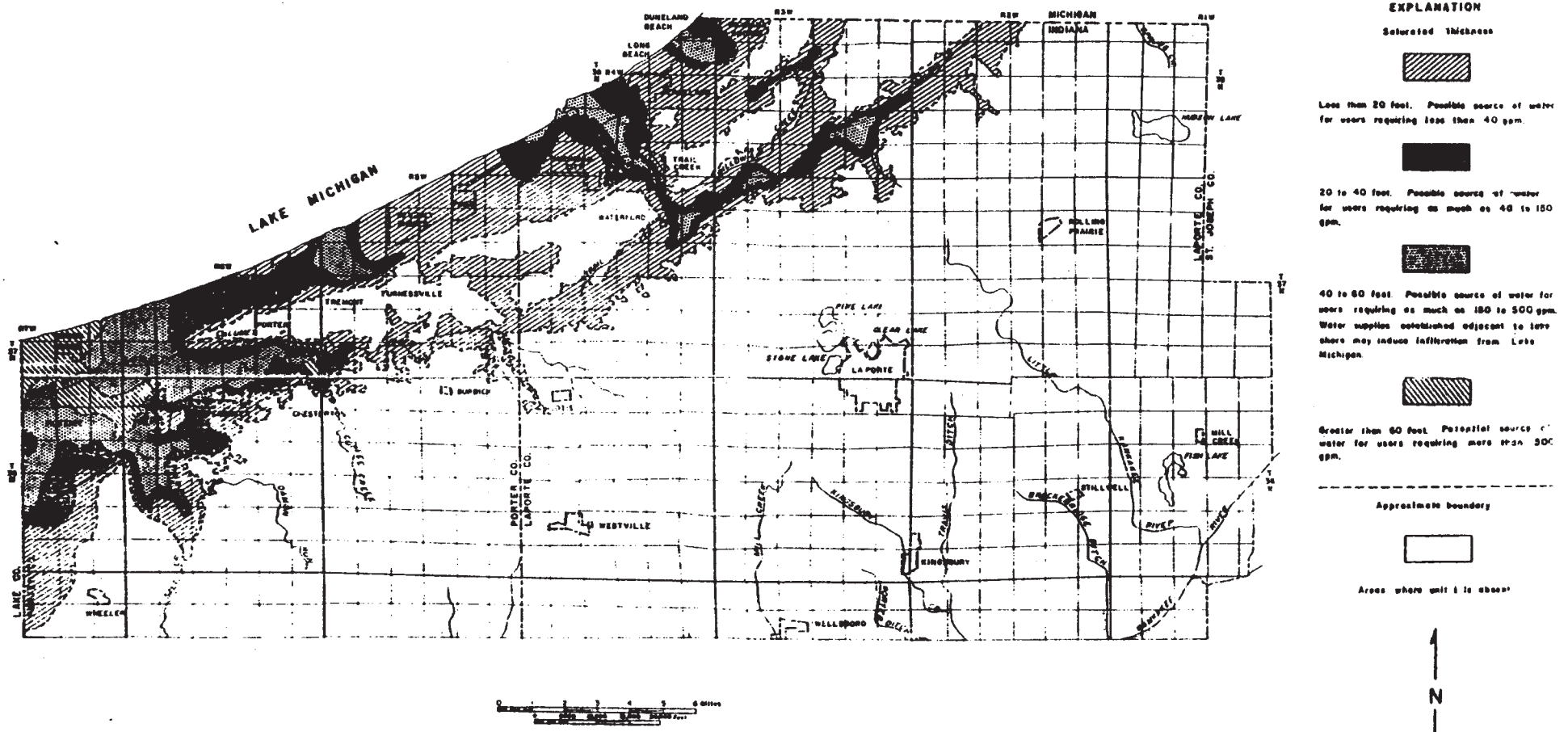
The hydrology of the unit has been altered since the early 1900's by ditching and industrial and urban development. This alteration has changed the natural balance between recharge and discharge. It has increased the natural discharge from the unit and decreased the natural recharge. The changes produced 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.



EXPLANATION

Saturated thickness

Less than 20 feet. Possible source of water for users requiring less than 40 gpm.

20 to 40 feet. Possible source of water for users requiring as much as 40 to 150 gpm.

40 to 60 feet. Possible source of water for users requiring as much as 150 to 500 gpm. Water supplies established adjacent to lake shore may induce infiltration from Lake Michigan.

Greater than 60 feet. Potential source of water for users requiring more than 500 gpm.

Approximate boundary

Areas where unit I is absent

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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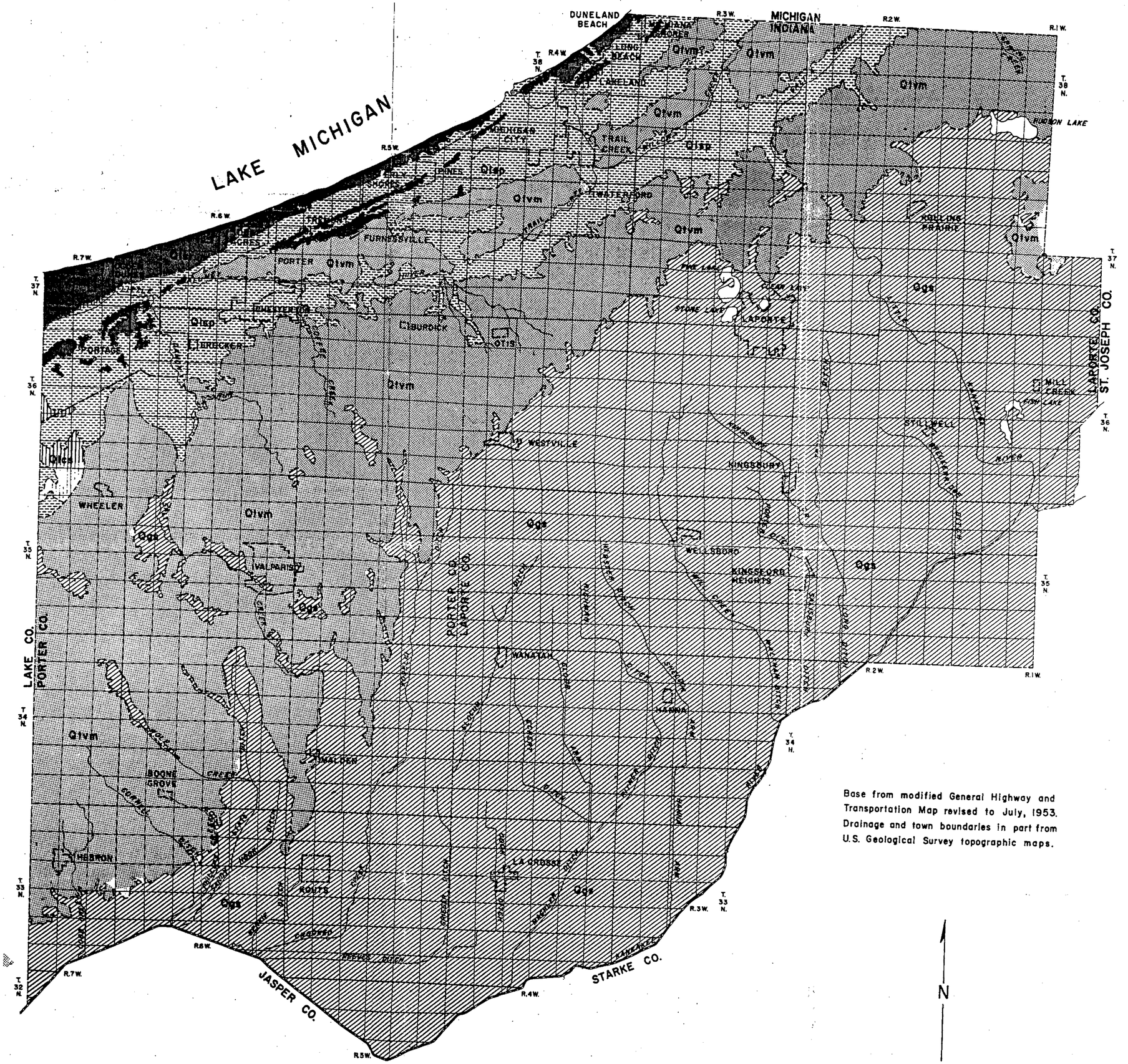


Base from modified General Highway and Transportation Map revised to July, 1953. Drainage and town boundaries in part from U.S. Geological Survey topographic maps.

EXPLANATION

Qlc

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.

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

Qtvm

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.

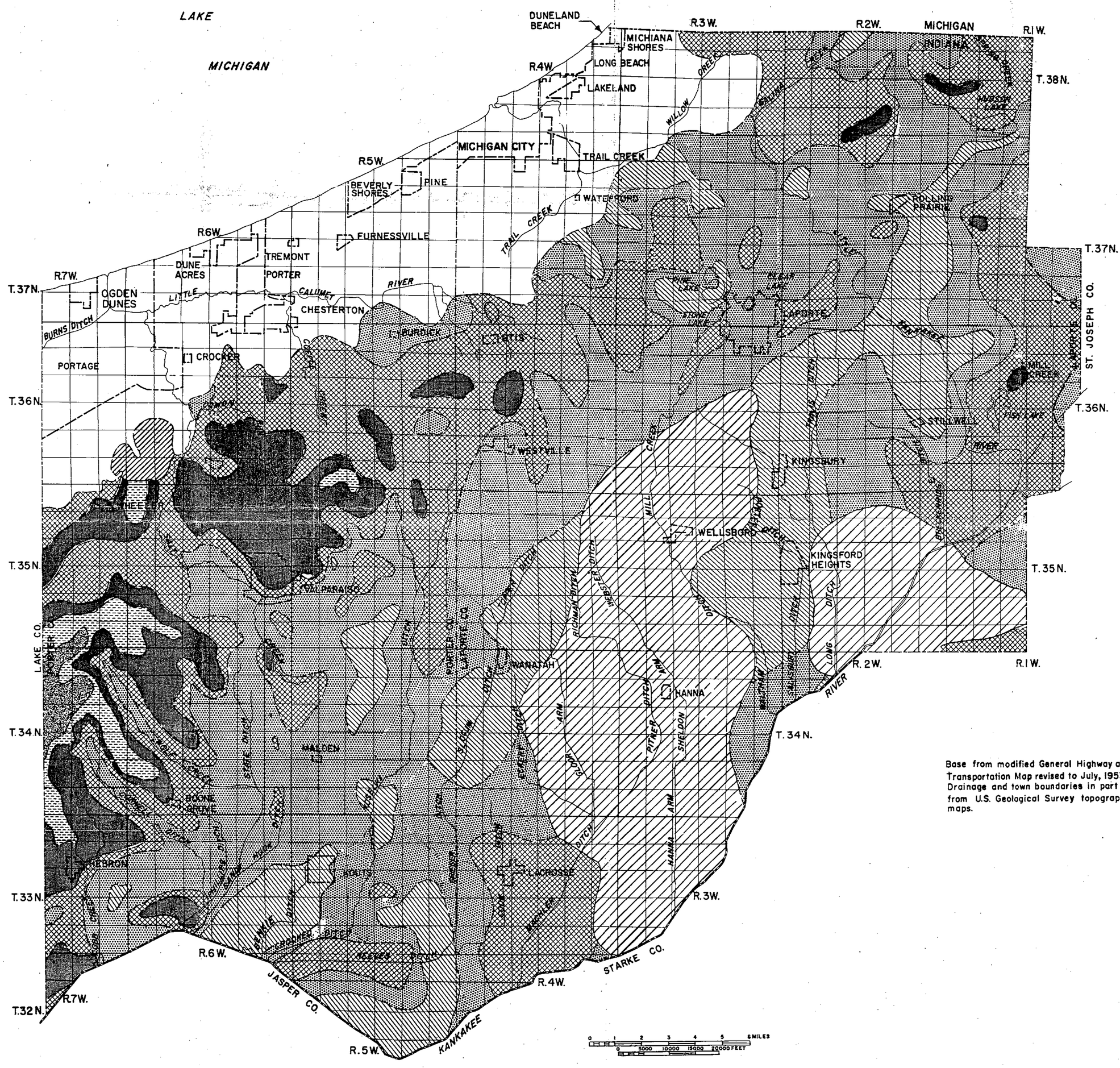
Pleistocene to Recent

QUATERNARY

GEOLOGIC MAP OF PORTER AND LAPORTE COUNTIES

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



EXPLANATION

Concentration of bicarbonate (HCO_3) in parts per million

- 100 – 200
- 201 – 300
- 301 – 400
- 401 – 500
- 501 – 600
- 601 – 700
- Data not sufficient to show concentration of bicarbonate
- Area not underlain by unit
- Approximate boundary of concentration; queried where less accurate.

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.

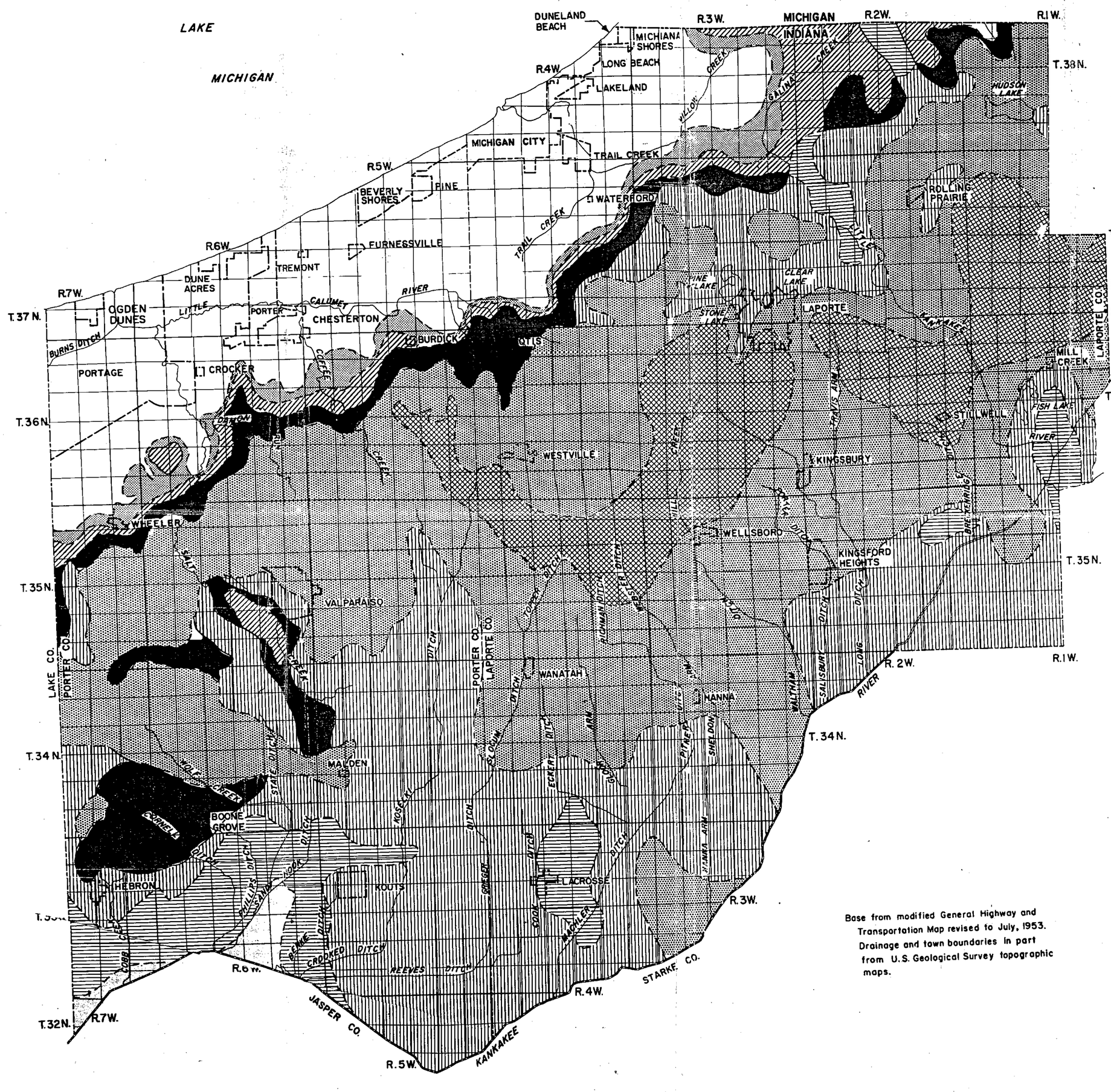
N

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
DIVISION OF WATER

PREPARED BY THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

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LAKE MICHIGAN

DUNELAND BEACH
MICHIANA SHORES
LONG BEACH
LAKELAND
MICHIGAN CITY
BEVERLY SHORES
DUNE ACRES
OGDEN DUNES
TREMONT
PINE
FURNESSVILLE
WATERFORD
TRAIL CREEK
PORTER
CHESTERTON
BURDICK
OTIS
CROCKER
PORTAGE
DAMON
WESTVILLE
WHEELER
VALPARAISO
MALDEN
BOONE GROVE
HEBRON
KOUTS
WANATAH
LACROSSE
HANNA
LAPORTE
PINE LAKE
CLEAR LAKE
STONE LAKE
ROLLING PRAIRIE
HUDSON LAKE
MILL CREEK
STILLWELL
FISH LAKE
KINGSBURY
WELLSBORO
KINGSFORD HEIGHTS

R.7W. R.6W. R.5W. R.4W. R.3W. R.2W. R.1W.

T.38N.
T.37N.
T.36N.
T.35N.
T.34N.
T.33N.

LAKE CO. PORTER CO. JASPER CO. STARKE CO. LAPORTE CO. ST. JOSEPH CO.

Burns Ditch, Little Calumet River, Coffee Creek, Salt Creek, Damon Run, Wolf Creek, Cornell Ditch, Phillips Ditch, Sandy Hook Ditch, Cobb Creek, Benkie Ditch, Crooked Ditch, Reeves Ditch, Kankakee River, Trail Creek, Galena Creek, Willow Creek, Little Creek, Pine Lake Ditch, Clear Lake Ditch, Stone Lake Ditch, Kankakee Ditch, Mill Creek, Travis Ditch, Fish Lake Ditch, Brecken Ridge Ditch, Porter Ditch, Mill Creek Ditch, Topper Ditch, Richman Ditch, Webster Ditch, Slocum Ditch, Eckert Ditch, Gloor Arm, Pitner Ditch, Sheldon Ditch, Hanna Arm, Waltham Ditch, Salisbury Ditch, Long Ditch, Gregger Ditch, Cook Ditch, Machler Ditch, Koselki Ditch, State Ditch, Porter Co. Ditch, Laporte Co. Ditch, Hanna Arm, Long River

EXPLANATION

Area not underlain by unit 3

40

Contours showing approximate depth to water-bearing zone.

Interval 40 feet, with supplementary contours at 20 foot intervals shown by dashed lines.

N

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.

0 1 2 3 4 5 6 Miles
0 5000 10000 15000 20000 Feet

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