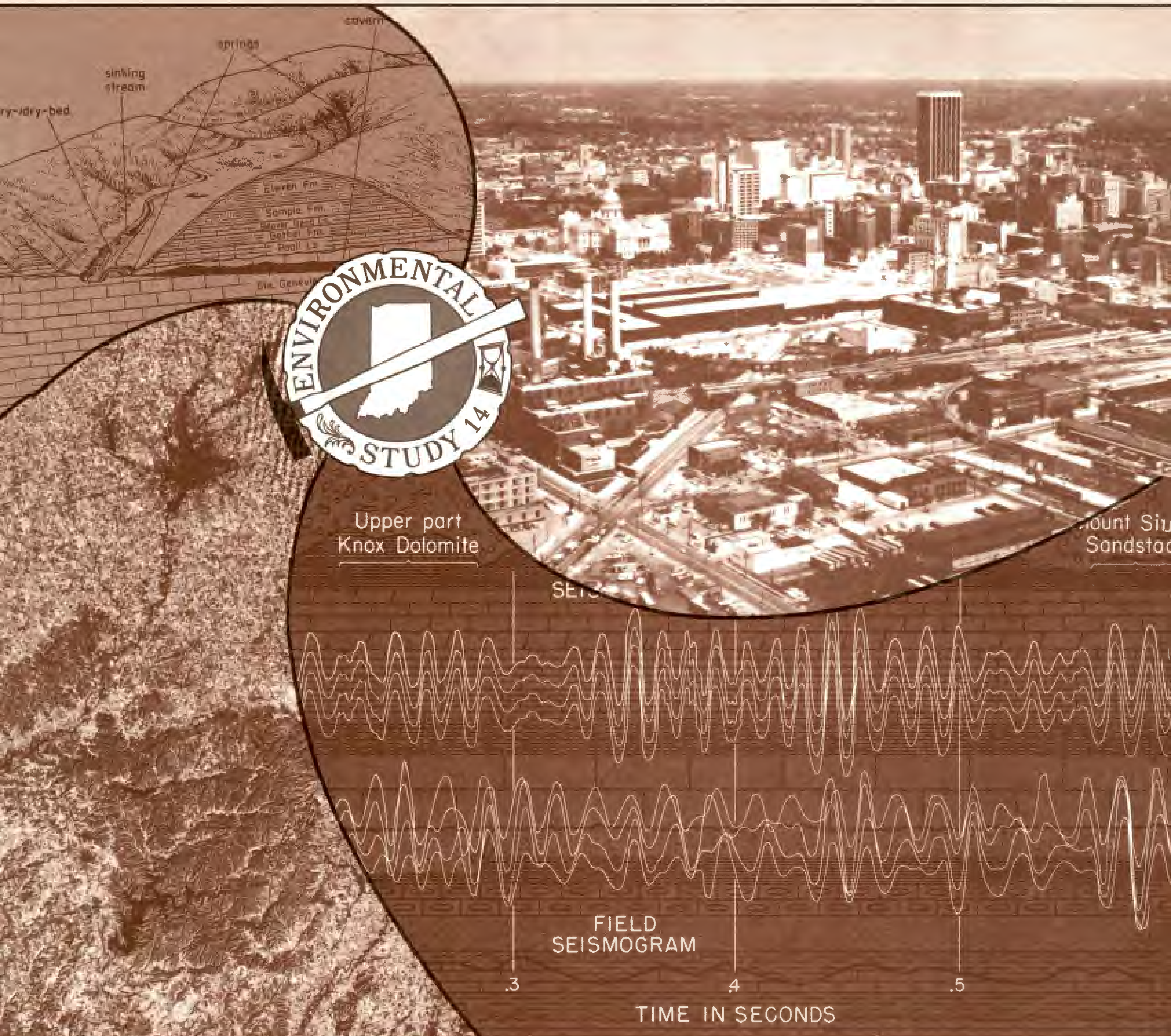
GEOLOGY AS A CONTRIBUTION TO LAND USE PLANNING IN LA PORTE COUNTY, INDIANA

Special Report 14



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Geology as a Contribution to Land Use Planning in LaPorte County, Indiana

By JOHN R. HILL, DONALD D. CARR, EDWIN J. HARTKE, *and* CARL B. REXROAD

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Geology as a Contribution to Land Use Planning in LaPorte County, Indiana

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Introduction

LaPorte County, in northwestern Indiana, is in a geologically complex region underlain at shallow depths by depositional sequences of glacial *till,*[1] *outwash* sand and gravel, and *lacustrine* silt and clay. The combined agents of ice, wind, and water have sculptured these deposits into a topographically varied landscape ranging from sandy flats of the Kankakee Outwash and Lacustrine Plain to partly wooded hilly uplands on the Valparaiso Moraine. Beneath the glacial materials, which range from 25 to 350 feet in thickness, is a sequence of *Paleozoic* rocks that is about 4,000 feet thick. Limestone, dolomite, sandstone, and shale, complexly interlayered and varying in thickness, make up the bedrock units, which provide ground water potential and contain potentially commercial deposits of gypsum near LaPorte.

Most of the environmental geologic factors are dependent on the thickness, continuity, and physical properties of the unconsolidated deposits that make up the surface of the county. The *texture,* mineralogy, and depositional origin of these sediments largely determine their engineering properties and subsequent suitability for sanitary landfilling, septic systems, and construction. The availability, quantity, and quality of ground water also depend on the geologic properties of the unconsolidated glacial deposits and on the underlying bedrock formations. Ground water, discussed on page 9, is abundant throughout much of LaPorte County because of porous and permeable sand and gravel deposits.

Besides the indirect applications of geology to environment, some earth materials have commercial value in their own right. Sand and gravel, clay, peat and marl, and gypsum and anhydrite are valuable commodities that may be extracted from glacial drift or bedrock.

[1]Words in italics are defined in the glossary of terms.

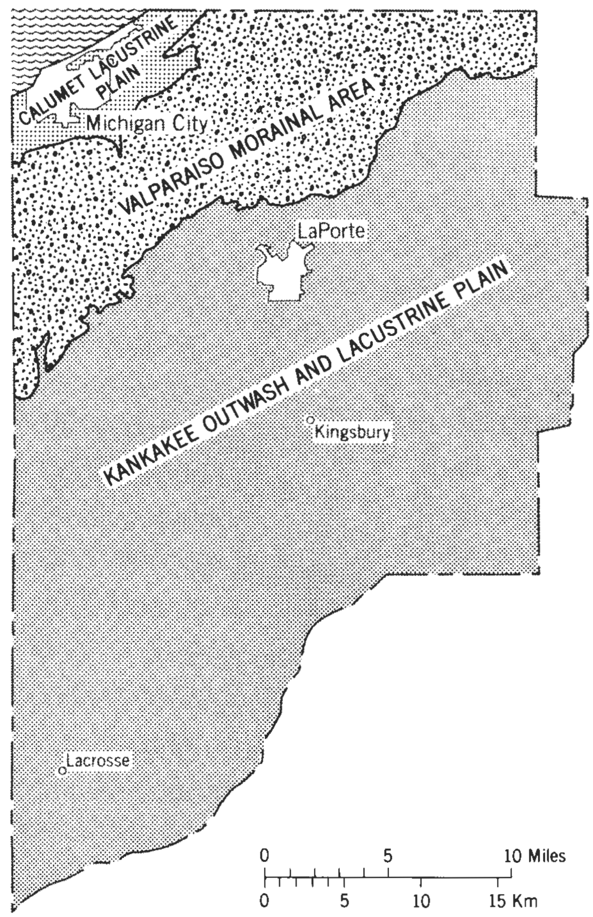

Figure 1. Physiographic map of LaPorte County.

Geology and Geography of the Unconsolidated Deposits

The unconsolidated sediments that mantle the bedrock surface throughout LaPorte County were deposited during the *Pleistocene Epoch* either directly by glaciers or by action of other agents, such as meltwater, associated with glaciation. During each

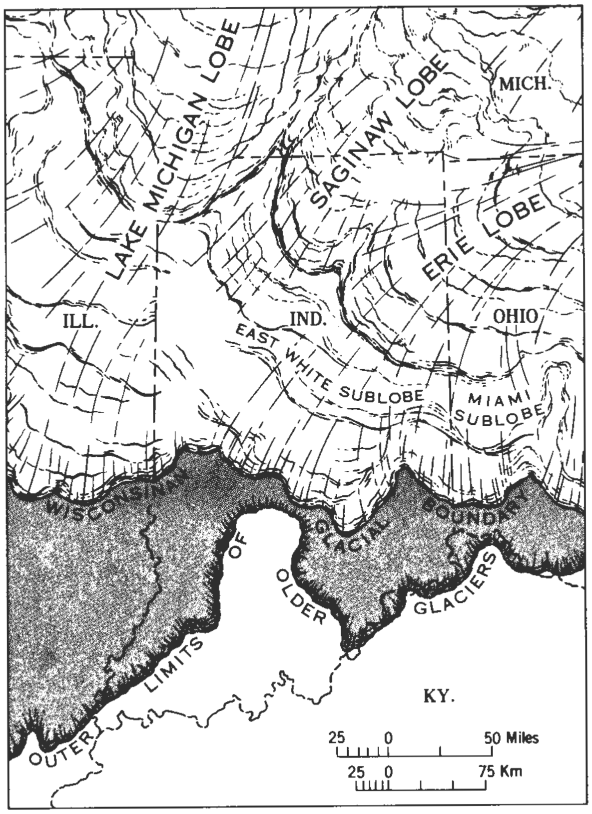

Figure 2. Glacial lobes and sublobes of the Wisconsinan ice sheet in Indiana.

Epoch	Age and subage
	Recent
	Wisconsinan
	Valderan
	Twocreekan
	Woodfordian
Pleistocene	Farmdalian
	Altonian
	Sangamonian (interglacial)
	Illinoian
	Yarmouthian (interglacial)
	Kansanan

Figure 3. Glacial ages and subages recognized in Indiana. Only the Wisconsinan Age is recognized in LaPorte County.

major interval of glaciation, deposition occurred in essentially two phases: the advance phase in which till was laid down as *ground moraine;* and the retreat phase in which till was deposited as *end moraine* and sand and gravel were washed out of the waning ice by meltwater. The distribution of materials left by the ice was complicated greatly because the ice advanced and retreated numerous times during the Pleistocene. Consequently, earlier ground moraine and outwash sequences were partly stripped away and then covered by deposits of the latest sequence; these events lasted until about 11,000 years ago, the end of the Ice Age in northern Indiana.

The present landscape of LaPorte County, resulting primarily from the last major glacial phase, is subdivided into three physiographically distinct areas: the Calumet Lacustrine Plain, the Valparaiso Morainal Area, and the Kankakee Outwash and Lacustrine Plain (fig. 1). The origins of these physiographic units are linked because the forces active in producing one system of landforms were operating simultaneously with related agents in creating the others.

One event does stand out as being distinct, however, and that is the formation of the Valparaiso Moraine, an arcuate end moraine that extends around the southern tip of Lake Michigan from southern Wisconsin through northeastern Illinois and northwestern Indiana to west-central Michigan. It is believed to mark the terminal position of the *Lake Michigan Lobe* during the *Cary Subage* (late Woodfordian) of the *Wisconsinan Age* (figs. 2 and 3). The Valparaiso Moraine is actually a complex of several end moraines composed of loam to silt loam till, each representing a stillstand of the glacier in that area (Qte, pl. 1). The entire morainic system is referred to physiographically as the Valparaiso Morainal Area, and its greatest relief is near Valparaiso in Porter County.

After formation of the Valparaiso Moraine some 13,000 to 15,000 years ago, the Lake Michigan Lobe (fig. 2) of the Wisconsinan glacier (figs. 2 and 3) retreated northward out of Indiana. In the wake of the waning glacier a considerable volume of meltwater remained, filling the freshly exposed part of the Lake Michigan basin. The water was held in the basin by the Valparaiso Moraine on the west, south, and east and by the receding glacier to the north.

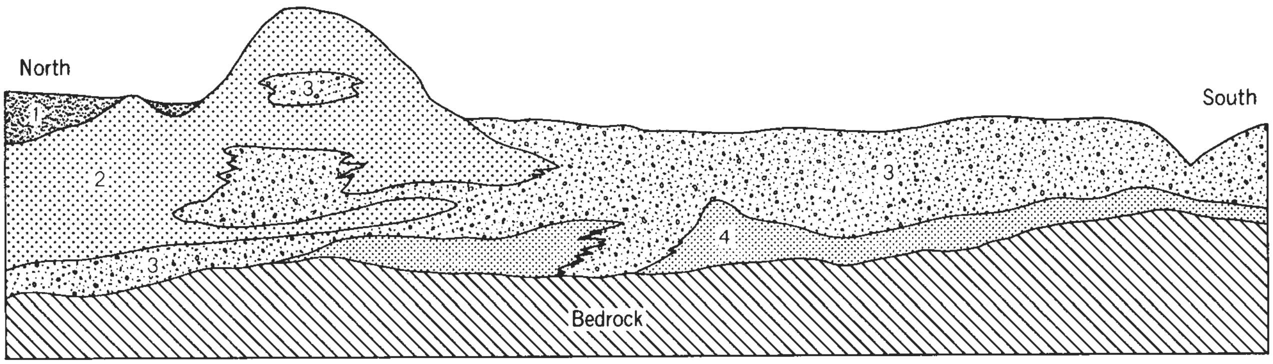

Figure 4. Diagrammatic cross section through LaPorte County illustrating the disposition of units 1 through 4. (See text for details.) Unit 1 consists of lake sediments, unit 2 is till, unit 3 is outwash sand and gravel, and unit 4 is the oldest till.

Thus glacial Lake Chicago (ancestral Lake Michigan) was born. At first, excess meltwater drained from the newly formed lake by way of a breach in the Valparaiso Moraine near Palos Park, Chicago. Later, as the Straits of Mackinac were freed of ice, the present northerly drainage route was established and the lake lowered, in stages, to its present level of 585 feet above sea level.

Deposits of lake clay and sand (Qcl and Qsl, pl. 1), laid down when Lake Chicago occupied various elevations descending from 640 feet above sea level to the present level of Lake Michigan, form most of the area called the Calumet Lacustrine Plain (fig. 1). In LaPorte County the lake plain is restricted to a narrow belt a few miles wide in the northwestern one-fifth of the county. The dominant landforms of the lake plain are sand dunes (Qsd, pl. 1), most of which formed during the lowering phase of Lake Chicago.

At the same time Lake Chicago was forming, meltwater from the *Huron-Saginaw Lobe* (fig. 2) created a torrent that flowed across most of LaPorte County. This massive river of meltwater, called the Kankakee Torrent, cut a swath an average of 8 miles wide through the southeastern two-thirds of the county, removing some sediments but completely blanketing older sediments with sand and gravel of outwash and *valley train* origin (Qgv and Qgp, pl. 1). This broad, flat outwash area, called the Kankakee Outwash and Lacustrine Plain (fig. 1), is the dominant physiographic feature in the county.

The stratigraphic sequence of the glacial deposits from bedrock to the surface can be subdivided into four major units, the same units that form the basis of the ground water discussion (p. 9). (See fig. 4.) The oldest unit (unit 4) is a hard till that mantles bedrock throughout most of the county. Directly above the lower till lies a thick outwash sand and gravel complex (unit 3) that is surficially exposed south of the Valparaiso Moraine throughout much of the Kankakee Outwash and Lacustrine Plain. Unit 3, discussed in the ground water section, also underlies much of the Valparaiso Moraine and serves as a main bearing unit for ground water. Above unit 3 lies unit 2, a loamy to silty loam till varying in thickness and composing the Valparaiso Moraine and the accompanying ground moraine. The youngest sequence (unit 1) is composed of lacustrine clay and sand units that overlap the northern limb of the Valparaiso Moraine and terminate at the Lake Michigan shoreline. Both units 1 and 2 are exposed at the surface where they are mapped as Qcl and Qte on plate 1. The total thickness of units 1 through 4 ranges from 25 to 350 feet.

Glacial deposits in LaPorte County, then, reflect a complex history involving several advance-and-retreat phases of at least one, and possibly two, lobes of the Wisconsinan glacier. The last major contribution of the Ice Age to the present landform of this county was the deposition of an extensive outwash sequence that was formed south of the Valparaiso Moraine by glacial meltwaters while Lake Chicago was simultaneously evolving north of the moraine. In the subsurface, the glacial deposits are separated into two main till units between which lies a thick sand and gravel sequence. A lake clay and sand zone overlies part of the upper till in the extreme northwest corner of the county.

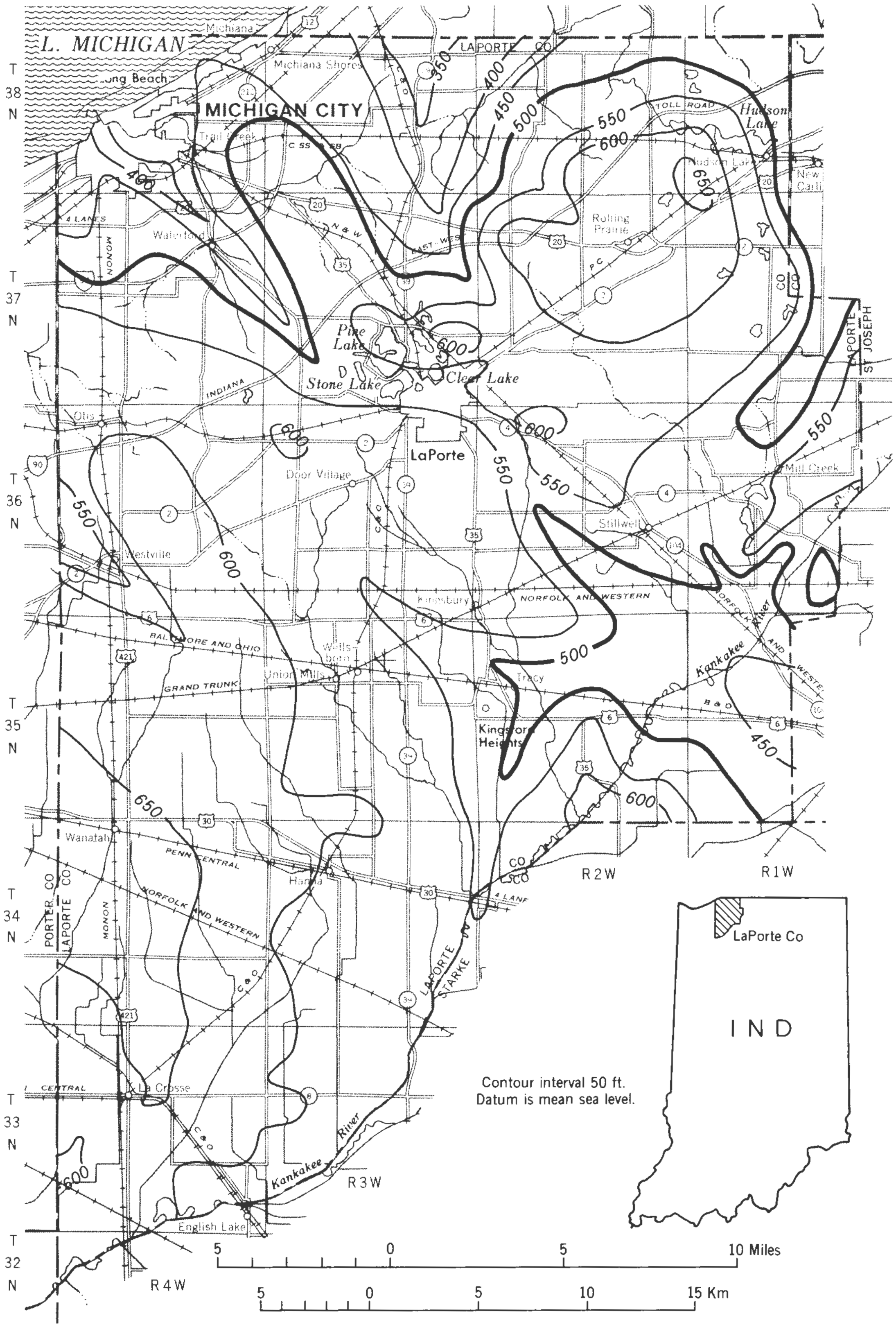

Figure 5. Map of LaPorte County showing bedrock topography. Mapping by Stanley J. Keller.

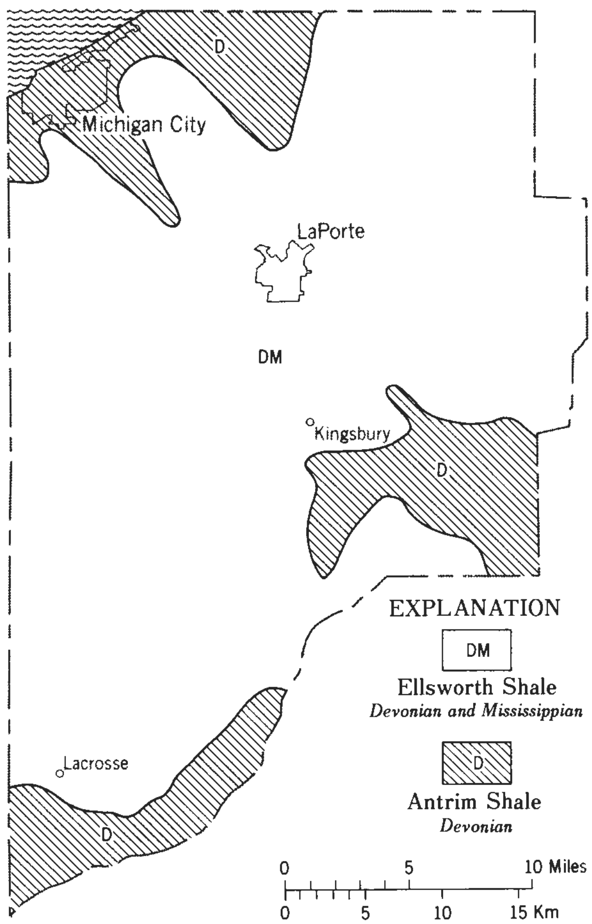

Figure 6. Map of LaPorte County showing bedrock geology.

Bedrock Geology

If all the glacial deposits of LaPorte County were stripped away, a gently rolling bedrock surface of shale accentuated by branching valleys would be exposed (fig. 5). This surface is essentially the result of preglacial erosion and now is covered by about 25 to 350 feet of glacial material. Most of the rock at the bedrock surface belongs to the Ellsworth Shale of Devonian and Mississippian age (figs. 6 and 7) and consists of gray-green shale, which in its lower part alternates with layers of black shale. In the areas of the northwestern, southwestern, and southeastern corners of the county, the hard black Antrim Shale, which is late Devonian in age and which directly underlies the Ellsworth, extends beyond the margins of the Ellsworth and is at the bedrock surface (fig. 5). The first bedrock encountered in drilling, then, would be one or the other of these two shales. Although the upper surface of the two shales has numerous joints or fractures, the shales otherwise are nearly *impermeable.*

Underlying the entire county beneath the Antrim Shale is a sequence of Paleozoic limestone, dolomite, shale, sandstone, and gypsum that is about 4,000 feet thick (fig. 7). The Paleozoic sediments rest on a Precambrian basement complex of dominantly igneous rocks. The deepest drilling in LaPorte County for which reliable records exist has penetrated only about 200 feet into the Knox Dolomite to a total depth of 1,821 feet. Therefore, information on rock units below this depth must be extrapolated from adjacent areas.

All the sedimentary rocks originated in or adjacent to ancient seas that spread over and withdrew from the area many times. The sandstones probably represent beach and near-shore deposits; the shales were deposited in relatively deep, quiet water; the limestones were deposited in sea water of varying depths; and gypsum probably formed along broad tidal flats adjacent to the sea.

Broad warping of the earth's crust caused the advance and retreat of the seas and the tilting of the rocks formed in them. The movement continued after the deposition of the sedimentary rocks, so now the layers of rock slope to the northeast at about 11 feet per mile. No major *faults* resulting from displacement along fractures in the rock during the warping and tilting are known in LaPorte County or in the immediately adjacent counties, an important factor in locating such structures as atomic power plants. In terms of major structural features, LaPorte County is on the southwestern flank of the *Michigan Basin* and the northern limb of the *Kankakee Arch.*

Bedrock has several uses for the residents of LaPorte County; the most significant include: (1) the contained mineral resources, particularly gypsum, but also varieties of limestone, dolomite, and shale; (2) reservoir potential for storage of hydrocarbons and liquid wastes; and (3) possible sources of ground water. (See the sections on mineral resources and ground water for further discussion.) Because of these possibilities, knowledge of the bedrock should be an integral part of any land use plan. The thickness of overlying glacial deposits makes it unlikely that bedrock will enter into most construction considerations.

ERA	SYSTEM	STRATIGRAPHIC UNIT		DOMINANT LITHOLOGY	THICKNESS IN FEET
CENOZOIC	QUATERNARY	Glacial drift		Sand, gravel, and clay	25-350
PALEOZOIC	MISSISSIPPIAN	Ellsworth Sh.		Shale	25-290
	DEVONIAN	Antrim Sh.			
		Traverse Fm. Detroit River Fm.		Limestone, dolomite, anhydrite, and gypsum	110-190
	SILURIAN	Salina Fm. Wabash Fm. Louisville Ls. Salamonie Dol. Brassfield Ls.		Dolomite and limestone	450-550
	ORDOVICIAN	Maquoketa Gr.		Shale and limestone	240-355
		Trenton Ls. Black River Ls.		Limestone and dolomite	310-360
		St. Peter Ss.		Sandstone	50-100
	ORDOVICIAN / CAMBRIAN	Knox Dol.		Dolomite	275-475
				No reliable data below this depth in LaPorte County	
	CAMBRIAN	Franconia Fm.		Dolomite and sandstone	25-100
		Ironton Ss.		Dolomite and sandstone	50-100
		Galesville Ss.		Sandstone	130-190
		Eau Claire Fm.		Shale, dolomite, and sandstone	300-450
		Mount Simon Ss.		Sandstone	1500-2000
PRECAMBRIAN				Granite	

Figure 7. Summary of bedrock stratigraphy in LaPorte County.

Engineering-Geologic Characteristics of the Unconsolidated Deposits

Four basic interdependent factors determine the engineering-geologic characteristics of a given tract of land: topography, drainage, texture of the materials, and mineralogy of the sediments. Topography affects drainage, which in turn causes variations in material strength due to an increase or decrease in moisture. Moisture, in the presence of certain clay minerals, causes sediments to expand. Composition of the coarser sediments is also an important factor. For example, the dominance of shale in gravel deposits throughout the county greatly diminishes their suitability and value as aggregates.

Particle size or texture also has a direct bearing on the physical behavior of the sediments. Generally speaking, fine-grained sediments, such as lake clay, show low *compressive strength* and poor *bearing capacity,* are subject to *slump* and *creep* when wet, and behave *plastically* under moderate moisture conditions but as a liquid when fully saturated. Sand and gravel, however, remain relatively stable throughout a wide range of saturation. The coarser fractions show good to excellent compressive strength and good bearing capacity and maintain much steeper grades than silt or clay under the ambient range of saturation conditions.

Most of the near-surface sediments in LaPorte County are coarse-textured (see appendix and fig. 8) outwash sand and gravel (for example, Qgp, Qs, Qsl, Qgk, Qgv, Qsa, and Qsb, pl. 1). The primary consideration in areas underlain by this type of sediment should be the water table. A seasonally high water table together with highly permeable materials could cause problems in *subgrade* construction, such as in basement excavations.

Most of the sandy areas are relatively flat, but where slopes are present some form of vegetation is required to prevent excessive gullying. Where grading of sandy soils is necessary, the slope gradient sould not exceed 30° to the horizontal. The sand dune complex along the lake shore (Qsd and Qsb, pl. 1) poses some special engineering problems because of the proximity of Lake Michigan, but shore erosion is not severe in this county. It is important to remember, though, that the beach is an ever-changing feature subject to variations in lake level, storm frequency and intensity, major climatic variations, and man's modification of the natural air-land-water system.

The Valparaiso morainal complex (Qte, pl. 1), ground moraine deposits (Qt), and lake sediments (Qcl and Qsl) contain most of the fine-grained deposits in this county. Because the sediments are so variable, prediction of their compressive strength, bearing capacity, or other engineering factors must be based on study of limited areas of not more than a few acres.

The till units (Qt and Qte) show considerable variance in texture. On the average, unit Qte is a *silt loam,* but it ranges from a sand to nearly a *clay loam.* (See appendix.) The till body in places is buried under 5 to 10 feet of sandy material—especially in the extreme northwestern part of the county as is illustrated by the information for auger hole 16 (appendix and fig. 8). Such abrupt changes in texture can create serious problems for construction unless they have been anticipated during early planning.

The clay minerals in a given soil unit affect its bearing capacity, strength, and general stability under the normal range of moisture conditions. The montmorillonite group (a series of expandable clay minerals typified by montmorillonite) and mixed-layer clays cause problems in soils in which they are present. On wetting, these clay minerals expand to many times their original volume, thereby causing quick conditions. Fortunately, the dominant clay minerals in this area are illite and chlorite, both of which show little or no expansion on wetting. Isolated areas on the Valparaiso Moraine (Qte) and throughout the Calumet Lacustrine Plain (Qcl and Qt), however, may contain significant amounts of expandable mixed-layer clay that will result in high plasticity indices and low aggregate strength.

Compressive strength for samples collected across the Valparaiso Moraine in LaPorte County ranges from 0.5 ton per square foot to slightly more than 4 tons per square foot. The range in values is probably due to a variation in moisture content, which is, in turn, a function of topography, soil texture, and amount of local precipitation.

Atterberg limit analyses for all samples collected showed a plasticity index range of 8 to 23 for unit Qte, a plastic limit range of 5 to 16, and a liquid limit range of 19 to 29 (table 1). Generally speaking, those samples for which the plasticity indices exceed 20 will also show a wide variation in bearing capacities and strengths between the wet and dry states. Thus, sample site 6 (fig. 8) is the only locality of the area sampled that indicates a potential soil stability problem for most types of construction. The Valparaiso morainal system is, in a very general sense, well suited to most types of construction, such as excavations, cutbanks, and borrow piles.

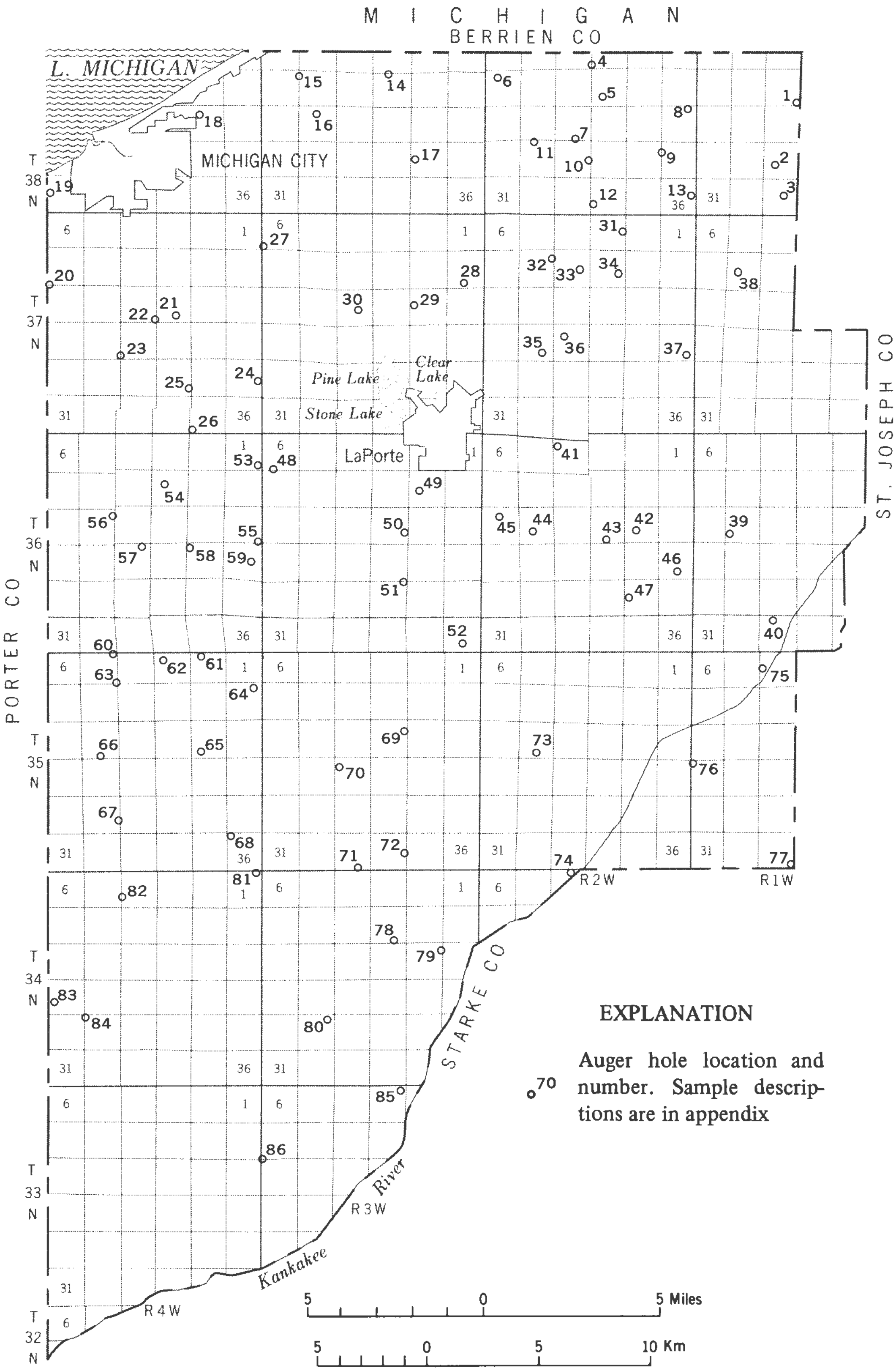

Figure 8. Map of LaPorte County showing auger hole locations.

Table 1. Atterberg limits of materials in the Valparaiso Moraine

Sample site[1]	Plastic limit	Liquid limit	Plasticity index
6	5	28	23
48	16	26	10
26	14	21	7
27	15	29	14
2	11	19	8
12	14	25	11

[1] See figure 8 for location of sample sites.

Because of the high degree of variability of the properties of till, it is essential to have a good onsite engineering profile prior to preparation of the site plan. This is true for any area but is especially important for *nonhomogneous* materials, such as till. Gravel zones within the till commonly carry water that will saturate the finer clay-silt fraction, thus reducing the aggregate strength of the unit. Only carefully gathered subsurface information can reveal such potential trouble zones.

On the whole, construction on unit Qte and most of unit Qt should not afford serious problems because relief is adequate to provide good drainage (except in obvious depressional areas) and strength of the materials is generally good. Slope stability may be a problem unless adequate vegetative cover is provided and the materials are compacted or allowed to settle before loading is attempted.

The primary problem unit in the county is a mixture of organic-rich silt and clay (called muck and peat, Qmp), which is mostly saturated and almost everywhere associated with depressions or areas that have a high water table. Because of the large amount of decayed organic matter in the muck and peat deposits, the bulk density is low. Compaction properties and compressive strengths are also low. Construction in these areas should be avoided if possible.

The areas mapped as lacustrine clay and silt (Qcl) are also potential trouble spots for construction. Because these deposits are mostly interlayered with permeable sand and gravel, they are generally saturated to or beyond their plastic limit. Consequently, compressive strength and load-bearing capacity are low. Excavation in this material is extremely difficult, and the maintenance of vertical faces, such as those in basement excavations, may be difficult during wet periods.

In summary, the coarse-grained sands and gravels of map units Qgp and Qgv have the best engineering characteristics where drainage is good. Poorly drained fine-grained deposits, such as those of units Qcl and Qmp and of parts of units Qt and Qte, show the poorest engineering properties. Any construction job should be undertaken only after careful onsite test borings have been made and the data from these borings processed in light of the developer's needs.

Ground Water Availability and Quality

Except for those living in Michigan City the residents of LaPorte County rely on ground water for their water supply. Michigan City draws its supply from Lake Michigan. Extensive sand and gravel materials, deposited as outwash or stratified drift, provide a productive *aquifer* system within the glacial *drift.* The underlying bedrock is a minor source of poor-quality water and will not be discussed here. According to Rosenshein and Hunn (1968), the unconsolidated system is composed of four hydrologic units: two sand and gravel aquifers and two confining glacial tills. The hydrologic characteristics of these units are a direct reflection of their lithologic properties. The total production potential from this system was estimated by Rosenshein and Hunn (1968) to be in excess of 400 mgd. Less than 5 percent of this potential is being used.

The four hydrologic units (fig. 9), described as units 1 through 4 in Rosenshein and Hunn (1968), are essentially tabular in form and limited in areal extent. Unit 4 is basically a clayey silty till containing discontinuous sand and gravel lenses. This unit, which is not exposed at the surface, overlies bedrock throughout most of the county. The low permeability of the till classifies it as a confining unit. There are, however, intratill sand and gravel lenses from which domestic and farm wells can be developed. The potential of these lenses is limited by their modest size and by the amount of recharge they receive from the enclosing till. Water quality is generally good, but the water may be highly mineralized in places.

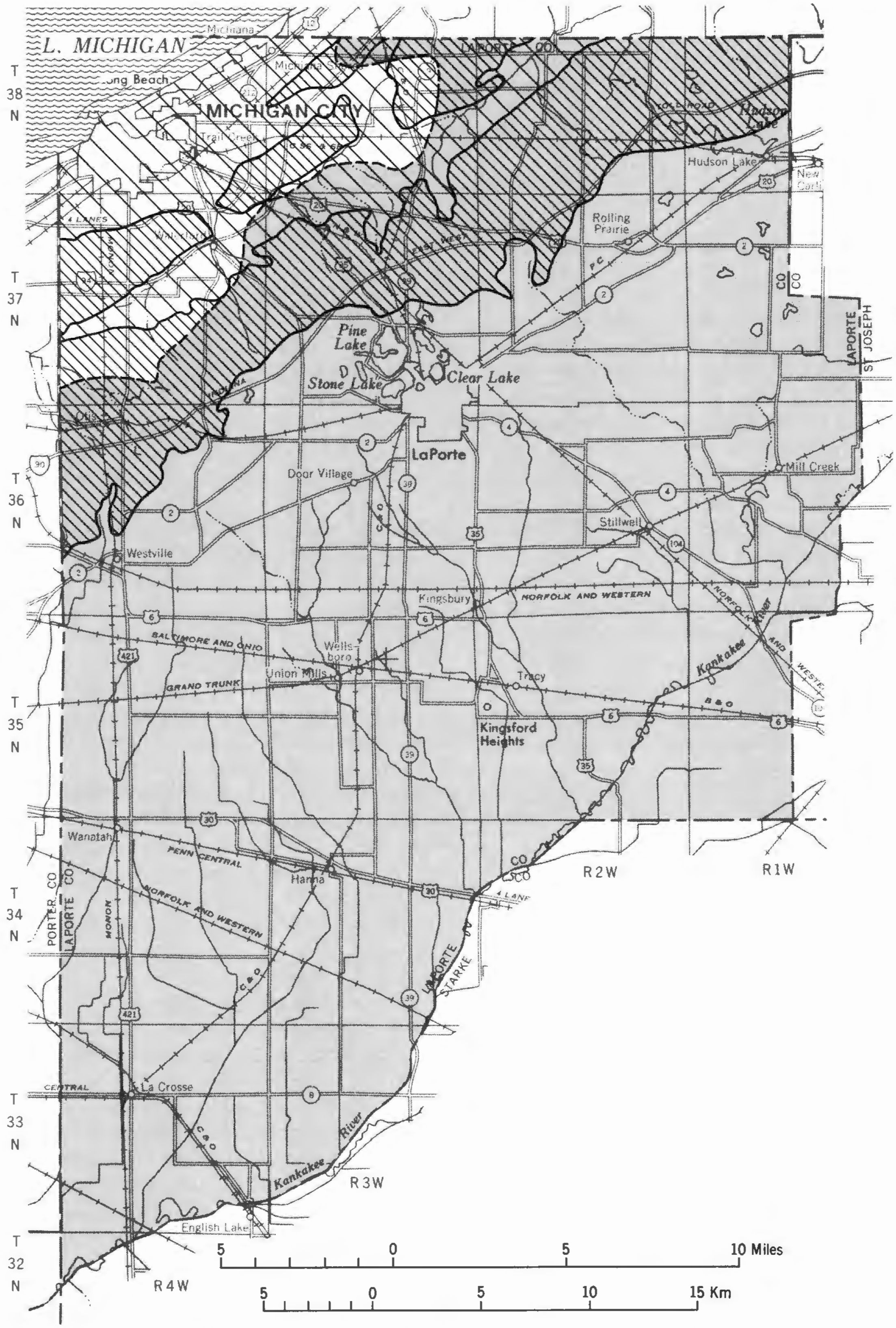

Figure 9. Map of LaPorte County showing ground water sources.

EXPLANATION FOR FIGURE 9

Unit 1. Silty sand with interbedded zones of beach sand, gravel, silt, and clay; potential yield is 50 to 500 gpm.

Unit 2. Glacial till containing discontinuous lenses of sand and gravel. Basically a confining layer, but sand and gravel lenses may be used for domestic and farm supplies.

Unit 3. Sand and sand and gravel containing in places thick clays of limited aerial extent. Principal aquifer is capable of yields from 50 to 3,000 gpm.

Northern boundary of unit 3

Unit 4. Glacial till, in places hard and compact with discontinuous intratill sand and gravel zones. Basically a confining layer, but sand and gravel lenses may be used for domestic and farm supplies. Unit 4 is not exposed at the surface and the exact aerial extent is not known, but it is at the bedrock surface throughout most of the county.

Unit 3 lies above unit 4 in the stratigraphic sequence. It is composed of glacial outwash consisting of silty sand and sand and gravel. The unit ranges from 0 to 250 feet in thickness but averages about 100 feet. It is the principal aquifer in the county, capable of yielding as much as 3,000 gpm to properly developed wells (Rosenshein and Hunn, 1968), and has great potential. The greatest part of the aquifer is exposed in the south where it forms the surface of the Kankakee Outwash and Lacustrine Plain. The southern section of unit 3 is therefore an unconfined aquifer, and depth to the water table ranges generally from 0 to about 20 feet. Water quality is generally good, but bicarbonate, chloride, sulfate, and dissolved solids are highly concentrated in places. The northern part of the unit is confined under glacial till, where it performs, in places, as an *artesian* aquifer. Depth to the aquifer under the confining till of unit 2 ranges from about 20 to 120 feet.

Unit 2 is a highly calcareous silty till with discontinuous sand and gravel lenses. This unit is contiguous with a part of the Valparaiso Morainal Area (fig. 1) and mantles the northern part of unit 3 in two narrow belts. The belts trend northeastward-southwestward and lie just north of LaPorte. Ground water produced from the unit is limited to the relatively thin sand and gravel lenses. These lenses are capable of supplying farm and domestic needs, but their small size and limited recharge potential restrict their production potential. Water quality is generally good, although the water may be somewhat hard. Because its permeability is low and it mantles a part of unit 3 in the north, unit 2 is best described as a confining layer.

Unit 1 lies in the northwestern part of the county and adjacent to Lake Michigan. It extends inland to include the belt of outwash that lies between the two separate sections of unit 2. The northern section of the unit consists primarily of dune sand, sandy lacustrine material, and beach and shoreline deposits of sand with some zones of sand and gravel. Unit 1 is an unconfined aquifer capable of yielding more than 500 gpm where its saturated thickness is greater than 50 feet. It is the second most productive aquifer in the county, but the yield from individual wells is limited through much of the unit because its saturated thickness is 20 to 30 feet or less. Water quality is generally good, but the susceptibility to contamination from surface sources is great.

Ground water is an abundant resource because extensive sand and gravel deposits in the county are conducive to infiltration of rainfall and rapid subsurface water movement. For the same reason, however, contaminants also readily infiltrate from the surface. Therefore, controlled waste-disposal systems, such as sanitary landfills, septic systems, and settling ponds, should be planned with care and placed only in geologically suitable areas to prevent ground water contamination (fig. 10).

Questions regarding the availability and quality of ground water in specific locations should be directed to the Indiana Department of Natural Resources, Division of Water. The Division of Water maintains an extensive file of water well logs and a liaison with many water well drillers in the state.

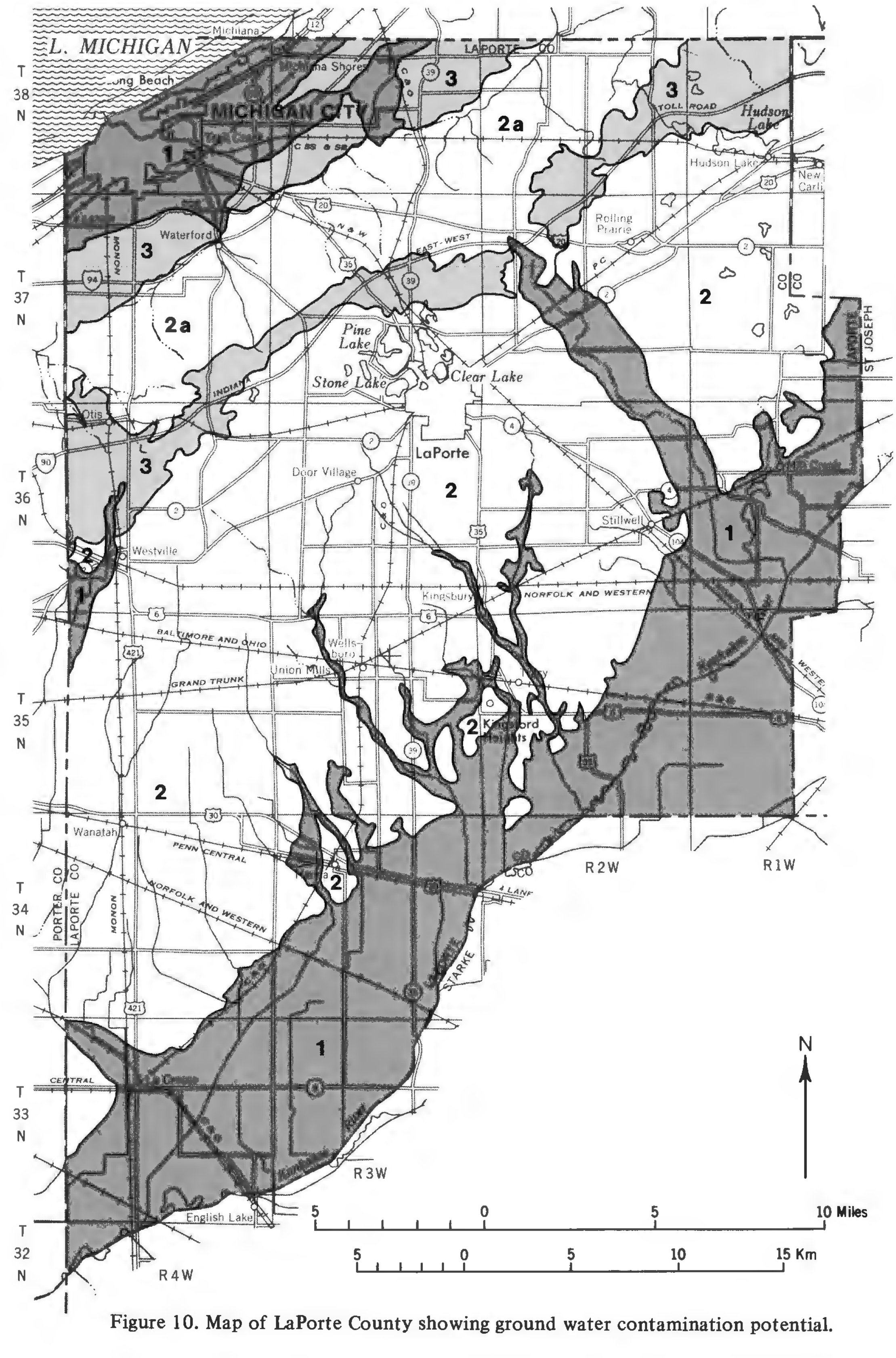

Figure 10. Map of LaPorte County showing ground water contamination potential.

EXPLANATION FOR FIGURE 10

1

Area 1. High susceptibility to contamination due to permeable surficial material and high water table.

2/2a

Areas 2 and 2a. Moderate susceptibility to contamination due to somewhat permeable surficial material and moderately high water table.

Area 2a consists of a near-surface unprotected aquifer and a deep aquifer generally protected by a rather extensive clay or silt layer that lies between the two aquifers. Most wells are in the deep aquifer.

3

Area 3. Low susceptibility to contamination due to low permeability of surficial material and (or) a deep water table.

Land Use Suitability for Septic Systems

Septic systems when properly installed in a satisfactory geologic setting provide adequate natural rehabilitation for liquid domestic wastes. A satisfactory geologic setting is one in which the depth to the highest seasonal water table is at least 5 feet below the tile field, the material between the tile field and the water table is of sufficiently low permeability to ensure rehabilitation of the *effluent,* the slope of the land surface is moderate, the land surface is above the highest expected flood level, and the material in which the tile field is placed is sufficiently permeable to accept the effluent. LaPorte County is particularly vulnerable to the deleterious effects of poorly planned septic systems because its extensive, highly permeable sand and gravel deposits provide little protection for the ground water.

For convenience of discussion, the county can be divided into three suitability categories on the basis of the pollution hazard of ground and surface water (fig. 11). Because the pollution hazard derives largely from geologic and hydrologic conditions in an area, the categories roughly reflect geologic boundaries. Placement of an area into a specific category implies that most of that area presents a distinct range of pollution hazard. The map depicting the contamination risk of ground and surface water (fig. 11) is of necessity generalized; therefore, each individual site must be judged on its own merit. The map is designed for use as a guide only.

Category 1 implies that properly installed septic systems in that area present a high degree of risk for contamination of ground and surface water. The areas in this category are generally low, have a high water table, and are composed of highly permeable surficial sand and gravel. In the south the materials in the area designated category 1 are glacial outwash, and in the north they are primarily beach and shoreline deposits of sand and gravel with some outwash deposits of sand and silt which may be overlain by lacustrine and *paludal* silt and muck.

Properly installed septic systems in category 2 areas present a moderate risk for contamination of ground or surface water. The areas in this category are topographically higher, at least above the highest potential flood level and have a lower water table level, 15 to 20 feet or more, but the surficial materials are highly permeable. The southern area shown as category 2 is composed of outwash sand and gravel but is somewhat higher and as a result has a lower water table. The northern areas designated as category 2 consist of high-permeability beach, shoreline, and outwash deposits that have a reduced risk of ground water contamination when they are combined with a low water table. Because surface drainage of both these areas is relatively good and because the surficial materials are quite permeable, there is little risk of surface water contamination.

The upland till in the northern part of the county has low permeability, a relatively low water table, and adequate surface drainage. It has therefore been classified in category 3 because the potential for contamination of ground and surface water is low. Because the till consists primarily of silt and clay, problems may be encountered with internal drainage in tile fields. Careful attention to proper construction and adequate field size can minimize this problem in all but the least permeable materials. There are relatively few steep slopes in this area, but where they do exist there is a strong risk of surface seepage from the tile field.

About 35 percent of the land surface in the county falls in category 1 and is therefore shown as a high-risk area for contamination of ground and

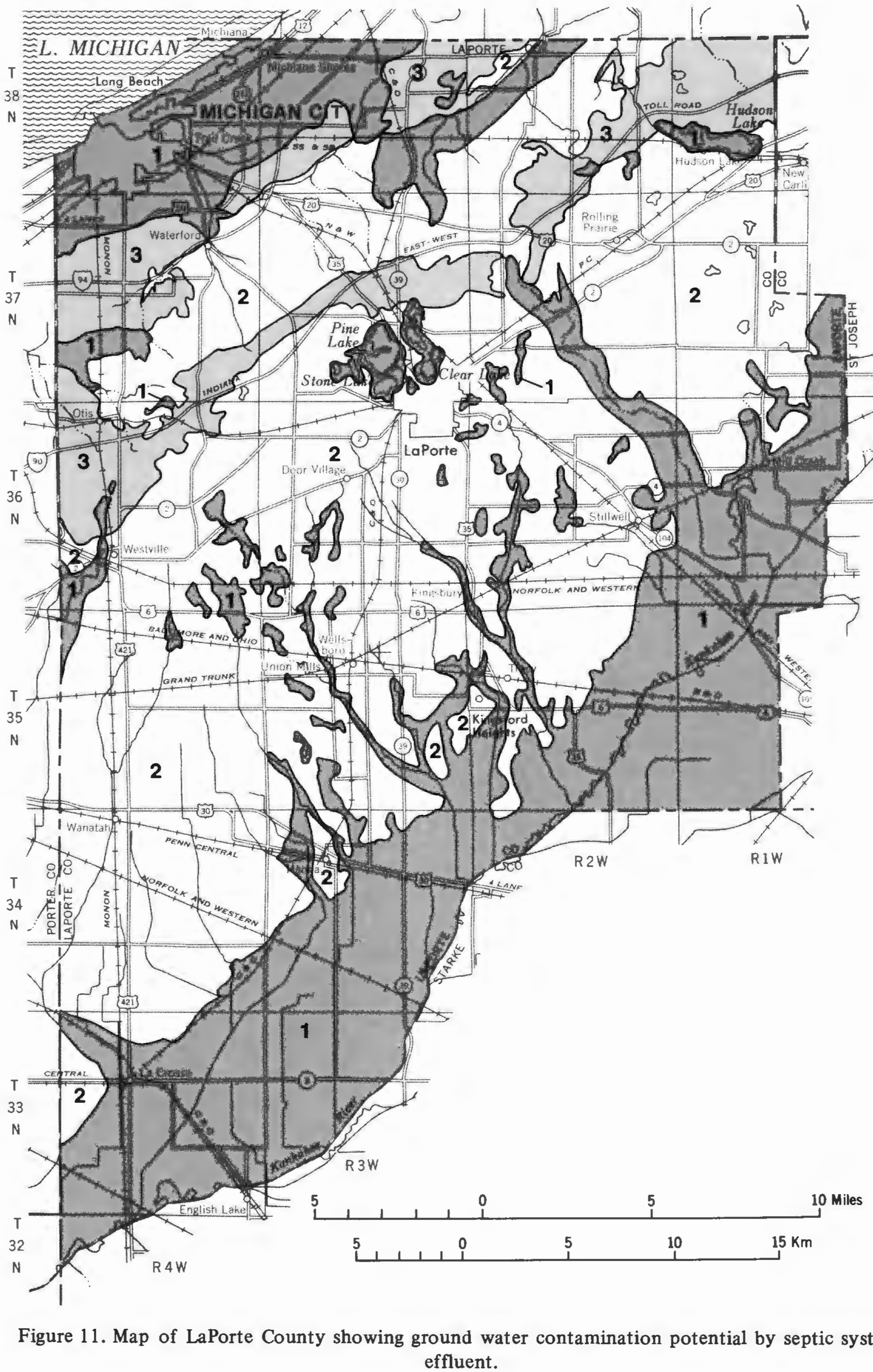

Figure 11. Map of LaPorte County showing ground water contamination potential by septic system effluent.

EXPLANATION FOR FIGURE 11

1

Area 1. High risk due to poor drainage, high water table, and high permeability of sediments.

2

Area 2. Moderate risk due to high water table and relatively high permeability of sediments.

3

Area 3. Low risk due to low water table and (or) low permeability of sediments. (Permeability may be low enough to create drainage problems in tile fields.)

surface water. There are, however, construction methods that can be used, at high cost, to install acceptable systems in these areas. They generally involve the importation of enough fill material to raise the complete system above the normal land surface. Costs and hazards are much greater than for septic systems installed in the proper geologic environment.

Land Use Suitability for Sanitary Landfilling

With steadily increasing land prices and decreasing land availability, suitable solid-waste disposal sites are becoming difficult to find. Some large cities, such as Chicago and Gary-Hammond, are no longer burying solid wastes but are using incineration and recycling techniques. The cost of these alternatives is very high, however, and for most municipalities sanitary landfilling is still the most feasible method of disposing of solid wastes.

The diverse matter in landfills consists of household garbage, industrial wastes (both inorganic and organic), demolition debris, metals of all types, and many other items. As these discarded byproducts of society break down chemically in water, a complex and sometimes poisonous liquid called leachate is produced along with such gases as carbon dioxide, carbon monoxide, methane, chlorine gas, bromine gas, nitrous oxides, sulfur dioxide, and hydrogen sulfide. Although the gases usually mix with air quickly enough to prevent harm, leachate is another matter. If appreciable quantities of leachate are introduced into supplies of drinking water, the results can be harmful.

Landfills are required by law to retain waste materials and the leachate produced by their breakdown to prevent organic and inorganic pollutants from contaminating surface and ground water and air. The reader is referred to the report, "Geologic Considerations in Planning Solid-Waste Disposal Sites in Indiana" (Bleuer, 1970), for greater details on the siting and operation of sanitary landfills.

Although the geographic and economic problems that arise in choosing a sanitary landfill site are complex, the delineation of broad areas that are generally well suited for the purpose is fairly simple. Most of the land that is best suited for refuse disposal is on the Valparaiso Moraine (figs. 1 and 12), where surface drainage is good, the till is thick and relatively impermeable, and the water table is generally well below grade.

Areas that afford intermediate suitability include those units mapped as lake clay (Qcl, fig. 12) and, to a lesser degree, gravel over till (Qgt, fig. 12). If the surface drainage is adequate or can be rendered suitable by grading or other techniques, and if the clay unit is sufficiently thick, the lake clay units can provide a good impermeable container for solid wastes. The major problems encountered while working a landfill in this material are: (1) difficulty in bulldozing clay, especially in winter when temperatures fall below freezing, (2) proximity to sand bodies within the lake sediment sequence (the sand bodies creating a potential contamination of ground water), and (3) poor stability of clay; graded slopes tend to creep under high moisture conditions.

The unit Qgt, gravel over till, has some potential for landfill sites, but sufficient borings must be taken to determine the elevation of the ground water table and thicknesses of gravel and till units. If the gravel member is sufficiently thin to be stripped off the underlying till without encountering the ground water table, the area may be suited to landfilling if criteria of the State Board of Health can be met for the remaining factors, including cover material, drainage, and unit impermeability.

The remaining areas in LaPorte County include sand and gravel deposits and scattered muck and peat deposits. These units are generally poorly suited for sanitary landfilling because of their high permeability and because of the fact that little, if any, impermeable cover material is associated with them.

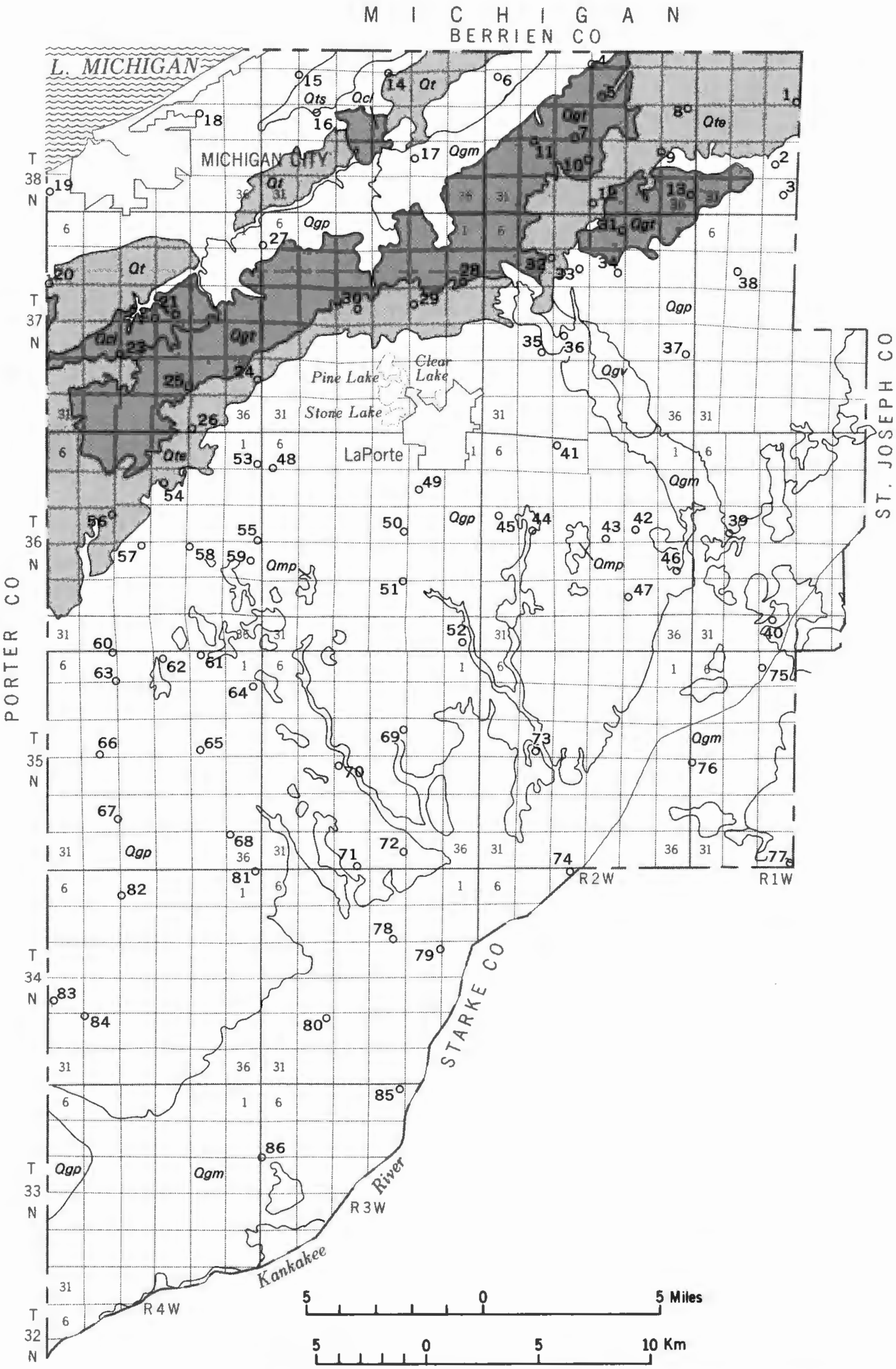

Figure 12. Map of LaPorte County showing land use suitability for sanitary landfilling.

EXPLANATION FOR FIGURE 12

o70

Auger hole location and number
(Sample descriptions are in appendix)

See plate 1 for descriptions of geologic units Qmp, Qgm, Qcl, Qgv, Qgp, Qgt, Qts, Qt, and Qte

Suitable

Suitable, but requires special caution because of abrupt changes in materials

Not suitable without severe preparatory alterations

With great care and expense, landfills can be engineered to function properly in these hazardous zones, but initial costs and maintenance may well offset the cost of transporting the waste to a suitable area farther away.

The best areas for landfilling, then, are to be found on the glacial till units (Qte and Qt). Good surface drainage, plenty of impermeable cover material, a depressed water table, and an impermeable floor are the basic requirements of any landfill. The first step in choosing a landfill site, after studying the basic information on hand, is to make test borings of the locality. The extreme variability of the glacial deposits in this county makes careful testing necessary.

Locations for many test borings are shown on the landfill suitability map (fig. 12), and data from them were used to supplement the surficial geologic information given. (See appendix.) The information from some borings does not agree with the older surficial mapping data. For example, the boring data for hole 57 indicate an upper unit of till, but figure 12 shows sand and gravel deposits. This emphasizes the need for subsurface control and the inadequacy of generalized soils and geologic maps for locating sanitary landfill sites.

Mineral Resources

The total value of minerals produced in LaPorte County in 1973 was $1.5 million. Principal mineral production was from four sand and gravel plants and one peat operation (table 2). In addition, several small sand and gravel pits, peat bogs, and marl deposits were operated on demand. The sand and gravel were used mainly as aggregate in concrete, but lesser amounts were used for road base material, road metal, fill, and masonry sand. Dune sand produced at Michigan City was used almost entirely for molding sand.

SAND AND GRAVEL

The best sand and gravel deposits in LaPorte County, as far as composition, quantity, and lateral continuity are concerned, are along the Kankakee Outwash and Lacustrine Plain (fig. 1). These deposits range widely

Table 2. Principal mineral producers in LaPorte County in 1973

Commodity	Producer	Address
Sand and gravel	Rieth Riley Construction Co., Inc., Hunt Lake Materials Div.	Route 6, Box 238 LaPorte 46350
Sand and gravel	Western Materials Co., Hanna Gravel Div.	Route 1 Hanna 46340
Sand and gravel	Webb's Sand and Gravel	Box 266 Kingsford Heights 46346
Specialty sand	Martin Marietta Aggregates, Industrial Sand Div.	East Dunes Highway Michigan City 46360
Peat	Millburn Peat Co.	Box 297 Otterbein 47970

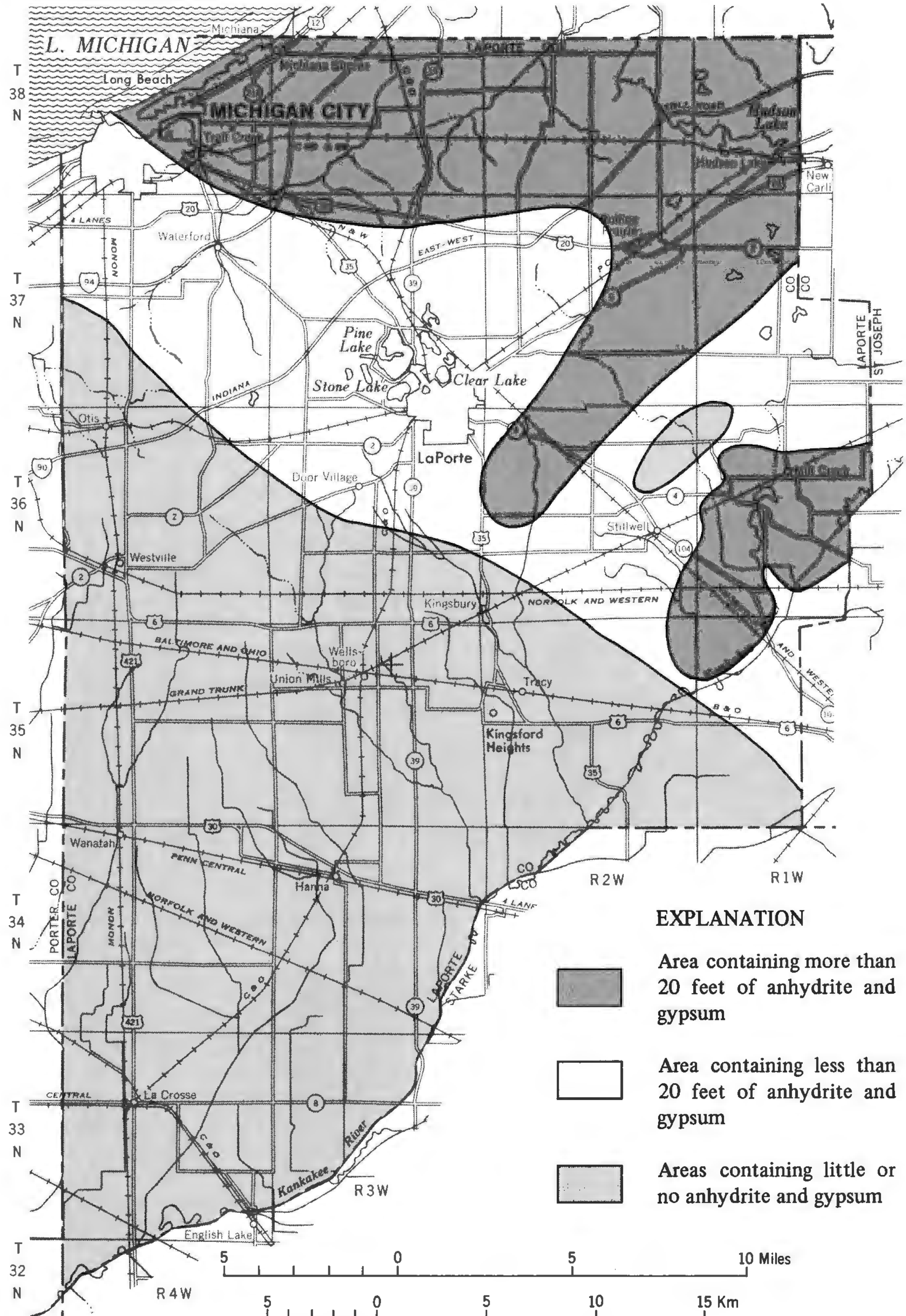

Figure 13. Map of LaPorte County showing thickness of gypsum and anhydrite in the Detroit River Formation.

in ratio of sand to gravel, but generally they have a higher percentage of sand than is desired for commercial aggregate operations.

Many small deposits of sand and gravel can be found within the area mapped as the Valparaiso Moraine (fig. 1 and Qte, pl. 1). These deposits are discontinuous and range greatly in size and composition. In some deposits beds of coarse gravels terminate abruptly and are replaced by clay or sand. Calculating reserves and producing proper size gradations from these deposits are difficult.

Specialty sand has been produced from dunes near Lake Michigan for many years. Dune sands are suitable for use as molding sand and for other special uses because of their high percentage of quartz and special distribution of grain sizes. Future development of these sand reserves is severely restricted because of urbanization in the Michigan City area.

CLAY

Clays deposited in ancient lakebeds are in the area mapped as the Calumet Lacustrine Plain (fig. 1 and Qcl, pl. 1). These clays are not now being used in LaPorte County, but similar clays are being used in Lake and Porter Counties for brick, pottery, and binder for molding sands.

PEAT AND MARL

Small quantities of peat and marl are produced in LaPorte County, principally for agriculture and horticulture. Scattered deposits are within the area mapped as the Valparaiso Moraine, but most are within the Kankakee Outwash and Lacustrine Plain. Numerous deposits occur in an eastward-trending belt, about 5 miles wide, that extends from Westville to the eastern county line near Fish Lake.

GYPSUM AND ANHYDRITE

These minerals are found together in nature, but they differ in composition, properties, and usefulness. Gypsum, a hydrated calcium sulfate mineral, has properties that allow it to be used to make wallboard and plaster products. Anhydrite, on the other hand, is a nonhydrated calcium sulfate mineral and has limited economic usefulness. It is generally considered to be an undesirable impurity in gypsum deposits, although some of it is used in manufacturing cement.

Beds of gypsum and anhydrite occur within the Detroit River Formation in the northeastern half of LaPorte County (fig. 13). These beds lie about 300 feet below the surface near LaPorte and Michigan City and increase to more than 600 feet in depth in the northeast corner of the county. As a rule, gypsum is found at shallower depths and anhydrite at deeper, but throughout the area variations occur in which gypsum thickens and anhydrite thins. The thickest known beds of gypsum, about 30 feet thick, are near the southeastern city limits of LaPorte.

LIMESTONE

Limestones of the Traverse and Detroit River Formations have potential use as crushed stone aggregate. They appear to have properties similar to stratigraphically equivalent rock units that are used elsewhere in Indiana for premium-quality crushed stone aggregate. Parts of these limestones are potential sources of cement raw materials.

Depths to these limestones range from about 100 feet in the southern part of the county to about 500 feet in the northeastern part. Glacial drift is probably too thick to permit open-pit mining, but underground mining might be practical, especially where limestone and gypsum could be produced together. The limestones directly overlying the gypsum beds are about 90 feet thick southeast of the LaPorte city limits.

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Glossary of Terms

Aquifer. A formation that is water bearing and is sufficiently permeable that the water can be extracted.

Artesian. Referring to ground water under hydrostatic head which will flow from a well or rise part way up a well pipe.

Bearing capacity. The amount of weight, expressed in tons per square foot, that a given body can support without failing.

Cary Subage. The most recent subdivision of the Wisconsinan Age.

Clay loam. A soil containing 27 to 40 percent clay and 20 to 45 percent sand.

Compressive strength. The stress, expressed in tons per square foot, that a given material can sustain without failing.

Creep. An imperceptibly slow, more or less continuous gravitational movement of soil or rock down a slope.

Drift. General term for all rock material transported by a glacier and deposited by the ice or associated running water.

Effluent. Here refers to the fluid discharged as waste from a septic system.

End moraine. A ridgelike accumulation of drift built along the terminal margin of a glacier.

Faults. Fractures in rock along which there have been displacements of the two sides relative to one another.

Ground moraine. A flat to gently rolling landform composed of glacial till.

Huron-Saginaw Lobe. A lobe of the Wisconsinan ice sheet that entered Indiana from the northeast corner of the state and lay between the Michigan Lobe to the west and the Erie Lobe to the south.

Impermeable. Referring to material providing a barrier to the transmission of a liquid; impervious.

Kankakee Arch. A large, broad fold, convex upward, in rocks of Paleozoic age extending from southeastern Wisconsin across northeastern Illinois into northwestern Indiana.

Lacustrine. Of or pertaining to a lake.

Lake Michigan Lobe. A lobe of the Wisconsinan ice sheet that occupied the Lake Michigan basin during Wisconsinan time.

Michigan Basin. A broad structural depression formed in Paleozoic rocks underlying Michigan, Lake Huron, Lake Michigan, and adjacent parts of Indiana, Illinois, Wisconsin, Ontario, and Ohio.

Nonhomogeneous. Referring to material with constituents of varied size, shape, arrangement, and mineralogy.

Outwash. Layered and sorted sediments washed from and deposited in front of a glacier.

Paleozoic. One of the eras of geologic time comprising the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods. It lasted from about 600 million years to about 225 million years B.P.

Paludal. Pertaining to a marsh or a swamp.

Plastically. Referring to the behavior of a material that can be molded into any form without rupturing and that will retain that form.

Pleistocene Epoch. A division of geologic time that essentially coincided with the Ice Age and that is the youngest epoch of the Cenozoic Era.

Silt loam. A soil composed of at least half silt and clay and sand.

Slump. The downhill movement of earth materials en masse.

Subgrade. A layer of material that is leveled off to receive the foundation of such a structure as a road or a building.

Texture. Referring to the size, shape, and arrangement of particles that constitute sediment.

Till. An unsorted conglomeration of earth materials ranging in size from boulders several tons in weight to fine silt and clay deposited directly by a glacier.

Valley train. The long, narrow body of material (outwash) deposited by a meltwater stream in a valley below a glacier.

Wisconsinan Age. The period of time during which the last of four major ice advances of the Pleistocene occurred; dating from about 220,000 years to 2,000 years B.P.

APPENDIX
AUGER HOLE DATA FOR LAPORTE COUNTY

Location No.	Depth (ft)	Description	Size analysis[1] Granule/sand/silt/clay (pct)	Calcite-dolomite content (pct)
1	0- 3	Upper weathered till surface	Sample at 3 ft	
	3- 6	Silt loam till	1.7/34.2/36.3/29.5	1.7
	6-10	Sandy loam till	Sample at 10 ft	
	10+	Sand	1.2/52.7/25.8/21.6	0.5
2	0-10	Sandy (till?)	Sample at 10 ft	
	10+	Silty sand	2.2/42.7/34.0/23.3	7.9
			Sample at 12 ft	
			2.3/80.6/11.8/ 7.5	9.2
3	0-20	Medium-brown sand with some clay inclusions	Sample near top	
			0.1/87.1/ 9.8/ 3.0	——
	20-30	As above		
	30-35	Gravel (crystallines) with sand		
	35-48	Clean medium sand with some pebbles		
4	0-10	Sand with some muddy sandy clay	Sample at 5 ft	
	10-14	Mixture of sand with pure clay	1.8/92.6/ 7.3/ 0.1	45.9 (mostly dolomite)
	14-20	Muddy water sand		
5	0- 3	Fill	Sample at 3 ft	
	3- 6	Silt loam till	0.3/21.1/34.2/44.8	0.7
	6-10	As above (sand at 10 ft)		
	10-30	Mostly sand with blue clay blebs at 11 ft; water sand at 30 ft		
6	0- 3	Sandy loam till	Sample at 3 ft	
	3- 6	Buff sandy loam till	0.5/14.9/52.8/32.3	1.0
	6-15	As above but increasingly drier with depth	Sample at 6 ft	
			2.0/35.7/32.1/32.2	6.2
	15-25	Blue-gray till	Sample at 16 ft	
			1.0/13.0/45.5/41.6	0.4
			Sample at 18 ft	
			2.5/72.8/19.5/ 7.7	24.9 (mostly dolomite)
7	0-12	Fine sand	Sample at 8 ft	
			0.0/58.3/34.2/ 7.4	2.2
	12-25	Wet sandy loam (till?)	Sample at 20 ft	
			0.2/59.0/30.8/10.3	24.4 (mostly dolomite)
8	0- 3	Oxidized sand and fill	Sample at 5 ft	
	3- 5	Qmp (muck and peat)	3.4/28.1/41.1/30.8	0.0
	5-10	Water sand, muddy	Sample at 10 ft	
	10-15	Buff medium sand with clay-silt binder	3.0/24.8/38.9/36.3	19.2 (mostly dolomite)
	15-25	As above		
	25-35	Wet till		

Location No.	Depth (ft)	Description	Size analysis[1] Granule/sand/silt/clay (pct)	Calcite-dolomite content (pct)
9	0- 1	Clay rich till		
	1- 5	Silty till		
	5-12	As above with sandy layer at 10 ft	Sample at 10 ft	
	12-17	Sandy loam with sand sand pockets; outwash sand and gravel	3.6/57.1/23.0/19.9	5.7
	17-20	Sandy loam (till?)		
10	0-15	Qmp (muck and peat)	Sample at 10 ft	
	15-25	Water sand with clay	0.4/41.5/44.3/14.2	55.4 (mostly calcium carbonate)
11	0-12	Medium sand	Sample at 15 ft	
	12+	Organic rich sand (Qmp)	3.5/57.3/29.3/13.4	1.3
12	0-20	Sandy loam till	Sample at 6 ft	
	20-25	As above with more sand and more highly saturated	0.3/39.5/37.6/22.9	0.5
			Sample at 15 ft	
			3.6/47.2/32.9/19.9	15.7 (mostly dolomite)
13	0- 3	Qmp and fill	Sample at 10 ft	
	3-25	Sand and gravel	14.$/84.2/ 9.0/ 6.8	0.7
	25-30	As above with increasing sand content		
14	0-25	Till	Sample at 10 ft	
			1.2/20.3/46.6/33.1	35.5 (mostly dolomite)
15	0-25	Saturated clay till		
16	0- 3	Oxidized sand and fill	Sample at 5 ft	
	3- 5	Qmp, strong organic odor	0.3/94.2/ 3.6/ 2.2	1.2
	5-10	Water sand, muddy	Sample at 10 ft	
	10-15	Light-buff medium sand with clay-silt binder	0.0/65.4/30.0/ 4.7	0.7
	15-25	As above	Sample at 25 ft	
	25-45	Till-like materials, saturated throughout; much silt and clay	2.4/24.2/42.5/33.3	26.5
17	0- 3	Fill and oxidized till	Sample at 5 ft	
	3- 5	Brown till	0.5/20.2/44.8/35.1	21.6 (mostly dolomite
	5-10	Buff fine sandy loam	Sample at 5 ft	
	10-15	As above (sandy at 15 ft)	0.1/74.6/17.2/ 8.2	28.4 (mostly dolomite)
	15-20	Muddy sand; good sand at 20 ft		
18	0- 3	Fine reddish sand	Sample at 3 ft	
	3-20	Buff sand with some iron oxide staining on quartz grains	0.0/97.4/ 1.5/ 1.1	
			Sample at 35 ft	
	20-38	Fine saturated water sand	0.2/96.2/ 3.1/ 0.7	
19	0- 8	Till; sand increases with depth	Sample at 5 ft	
	8-15	Good till, drier with increasing depth	2.7/39.7/35.4/24.9	8.3

20	0- 3	Sand	Sample at 6 ft	
	3-20	Till (Valparaiso Moraine)	1.4/ 8.1/44.3/47.5	9.6
21	0- 5	Sandy loam	Sample at 5 ft	
	5-40	Mostly sand with some gravel at 8 ft	6.2/56.0/24.6/19.4	0.5
22	0-35	Sand; increasing coarseness with depth	Sample at 5 ft	
			1.5/92.3/ 3.7/ 4.0	0.5
23	0-45	Sand; muddy sand from 5 to 25 ft	Sample at 15 ft	
			1.5/79.3/14.4/ 6.3	29.3 (mostly dolomite)
24	0- 3	Buff silty-clay loam	Sample at 7 ft	
	3- 7	As above; sand at 7 ft	4.1/ 7.7/69.8/22.5	0.7
25	0-13	Till	Sample at 8 ft	
	13-21	Till; sandier with depth	1.9/23.1/45.5/31.4	1.0
	21-30	As above; gravel at 30 ft	Sample at 13 ft	
			1.6/27.3/45.5/27.3	20.2 (mostly dolomite)
26	0- 7	Till	Sample at 7 ft	
	7+	Outwash sand and gravel	3.7/59.8/24.7/15.5	0.7
27	0- 3	Sand	Sample at 10 ft	
	3-30	Till	1.2/23.6/39.3/37.0	0.7
28	0- 3	Soft dry loamy till	Sample at 3 ft	
	3- 8	Light-brown dry till; increasing clay with depth	0.6/26.2/53.4/20.4	0.8
	8-15	As above	Sample at 15 ft	
			7.4/47.1/30.1/22.8	17.3 (mostly dolomite)
	15-21	Coarse gravelly till	Sample at 21 ft	
	21-22	Sandy layer in till	9.1/85.1/ 0.7/14.2	28.2 (mostly dolomite)
	21+	Till; sand layers at varying intervals		
29	0-25	Dirty sand	Sample at 7 ft	
			1.3/84.3/ 9.6/ 6.1	10.9
30	0- 8	Buff silt-loam till	Sample at 8 ft	
	8-15	As above, but hardpan at 15 ft	2.0/17.4/44.9/37.8	12.5 (mostly dolomite)
	15-40	As above; resistant layer at 32 ft	Sample at 18 ft	
			2.6/34.4/41.8/23.8	25.2 (mostly dolomite)
			Sample at 28 ft	
			0.9/23.3/41.9/34.7	19.0 (mostly dolomite)
31	0- 5	Sand and gravel, oxidized	Sample at 7 ft	
	5-20	As above; kame deposit	6.3/63.3/ 7.9/ 8.9	0.2
32	0-25	Sand	Sample at 5 ft	
			2.1/77.7/11.7/10.5	2.0
			Sample at 20 ft	
			0 /94.0/ 2.4/ 3.6	11.5

APPENDIX—Continued

Location No.	Depth (ft)	Description	Size analysis[1] Granule/sand/silt/clay (pct)	Calcite-dolomite content (pct)
33	0-35	Medium-brown sand	Sample at 10 ft	
			0.3/92.0/ 4.4/ 3.6	0.3
			Sample at 25 ft	
			1.5/93.3/ 3.1/ 3.6	3.6
34	0- 3	Veneer of Qmp with some coarse sand and gravel	Sample at 7 ft	
	3- 5	Medium sand, red, oxidized	1.4/91.5/ 4.6/ 3.9	0.0
	5-35	Sand; some clay blebs	Sample at 20 ft	
			0.0/94.2/ 3.4/ 2.3	28.5
35	0- 3	Fill	Sample at 12 ft	
	3- 7	Red sand with shale fragments	1.3/88.7/ 6.7/ 4.5	0.0
	7-35	Graded sand		
36	0-15	Sand	Sample at 8 ft	
	15-45	Sand with gravel lenses	0.7/93.9/ 2.1/ 3.9	0.5
			Sample at 15 ft	
			1.4/92.4/ 3.6/ 4.0	4.0
37	0- 3	Fill	Sample at 7 ft	
	3-25	Dirty sand	6.3/63.3/ 7.9/ 8.9	0.0
38	0- 3	Medium-coarse sand	Sample at 3 ft	
	3- 6	Fine sand	9.6/88.6/ 4.9/ 6.5	1.0
	6-25	Same		
39	0- 3	Fill		
	3-30	Sand with some fine gravel	Sample at 18 ft	
			16.6/85.4/ 9.0/ 5.6	6.7
40	0- 5	Sand and clay	Sample at 5 ft	
	5+	Coarse sand	2.1/66.3/18.9/14.7	0.6
41	0- 3	Qmp (muck and peat)	Sample at 6 ft	
	3-30	Coarse sand with gravel	2.6/79.0/11.9/ 9.2	0.2
42	0-20	Coarse sand	Sample at 8 ft	
			0.0/87.1/ 6.1/ 6.8	0.5
			Sample at 17 ft	
			0.0/91.6/ 4.2/ 4.2	0.5
43	0- 3	Fill	Sample at 19 ft	
	3-30	Sand and gravel	1.2/84.0/ 7.2/ 8.7	0.2
	30+	Mostly gravel		

44	0-20	Medium-brown sand	Sample at 10 ft		
			0.3/85.8/ 6.0/ 8.1	0.5	
			Sample at 16 ft		
			1.8/87.2/ 6.9/ 5.9	10.2	
45	0- 3	Fill	Sample at 7 ft		
	3- 7	Red sand	2.0/82.9/ 7.7/ 9.4	0.0	
	7-10	Gravel and coarse sand			
	10-15	Coarser gravel and brown sand			
	15-30	Mostly brown sand			
46	0-20	Medium-brown sand	Sample at 8 ft		
			0.8/87.1/ 5.3/ 7.7	0.6	
			Sample at 20 ft		
			1.6/91.0/ 5.0/ 5.0	0.6	
47	0-20	Medium sand	Sample at 25 ft		
			1.6/90.8/ 4.7/ 4.5	0.5	
48	0-12	Sand and gravel	Sample at 3 ft		
	12-27	Sand and gravel with mud binder	1.1/12.3/47.2/40.4	0.5	
			Sample at 15 ft		
			3.2/62.1/20.0/17.9	6.4	
49	0-20	Medium sand	Sample at 20 ft		
			2.5/93.8/ 0.4/ 5.8	5.1	
50	0-43	Sand; water sand at 12 ft	Sample at 10 ft		
			4.6/76.9/11.7/11.3	0.7	
			Sample at 40 ft		
			5.2/91.7/ 5.2/ 3.2	11.2	
51	0-10	Sand	Sample at 10 ft		
			3.7/81.3/10.4/ 8.3	0.5	
52	0- 5	Sandy silt loam	Sample at 15 ft		
	5-45	Sand (graded)	3.0/97.1/ 3.4/ 0.5	0.5	
53	0- 6	Sandy loam till	Sample at 6 ft		
	6-10	As above; sand at 10 ft	0.4/56.7/26.0/17.4	0.2	
54	0- 8	Fine sand to silt loam	Sample at 8 ft		
	8-15	Fine sandy silt, stiff	2.4/24.1/45.2/30.7	10.2	
	15-28	Buff silty clay	Sample at 21 ft		
			2.0/35.9/43.7/20.4	25.7	(mostly dolomite)
55	0- 3	Brown loamy till	Sample at 3 ft		
	3-10	Sandy loam till	1.1/29.2/32.0/38.8	4.2	
	10-20	Progressively sandier; sand at 14 ft	Sample at 10 ft		
			2.9/38.3/34.2/27.5	2.1	

APPENDIX—Continued

Location No.	Depth (ft)	Description	Size analysis[1] Granule/sand/silt/clay (pct)	Calcite-dolomite content (pct)
56	0- 5	Sand and gravel	Sample at 10 ft	
	5-10	Till; sandy silt loam	1.6/26.9/43.0/30.2	0.0
	10-15	As above; sand at 15 ft	Sample at 20 ft	
	15-40	Alternate layers of sand and gravel with clay-silt blebs	3.8/64.2/20.7/15.1	0.5
			Sample at 45 ft	
			0.3/13.3/65.7/21.0	0.2
57	0-13	Silt loam till	Sample at 8 ft	
	13-21	Progressively sandier with depth	1.9/23.1/45.5/31.4	1.0
	21-30	As above; gravel at 30 ft	Sample at 13 ft	
			1.6/27.3/45.5/27.3	20.2 (mostly dolomite)
58	0-15	Medium sand	Sample at 15 ft	
			0.9/85.2/ 7.5/ 7.5	0.5
59	0-20	Medium-brown sand	Sample at 20 ft	
			3.4/69.9/17.3/12.8	0.5
60	0- 7	Brown sand and Qmp	Sample at 7 ft	
	7-30	Brown moist sand	1.7/79.7/11.4/ 8.9	0.5
61	0-30	Medium sand	Sample at 10 ft	
	30-33	Coarse sand with shale fragments	0.7/89.2/ 5.1/ 5.7	0.9
			Sample at 30 ft	
			16.0/88.0/ 6.5/ 5.5	10.6
62	0-17	Medium sand	Sample at 12 ft	
	17-20	Coarse shaly sand	0.7/95.7/ 3.1/ 1.2	21.8 (mostly dolomite)
			Sample at 17 ft	
			8.2/95.9/ 2.6/ 1.5	19.6 (mostly dolomite)
63	0-20	Medium sand	Sample at 15 ft	
			4.3/71.9/18.4/ 9.7	1.0
			Sample at 20 ft	
			2.4/73.0/17.1/ 9.9	0.5
64	0-35	Graded sand and gravel	Sample at 35 ft	
			0.1/88.2/10.8/ 1.0	23.1 (mostly dolomite)
65	0-25	Graded sand; water sand at 17 ft	Sample at 17 ft	
			1.2/95.4/ -1.1/ 5.7	1.7
			(laboratory error)	
66	0-30	Graded sand; water sand at 15 ft	Sample at 23 ft	
			2.6/97.3/ 0.0/ 2.7	8.7

67	0-35	Graded sand, progressively coarser with depth	Sample at 5 ft 1.5/92.3/ 3.7/ 4.0	0.5
68	0-50	Graded sand and gravel; clay stringer at 20 ft and 35 ft; water sand at 22 ft	Sample at 50 ft 0.2/95.9/ 4.0/ 0.1	30.4 (mostly dolomite)
69	0-10 10+	Muck and peat and silty sand Sand	Sample at 10 ft 0.7/81.6/10.1/ 8.3	1.4
70	0-32	Sand; top 15 ft oxidized	Sample at 3 ft 1.3/85.6/ 6.7/ 7.7	0.5
71	0-25	Muddy sand	Sample at 8 ft 3.5/77.2/ 6.5/16.4 Sample at 23 ft 1.6/80.4/10.8/ 8.9	0.5 2.1
72	0-13	Sand; saturated from 3 ft down	Sample at 8 ft 0.5/86.7/ 7.0/ 6.3 Sample at 13 ft 0.3/88.5/ 5.5/ 5.9	1.2 1.6
73	0-31	Sand; saturated below 22 ft	Sample at 3 ft 1.4/78.2/12.8/ 9.0 Sample at 17 ft 0.3/94.5/ 0.5/ 5.0	3.6 1.0
74	0-25	Interstratified sand and gravel	Sample at 25 ft 3.5/96.6/ 0.4/ 3.0	14.2 (mostly dolomite)
75	0-25	Sand	Sample at 11 ft 0.1/65.0/31.8/ 3.2 Sample at 21 ft 15.0/97.7/ 0.1/ 2.2	1.2 7.0
76	0-25	Coarse sand	Sample at 15 ft 6.2/98.1/ 1.2/ 0.7	25.6 (mostly dolomite)
77	0-25	Sand, muck, and peat	Sample at 25 ft 1.0/97.5/ 0.1/ 2.6	6.3
78	0-10 10-21	Fill to 3 ft followed by muck and peat Muddy gravel	Sample at 11 ft 8.0/94.1/ 3.5/ 2.4	1.0
79	0- 7 7-12 12-20 20-35 35-50	Fill Qmp Muddy sand Poorly sorted water sand Pea gravel and coarse sand	Sample at 40 ft 8.7/91.6/ 7.4/ 1.0	13.6
80	0- 4 4-25	Qmp Sand with some clay	Sample at 20 ft 2.4/96.6/ 0.5/ 2.9	18.2 (mostly dolomite)

APPENDIX–Continued

Location No.	Depth (ft)	Description	Size analysis[1] Granule/sand/silt/clay (pct)	Calcite-dolomite content (pct)
81	0- 8	Road fill	Sample at 15 ft	
	8-15	Dirty sand	0.1/90.9/ 3.8/ 5.3	1.0
82	0-25	Sand; some silty material in top 3 ft	Sample at 3 ft 0.3/47.1/26.2/26.0	0.5
83	0-22	Sand; 1 ft Qmp on top	Sample at 12 ft 2.4/90.2/ 1.9/ 7.9	1.0
84	0-22	As 83	As 83	As 83
85	0-35	Sand and gravel; sand increasing with depth	Sample at 20 ft 5.7/95.3/ 5.0/ 0.3	18.9 (mostly dolomite)
86	0-21	Sand with some gravel	Sample at 5 ft 0.6/73.0/11.8/15.2	0.3

[1]Only the sand, silt, and clay fractions are used in computing the weight percentage of those size ranges, the granule percentage being computed separately as a function of total sample weight. Therefore, the percentages for sand, silt, and clay will add up to 100 percent with granule weights being considered separately.

OVERSIZED DOCUMENT

The following pages are oversized and need to be printed in correct format.

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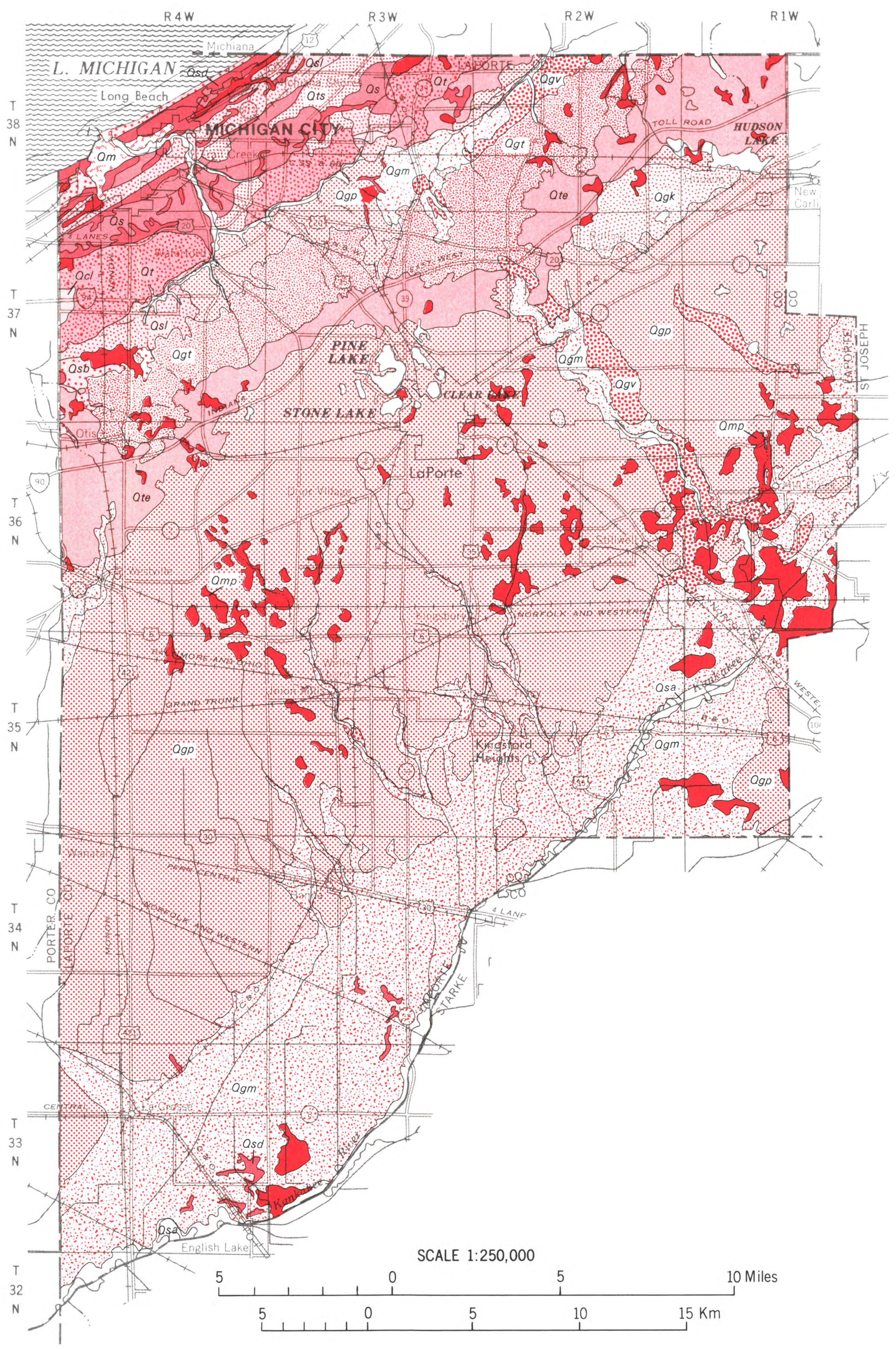
GEOLOGICAL SURVEY
JOHN B. PATTON, STATE GEOLOGIST



Unit and Description	Engineering Characteristics and Use	Mineral Resource Potential	Ground Water Resource Potential	Land Use Potential
UNCONSOLIDATED DEPOSITS — QUATERNARY (PLEISTOCENE)				
Recent				
Qm — Made and modified land. *Artificial fill and land substantially modified by the removal of unconsolidated deposits. Many small areas not mapped*	Major problems. Material is variable and in some places unknown. Subsidence due to compaction is to be expected. Tests for stability are advisable before planning structures or other uses requiring addition of load. In the north part of LaPorte, underlying lake clay permits subsidence under load.	None.	Unit contains little or no ground water. Because of variable nature of material, quality of water is questionable.	Variability of materials makes careful planning mandatory. Most of made land in LaPorte was created for industrial purposes. Adapting to other purposes would require materials inventory or engineering profiles.
Qsa — Silt, sand, and gravel. *Mostly alluvium, but includes some colluvial and paludal deposits. Martinsville Formation*	Major problems. Material is variable; loose sand and weak compressible clay are common. Water table is high; surface is subject to flooding. Not suitable for fill and poor as foundation material. Unified Soil Classification: GM, SM, ML, or CL.	A source of poor-quality sand and gravel in some places; in LaPorte may be underlain by good gravel sources along the Kankakee River.	Deposits yield some water, but are not, themselves, major sources of ground water.	Well suited to agricultural uses. Not suited to residential or industrial uses because of high water table and flood potential. Septic tanks and sanitary landfills are not practical.
Qmp — Muck, peat, and marl. *Paludal and lacustrine deposits. Martinsville Formation*	Major problems. Material has soft to very soft consistency and is easily compressed. Water table is high; flooding is likely. Poor strength factors make this unit poor as fill. Unified Soil Classification: OL, OH, or PT.	A source of organic material for agricultural use.	Some areas of peat contain considerable water, but organic acid content is generally too high for human consumption.	Areas best suited to wetland or woodland. Agricultural use is good where drainage is possible. Not suited to industrial or residential uses as a general rule.
Wisconsinan and Recent				
Qgm — Muck or silt over sand and gravel. *Outwash (mostly valley train) deposits of sand and gravel overlain in places by thin (generally less than 3 to 5 feet) lacustrine, paludal, or alluvial deposits of muck, peat, clay, silt, or fine sand. Martinsville Formation over outwash facies of Atherton Formation*	Upper part like Qmp; has soft to very soft consistency and is easily compressed. Underlying gravel is similar to Qgv/Qgp; is incohesive and nonplastic and has high porosity and permeability. Water table is high; area is subject to flooding. Bearing capacity of upper part is poor; lower part is fair to good. Unified Soil Classification rating for upper part: OL, OH, or PT; for lower part: GP, SW, SP, or SM.	Lower part is an important source of commercial sand and gravel. Upper part, where sufficiently thick, is a source of organic materials for agricultural use.	Sand and gravel deposits of lower part of unit are good aquifers from which high water yields are possible.	See explanation for Qmp above.
Qsd — Sand and some silt. *Dune deposits. Dune facies of Atherton Formation*	Material is generally incohesive, loose, and nonplastic. Porosity and permeability are moderate to high. Water table is seasonally high in low-lying areas. Bearing capacity is good. Unified Soil Classification: SP or SM.	Limited use as mortar and foundry sand.	Deposits yield some water but are thin; water table fluctuates or is low; supply is not dependable. Deposits serve as infiltration zones for Qgv.	Soils subject to drought and erosion. Suited to industrial or residential use. Septic tanks and sanitary landfills are not practical.
Qs — Sand and some fine gravel. *Outwash, lacustrine, and some beach deposits that have been reworked by wind action. Includes much eolian sand. Atherton Formation*	Material is generally incohesive, loose, and nonplastic. Porosity and permeability are modertate to high. Water table is seasonally high in low-lying areas and subject to ponding. Bearing capacity is fair to good. Unified Soil Classification: SP, SM, or SW.	A possible source of sand and gravel. In some place underlain by Qgp, a good source of gravel. Not of importance in this county, though.	As above.	As above.
Qsb — Sand and gravel. *Beach and shoreline deposits in bars, spits, deltas, and beaches. Includes some dune sand. Atherton Formation*	Material is generally incohesive, loose, and nonplastic. Porosity and permeability are high. Area subject to beach erosion. Bearing capacity is fair to good. Unified Soil Classification: GW, GP, SW, or SP.	A possible source of sand and gravel.	Poor.	Area subject to shoreline erosion and deposition; not stable near shore. Residential and industrial use is possible. Sanitary landfills are not practical.
Wisconsinan				
Qcl / Qsl — Clay, silt, and sand. *Lacustrine deposits. Qcl, mostly clay and silt; Qsl, mostly sand. Lacustrine facies of Atherton Formation*	Major problems. Material has soft to very soft consistency, moderate plasticity, and moderate compressibility. Permeability is low. Bearing capacity is poor. Compaction characteristics are poor. Unified Soil Classification: ML, CL, MH, or CH.	Has some potential as a source of clay for common clay products, but only weathered material is used, as calcium carbonate content of unweathered part is too high.	Poor.	Flooding, high water table, or perched tables are common. Construction problems abound because of plastic clay. Where wetness is controlled, sanitary landfills are possible.
Qgv / Qgp — Gravel, sand, and silt. *Outwash deposits. Qgv, valley train deposits; Qgp, outwash plain deposits. Outwash facies of Atherton Formation*	Material is incohesive and nonplastic. Porosity and permeability are generally high. Water seepage may cause slope failure in cuts.	An important source of commercial sand and gravel. But coarser size fraction is usually shale in this county.	Deposits are important aquifers. Infiltration areas should be protected from contamination.	Subject to drought in agricultural use. Low-lying areas are subject to flooding and seasonally high water tables. Septic tanks and sanitary landfills are not practical.
Qgk — Gravel, sand, and some silt. *Ice-contact stratified drift in kames and kame moraines. Kame facies of Lagro Formation*	Material is incohesive and nonplastic. Porosity and permeability are high. Bearing capacity is good. Water seepage may cause slope failure.	An important source of sand and gravel, especially east of LaPorte. Major problem is shale contamination.	Low.	Hilly topography limits residential and industrial use. Septic tanks and sanitary landfills are not practical.
Qgt — Sand, gravel, and till. *Undifferentiated ice-contact stratified drift, till, and dune sand in end moraines. Lagro, Trafalgar, and Atherton Formations*	Material is variable. Problems caused by mixing of many different kinds of deposits: cohesive to incohesive, plastic to nonplastic, etc. Perched and artesian water systems are common. Slope failure caused by seepage of ground water is common in hilly areas.	A fair to poor source of sand and gravel.	Not important in this county.	Sloping areas are subject to erosion; flat areas are wet. Septic tanks and sanitary landfills are not practical because of wetness and probable ground water flow.
Qts — Sand or gravel over till or clay. *Thin (generally less than 3 to 5 feet) deposits of dune sand and (or) outwash gravel and sand over till or over lacustrine clay in places in Michigan and northernmost Indiana. Part of Atherton Formation over Lagro and Trafalgar Formations*	Upper part is incohesive, nonplastic, and moderately porous and permeable. Lower part has medium to stiff consistency, moderate plasticity, and lower permeability than in the upper part. Bearing capacity is fair to good. Compaction characteristics are good. Unified Soil Classification for upper part: SW to SP; for lower part: ML, CL, MH, or CH.	Limited use potential for common clay products.	Some potential for domestic use only.	Suited to agricultural, industrial, and residential uses. Sanitary landfills are possible.
Qt / Qte — Till. *Includes some ice-contact stratified drift. Qt, mainly ground moraine deposits; Qte, mainly end moraine deposits; Lagro Formation*	Cohesive, soft to stiff consistency, and moderate plasticity. Permeability is low. Bearing capacity is fair to good. Subject to frost damage. Weathered material may swell when wetted. Seepage-induced slope failure is possible. Unified Soil Classification: ML, MC, or CH.	Limited if any.	Interlayers of sand and gravel yield water adequate for domestic use.	Depressions are subject to ponding. Generally suited to industrial, agricultural, or domestic use. Septic tanks and sanitary landfills are possible in well-drained areas.

GEOLOGIC PROPERTIES AND LAND USE POTENTIAL, LA PORTE COUNTY, INDIANA

By John R. Hill

1979

Modified from Indiana Geological Survey Regional Geologic Map 4, 1970, and Regional Geologic Map Series, Supplementary Chart No. 1, 1973.