Ontario Geological Survey

Aggregate Resources Inventory Paper 4

AGGREGATE RESOURCES INVENTORY OF TOWN OF PELHAM REGIONAL MUNICIPALITY OF NIAGARA SOUTHERN ONTARIO

by

Staff of the Engineering and Terrain Geology Section

Ontario Geological Survey

1980

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CONTENTS

Page

TABLES

FIGURES

MAPS
(back pocket)

ABSTRACT

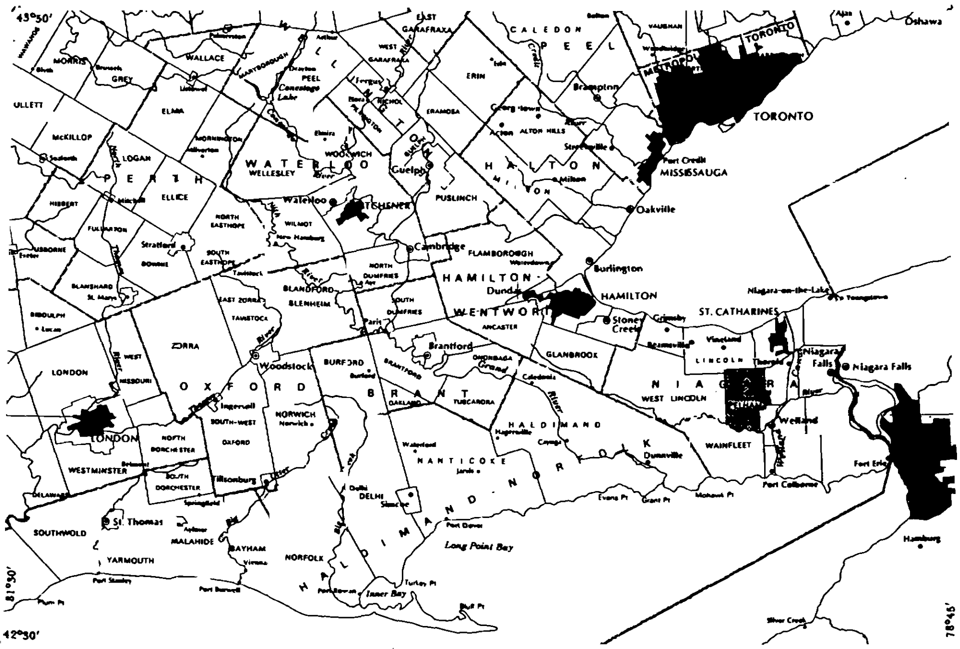

Figure 1 - Key Map Showing Location of The Town of Pelham. Scale 1: 1 800 000.

An inventory and evaluation of aggregate resources, which includes crushed stone derived from bedrock as well as natural sand and gravel, was completed for the Town of Pelham in 1979. This is part of the Aggregate Resources Inventory Program for townships and municipalities designated under The Pits and Quarries Control Act, 1971. The aggregate resources in the town have been assessed according to standards developed for the Program.

In the Town of Pelham, three areas containing significant amounts of sand and gravel have been selected for possible resource protection. Selected Sand and Gravel Reosurce Areas have an area of 2030 acres (820 ha). An estimated 1090 acres (440 ha) are currently available for extraction, containing possible resources of 95 million tons (86 million tons). The available parts of the Selected Areas represent 10 percent of the total area occupied by sand and gravel deposits in the town and 6 percent of the total resource tonnage.

Selected Sand and Gravel Resource Area 1, near Fonthill, is part of the Fonthill Kame deposit and constitutes the most important natural aggregate deposit in the Niagara Peninsula. The deposit contains an estimated 41 million tons (37 million tonnes) of sand and gravel suitable for a range of road-building and construction aggregates.

Selected Sand and Gravel Resource Areas 2 and 3 are also parts of the Fonthill Kame deposit. These areas are similar in texture and composition to Selected Area 1. The two Resource Areas contain an estimated 40 million tons (36 million tonnes) and 14 million tons (13 million tonnes) respectively.

Generally, the Town of Pelham has large possible resources of sand and gravel, and is a very important regional source of road-building and construction material. Care should be taken to ensure the continuing availability of as much of these resources as possible.

Possible aggregate resources derived from bedrock formations in the Town of Pelham are of only one type. Stone from the Gasport Member of the Lockport Formation is suitable for building stone and a range of crushed stone products for road building and construction. Two areas have been selected for resource protection. They have an available acreage of 350 acres (142 ha) and contain possible resources of 63 million tons (57 million tonnes).

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

AGGREGATE RESOURCES INVENTORY OF THE TOWN OF PELHAM

BY
STAFF OF THE ENGINEERING
AND TERRAIN GEOLOGY SECTION

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1976, the total tonnage of mineral aggregates extracted was greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1977).

Although mineral aggregate deposits are plentiful in southern Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand, gravel and crushed bedrock. The most recent information available has been used to prepare the reports. As new information becomes available, revisions may be necessary.

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References). Wherever possible, field examination of potential resource areas was also undertaken to confirm interpretations made in the office. Field methods included the examination of natural and man-made exposures of granular material. Most observations were made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-size fragments in the deposit. Observations were also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing and hand-augering techniques were used to assess subsurface materials. Air photos at various scales were used to determine the continuity of deposits, especially in areas of limited subsurface information.

In the office, the pit data were supplemented by information on file with the Engineering Materials Office of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under The Pits and Quarries Control Act, 1971 were obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate thickness estimates, or to indicate the presence of buried granular material. These records were used only in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a township base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows: First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot thick layer of sand and gravel, one acre in extent, assuming an average density of 110 pounds per cubic foot.

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 represent only those parts of the deposit lying outside licenced areas (Column 2).

Two successive subtractions are made from the unlicenced area. Column 3 accounts for the number of acres unavailable due to the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage presently available for extractive development and/or resource protection.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of favourrable bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated workable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of a workable thickness of 60 feet (18 m) is used. Volume estimates are then multiplied by 3600 (the estimated weight in tons of a one-foot thick section of dolostone, one acre in extent, assuming a bulk density of 165 pounds per cubic foot).

Resources of sandstone are calculated using a bulk density estimate of 146 pounds per cubic foot or approximately 3200 tons per acre. Shale resources are calculated on the basis of a bulk density estimate of 150 pounds per cubic foot.

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel as well as bedrock-derived aggregates are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975,p.7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

PART II - DATA PRESENTATION AND INTERPRETATION

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources", shows the distribution of bedrock formations, the distribution of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Map 1 is derived directly from the existing surficial geology maps of the area or from air photo interpretation where surficial mapping is incomplete. It shows the extent of sand and gravel deposits within the study area and serves as a base for the calculation of the total sand and gravel resources.

Map 1 presents a summary of all available information related to the quantity and quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbol which identifies each deposit. The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for a given deposit. These components are illustrated by the following example:

Gravel Content **Geological Type**

$$G\ 2\ \frac{OW}{C}$$

Thickness Class **Quality**

This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess fines may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate makes up less than 35 percent of the whole deposit. "G" indicates that the aggregate probably contains more than 35 percent gravel. If no information is available, the letters are omitted.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identify the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identify the main quality limitations that may be present in the deposit as discussed in the next section.

The other information presented on Map 1 is designed to give an indication of the present level of extractive activity in the study area. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits are also identified and numbered on Map 1 and described in Table 2.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary, and tertiary. These areas are identified on Map 2 by different shading patterns.

Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by a medium-grey tone on Map 2.

Selected Aggregate Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such resource areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by a light grey tone on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resource areas in a municipality, they may contain large quantities of sand and gravel and should be considered an integral component of the aggregate supply of the municipality.

Areas of tertiary significance are indicated on the map by a dashed line but have no grey tone. They are neither rated nor considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the municipality is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

DEPOSIT SIZE

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6m) and containing more than 35 percent crushable gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

AGGREGATE QUALITY

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S), fines (C), oversize (O) and lithology (L).

Three of the indicators deal with grain size distribution. The "gravel content", (G or S), indicates the suitability of aggregate for various uses. Deposits containing more than 35 percent crushable gravel are considered to be favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess "fines" or high silt and clay content may severely limit the potential use of an aggregate. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent "oversize" particles (those greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is "lithology". Just as the unique physical and chemical properties of bedrock formations determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high-quality uses. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O" or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations. The Engineering Materials Office of the Ontario Ministry of Transportation and Communications has recently compiled a detailed assessment of aggregate suitability for selected areas in southern Ontario. This material has been consulted extensively in preparation of the inventory reports.

LOCATION AND SETTING

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of those natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, power-lines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3.

The assessment of sand and gravel deposits and bedrock resource areas with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report but readers are encouraged to discuss them with personnel of the Ontario Ministry of Natural Resources' District Office.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain at roughly the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, bedrock topography, drift thickness maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources), and from geotechnical well data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the labelled bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of the areas of thin drift are shown by three tones. The darkest tone indicates areas where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas of primary significance due to their easy access. The medium tone indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these also represent potential resource areas. The lightest tone indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive sand and gravel deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the municipality. Those areas which are licenced for extraction under The Pits and Quarries Control Act, 1971 are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, and licenced acreage of the quarry and an estimate of face height. Unlicenced quarries are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and uses of the bedrock formations found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations of sufficient thickness to support quarry operations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource is usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of bedrock resource areas has been restricted to a single level of significance. Three factors support this approach. Quality and quantity variations are gradual. The areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material. Since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The wider range of possible resource areas allows greater flexibility in locating quarry operations away from areas of intensive land use competition. The Selected Areas are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such a resource area may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

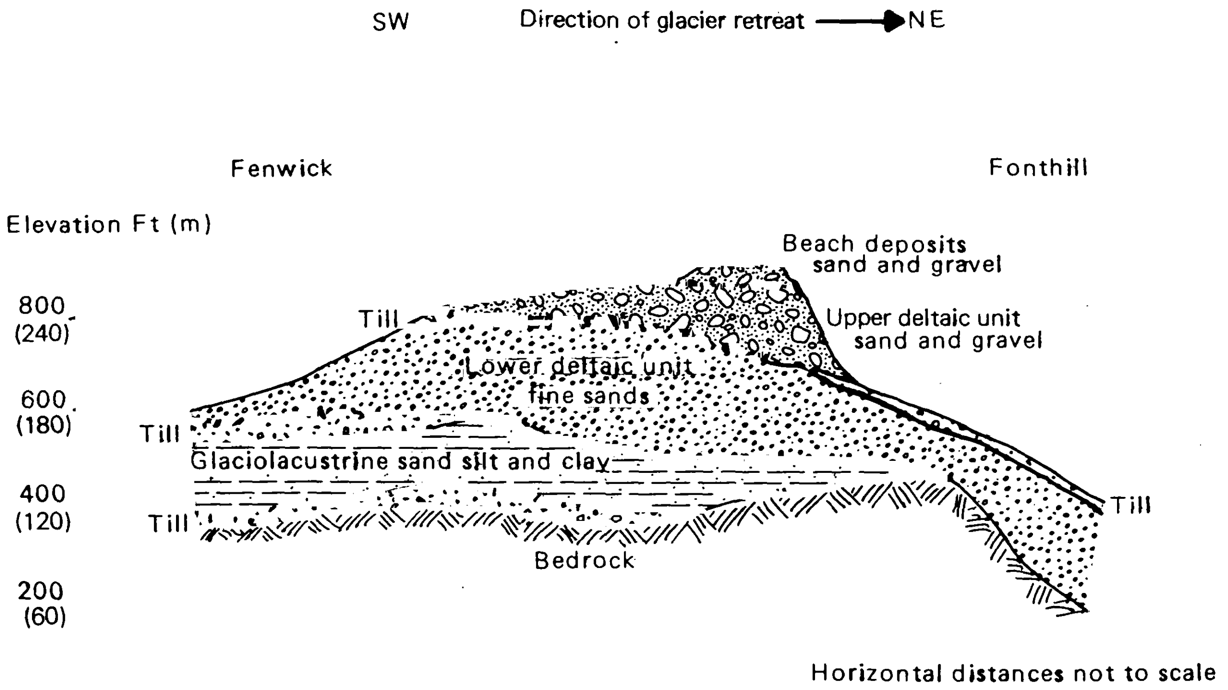

Figure 2 - Generalized Internal Structure of the Fonthill Kame (southwest ridge). After Feenstra, unpublished.

LOCATION AND POPULATION

The Town of Pelham occupies a rectangular area of 20,896 acres (8457 ha) in the central portion of the Regional Municipality of Niagara, northwest of the City of Welland (see Figure 1). It is shown on the Niagara sheet of the National Topographic System, at a scale of 1:50 000. The Town of Pelham was created by the amalgamation of Pelham Township and the Village of Fonthill on January 1, 1970, as part of the incorporation of the Regional Municipality of Niagara.

The Village of Fonthill, situated at the eastern boundary of the town, is the local trade and retail center and a recent focus of residential development. Other settlements are Effingham, North Pelham, Fenwick, Pelham Centre, Ridgeville, and Pelham Corners.

The total population of the Town of Pelham was 10,808 in 1978 (Ontario Ministry of Intergovernmental Affairs 1979), and figures from previous years indicate that the rate of population growth has been less than one percent annually. Population projections recently made by the Regional Planning Branch of the Ontario Ministry of Treasury, Economics and Intergovernmental Affairs (1976, p.133) indicate that by the year 2001, the population of the Town of Pelham may be between 12,300 and 12,800; an increase of approximately 15 percent over the present population. Thus the Town of Pelham has experienced low to moderate growth in the recent past and is expected to grow at similar rates in the near future.

The Official Plan for the Town of Pelham indicates that rural-residential development will be restricted throughout the town, and urban-residential development will be restricted to the area south of Fonthill. Rural-residential development northwest of Fonthill, or a northwest extension of the village would limit the extraction of parts of the regionally important Fonthill Kame sand and gravel deposit.

Access to most of the town is excellent, and a variety of transport modes are available. Road access is provided by a well developed network of paved and gravel-surfaced regional roads, and by King's Highway 20, which trends northeast through Fonthill. In addition, the area is served by railway lines and by the Welland Canal.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography and distribution of unconsolidated sediments in the Town of Pelham, including sand and gravel deposits, are the result of extensive glacial activity which took place in Late Wisconsinan time during the Pleistocene Epoch. This period of time, which lasted from approximately 23,000 to 12,500 years ago, was marked by the repeated advance and retreat of immense continental ice sheets.

The Town of Pelham was covered several times during Wisconsinan time by a lobe, or submass of the continental ice sheet, which advanced southward out of the Lake Ontario basin and across the Niagara Peninsula. Deposits representing glacial events of the Early and Middle Wisconsinan are not present, or are buried by younger sediments deposited by the last major oscillations of the "Ontario-Erie" ice lobe (Feenstra 1972a, 1972b, 1975, unpublished).

The last major advance of the ice mass, approximately 13,000 years ago, resulted in the deposition throughout the Niagara Peninsula of Halton Till; a brownish, silt to clayey silt till (Feenstra, upublished). The Halton Till has a low stone content and is of no value as an aggregate resource. In the Town of Pelham, the Halton Till is buried by younger, glaciolacustrine deposits.

The melting and retreat of the Ontario-Erie ice lobe northward from the peninsula was accompanied by the formation of several successive glacial lakes, which at different times covered most of the Niagara Peninsula. The lakes were formed by the ponding against the ice margin of vast amounts of glacial meltwater at successive stages in its retreat. Feenstra (unpublished) and others have identified at least eight distinct lake levels that were formed under conditions of a fluctuating ice front in a 400-to 500-year period following the deposition of the Halton Till. Large amounts of fine-grained sediment were deposited in the glacial lakes and glaciolacustrine sand, silt, and clay deposits cover much of the Niagara Peninsula, including most of the Town of Pelham. These deposits contain virtually no coarse-grained material and are of little value as aggregate resources.

While the ice margin was relatively stationary at the Niagara Escarpment, meltwater poured off the ice into the glacial lakes, depositing stratified sand and gravel in an ice-contact delta deposit known as the Fonthill Kame. Feenstra (unpublished) describes the deposit as follows: "This large ice-contact deltaic complex rises between 40 to 76 metres above the surrounding lake plain on the upland (Haldimand Clay Plain) near the head of the Twelve Mile re-entrant valley in the Niagara Escarpment. It consists of three ridges merging in the area between Effingham and Fonthill: one to the southwest extending for about 5 kilometres to Fenwick, another for about 3 kilometres to the southeast in the direction of Welland, and a third also for about 3 kilometres west-northwest to North Pelham... The area of coalescence is marked by a scarp and a platform above it at elevation 830 feet. Multiple beach ridges occur on top of this platform, and the crest of two of them rises to elevations slightly above 850 feet."

The shape and extent of the Fonthill Kame deposit can be seen on Map 1. Figure 2 shows that the internal structure and stratigraphy of the deposit consist generally of three units. The lower deltaic unit rests on glaciolacustrine silt and clay and forms the base of the deposit. It consists almost entirely of well sorted and stratified fine to medium sand. The sand is overlain by an upper, coarser deltaic unit which in places is more than 100 feet (30 m) thick. The highest portions of the upper deltaic unit have been reworked by wave action to form thin beach deposits.

The northward retreat of the Ontario-Erie lobe, below the Escarpment, permitted meltwaters to drain eastwards. The consequent lowering of lake levels led to the gradual, eastward, progressive re-emergence of the Niagara Peninsula. The re-emergence marked the end of glacial activity in the region.

Postglacial erosional and depositional processes have been of relatively minor importance in the area. Some extensive stream erosion has taken place, however, on the flanks of the Fonthill Kame and along the tributaries of Twelve Mile Creek.

EXTRACTIVE ACTIVITY

The Town of Pelham has large possible resources of sand and gravel in the Fonthill Kame deposit, and has been the traditional source for much of the road-building and construction aggregate used in the eastern portion of the Niagara Peninsula. The peninsula, as a whole, has very low possible resources of sand and gravel, and the Fonthill Kame deposit constitutes a resource area of strategic importance in minimizing the cost of construction in the region. Much of this resource area is presently being threatened by residential and other development, and comprehensive resource management plans are required to ensure the availability of as much of the remaining aggregate as possible.

Extractive activity in the town has been restricted to the Fonthill Kame itself. Several pits have been opened in the deposit in the past. Some were abandoned after designation of the town under The Pits and Quarries Control Act, 1971. At the time of writing, three areas were licenced to operate under the terms of the Act (Table 2). The pits are all located along the northwestern flank of the kame, in the coarser upper deltaic unit.

The licenced sources occupy 462.5 acres (187.7 ha) according to pit site plans on file Regional and District Offices of the Ontario Ministry of Natural Resources. Using resource calculation techniques similar to those outlined in the Introduction, the presently licenced properties are estimated to contain possible resources of 7.3 million tons (6.6 million tonnes) of sand and gravel. The aggregate is suitable for a range of pit- and crusher-run gravel and for some higher-quality, blended products. Areas of gravel cementation and high siltstone content limit uses in some areas.

Total production figures from the licenced sources have been compiled on an annual basis by Regional and District Offices of the Ontario Ministry of Natural Resources, since designation of the town. The average annual production during the last 5 years has been approximately 1.2 million tons (1.1 million tonnes).

Assuming equal or greater future production rates, the remaining licenced resources in the Town of Pelham will be depleted in the relatively near future. Considering the strategic importance of the Fonthill Kame deposit for the entire Niagara Peninsula, it is necessary to protect as much of the remaining unlicenced resources as possible.

SELECTED SAND AND GRAVEL RESOURCE AREAS

The sand and gravel deposits selected for possible resource protection in the Town of Pelham are shown on Map 2. The three areas of primary significance are portions of the Fonthill Kame. They are indicated on Map 2 by a dark tone and are numbered sequentially. The numbers correspond to the descriptions and tonnage calculations given on Table 3.

The Selected Sand and Gravel Resource Areas cover an area of 2030 acres (820 ha) and have available resources of 95 million tons (86 million tonnes).

The available acreage of the Selected Sand and Gravel Resource Areas represents 10 percent of the total area of sand and gravel deposits in the Town of Pelham and 6 percent of the total resource tonnage. The Selected Areas contain virtually 100 percent of the town's resources of crushable aggregate.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 forms the highest elevation portions of the Fonthill Kame. The area has an available acreage of 270 acres (109 ha) and has been relatively unexploited. Its western edge is presently under licence to TCG Materials Limited.

Several beach ridges occur in the upper deltaic material and form the uppermost coarse unit in the deposit. The beaches vary from 15 to 30 feet (5 to 9 m) in thickness, and consist of well sorted and stratified sand and gravel containing up to 50 percent gravel.

The beach deposits are underlain by 30 to 50 feet (9 to 15 m) of fine- to coarse-grained, cross-bedded, gravelly sand and some gravel which compose the upper deltaic unit of the deposit. Although gravel content throughout the deposit is low and variable, coarse aggregate is most plentiful in Area 1 and ranges as high as 50 percent.

As in other portions of the Fonthill Kame, the petrographic quality of both the coarse and fine fractions is poor. The constituent lithologies are predominantly weathered sandstone, siltstone, and shale eroded from the Queenston Formation and from the Clinton and Cataract Groups at the base and on the face of the Niagara Escarpment. In places, extensive beneficiation, including washing and jigging is required to produce acceptable crushable aggregate (Deike 1978). Blending with quarry screening is another beneficiation method used in the area to produce acceptable concrete and asphaltic aggregate. In some areas the material cannot be made acceptable and is suited only for lower specification uses. Beneficiation is an acceptable economic process due to the limited supply of crushable gravel throughout the region.

In some areas the gravel has been cemented by calcium carbonate precipitated from percolating groundwater. Sections of cemented gravel form large dense masses which are extremely difficult to process and impede extraction (Deike 1978). Recent testing in the northern part of Area 1 has confirmed that cementation is common, though erratically distributed throughout the deposit (Gartner Lee and Associates 1978).

Resource tonnage values in Area 1 were calculated separately for the beach and deltaic portions of the deposit. Assuming an average deposit thickness of 60 feet (18 m), the total possible resources in both deposit types are estimated to be 41 million tons (37 million tonnes).

The soil and drainage characteristics in the Resource Area make most of the Fonthill Kame deposit well suited for growing crops. As a result, vineyards and orchards have been cultivated throughout the area.

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 totals 1290 acres (520 ha) of the upper deltaic sands and gravels deposited in the two southerly trending ridges of the Fonthill Kame. Only the uppermost portions of the underlying sandy deltaic deposit presently exposed in pits in the area have been included in the Resource Area. Most of the extractive activity in Area 2 and in the deposit as a whole, is centred on the area of coarsest gravel, along the northerly ice-contact slope of the southwesterly trending ridge. The unexploited area, south of Highway 20, contains mainly stratified sand and very little gravel.

A licenced pit, operated by Moyer Sand Division of Steed and Evans Ltd., is located along the north slope between Cream and Centre Streets and is the largest property in the area. It has produced large amounts of aggregate in the past. This source is virtually depleted and much of the area has been rehabilitated. Faces in the pit expose 25 feet (8 m) of fine-to coarse-grained gravelly sand, commonly cemented, overlain by 5 feet (2 m) of weathered, fine-to coarse-grained gravelly sand, and underlain by 25 feet (8 m) of fine to medium sand. The gravel and sand portions of the deposit both contain a high siltstone percentage (Feenstra, unpublished).

Other pits in the vicinity, such as that operated by TCG Materials Ltd., east of Centre Street, expose similar material, generally characterized as 25 feet (8 m) of upper deltaic unit sand and gravel underlain by at least 30 feet (9 m) of fine-to medium-grained sand of the lower unit. The coarser material has been used for a range of crushed aggregate products, but as in Selected Resource Area 1, extensive beneficiation of the gravel is necessary, due to the large amounts of unsound lithologies. Even with beneficiation the aggregate may not be suitable for some high specification uses, such as hot-laid asphaltic aggregate. The lower unit deltaic sands are used in various products including asphaltic and blending sand but again, are petrographically poor.

Extensive urban and suburban development, especially on the southeastern ridge of the Resource Area, has made much of the aggregate unavailable for extraction. In addition, former extractive activity has been moderate to high. The area currently available for extraction is thus calculated to be 530 acres (214 ha). Assuming an average deposit thickness of 30 feet (9 m), possible resources are estimated to be 40 million tons (36 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Sand and Gravel Resource Area 3 totals 355 acres (144 ha) and constitutes the small ice-contact ridge which trends west from the main deposit to the intersection of Metler Road and Cream Street.

As in the other Resource Areas, the deposit consists of an upper deltaic sand and gravel unit (reworked into beach gravel in places), underlain by a lower unit of deltaic sands. The thickest portion of the upper unit, in the vicinity of Moore Drive, may be up to 75 feet (23 m) thick (Feenstra, unpublished). The lower unit in this area may be quite fine-grained and contains large amounts of silt. The quality of the aggregate is generally similar to that in Resource Areas 1 and 2, and the possible uses of the aggregate are subject to the same limitations.

Physical and cultural constraints reduce the area available for extraction to 290 acres (117 ha). Assuming an average deposit thickness of 20 feet (6 m), possible resources in Selected Area 3 are estimated to be 14 million tons (13 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

Possible resources of fine-grained aggregate in the Fonthill Kame complex are extremely large, and cover much of the central portion of the Town of Pelham. Granular material of all types are scarce throughout the Niagara Peninsula so resource protection should be provided for as much of the existing material as possible. The entire extent of fine-grained sediments in the area has thus been selected as a Resource Area of Secondary Significance. The Area is shown by a light tone on Map 2, and is not numbered.

The aggregate consists of lower deltaic sand and silts and associated fine-grained, nearshore lacustrine sediments. A small property licenced to Mrs. E.M. Bishop, just west of Ridgeville, exposes uniformly fine- to medium-grained sand of the lower deltaic unit, which may be representative of much of the material in the Resource Area. Further to the south, Feenstra (unpublished) notes that several small abandoned pits south of Camboro Road and some valley cuts in Twelve Mile Creek to the north expose deltaic and nearshore lacustrine sand which is very fine-grained and very silty. This sand is probably of little commercial value.

BEDROCK GEOLOGY

The Town of Pelham is underlain by a succession of sedimentary shales, limestones and dolostones of Ordovician and Silurian age. The formations are exposed in east-west trending bands and have a gentle regional dip to the south. They occur in the Town of Pelham in sequences; from the oldest units in the north, to the youngest in the south. The distribution of the formations is shown on Map 3.

The bedrock surface is almost completely obscured by overlying drift, but its general topography can be inferred from various subsurface data (Feenstra, unpublished). The bedrock surface is generally smooth and level, but is dominated by a broad, deep depression formed by a preglacial river, which trends northward to the Escarpment through the central portion of the town.

The distribution and thickness of sediments overlying the bedrock surface varies from 100 to 400 feet (30 to 122 m), except on the northern edge of the town (Feenstra, unpublished). In the north, near the brow of the Niagara Escarpment, drift is generally less than 50 feet (15 m) thick and bedrock exposures are common, especially in parts of Twelve Mile Creek valley, where postglacial stream erosion has cut down to the bedrock surface.

The Queenston Formation, a red shale found at the base of the Escarpment, is the oldest rock formation in the area. It has been used elsewhere for the manufacture of brick and tile products (Guillet 1967).

The Queenston Formation is overlain in the Escarpment face by a succession of limestones, dolostones, shales and sandstones which collectively form the Clinton and Cataract Groups. Several of the formations in both groups have been extracted in the past at various places in the Province for use as building stone, crushed stone and for cement (Hewitt 1960, 1964; Vos 1969a, 1969b).

The Clinton and Cataract Groups are overlain by the hard, resistant dolostones and limestones of the Lockport Formation. These rocks form the face and "cap rock" of the Escarpment. The Lockport Formation is the uppermost bedrock unit in the northern third of the Town of Pelham. The Gasport Member, a subunit of the Lockport, is being mined nearby and is suitable for the production of cement, aggregate and building stone (Feenstra, unpublished). The Eramosa Member, the other subunit of the Lockport, is mined for aggregate elsewhere in the region.

The Guelph Formation, a high purity, fine-grained dolostone is an important source of cement elsewhere in the Province. The formation is present in the Town of Pelham but is buried too deeply to be mined economically. Similarly, the Salina Formation is buried too deeply to be mined in the Town of Pelham. This latter formation is mainly dolostone and shale, but has significant salt and gypsum deposits which have been mined elsewhere in the Province.

The Queenston Formation, Clinton and Cataract Groups, and Gasport and Eramosa Members have potential mineral resources in the Town of Pelham. The Queenston Formation and the lower part of the Clinton Group have been used in the past. They are unlikely to be used in the future because the areas of exposure are too small for modern extraction methods and exposures are in areas of significant recreation potential.

A quarry now long abandoned, was opened in the Lockport Formation and the upper part of the Clinton Group. It provided material for cement manufacture, but other rocks in the area are better suited to present manufacturing methods (Goudge 1938, p.278). The hilly, irregular topography of the area makes extraction difficult. The same hilly, irregular topography has significant aesthetic and recreational value.

The Gasport Member (Lockport Formation) is presently being quarried by Walker Industries Ltd., near Thorold and elsewhere in the region (Telford, Liberty and Feenstra 1976; Vos 1969b). It is suitable for use as cement, aggregate and building stone.

SELECTED BEDROCK RESOURCE AREAS

Two areas of the Gasport Member (Lockport Formation) overlain by thin drift have been selected for possible resource protection in the Town of Pelham. The selected Areas are numbered and identified by a diagonal line pattern on Map 3. Both Areas lie within an area of "possible interest for quarry development" identified and discussed by Vos (1969a; 1969b, p.27). The Selected Bedrock Resource Areas are defined by the 25-foot (8 m) drift thickness contour line and are underlain by "brown fine crystalline Lockport dolomite ....It is estimated that a section of up to 50 feet of quarriable rock is available in this area. "(Vos 1969b, p.27).

SELECTED BEDROCK RESOURCE AREA 1

Selected Bedrock Resource Area 1 comprises 225 acres (91 ha) at the northern boundary of the town, just south of Rockway Falls. Constraints on extraction are minimal and there is no evidence of any previous extractive activity. The area currently available for extraction is thus calculated to be 210 acres (85 ha). Assuming a workable thickness of 50 feet (15 m), possible resources in Area 1 are estimated to be 38 million tons (34 million tonnes) of crushed stone suitable for a variety of road-building and construction uses.

SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2 covers 165 acres (67 ha) to the east of Area 1. The geologic boundary in the Area defines the brow of the Niagara Escarpment, and there are exposures in several localities. In sum, 15 acres (6 ha) of bedrock are exposed and 150 acres (61 ha) are covered by less than 25 feet (8 m) of drift.

Constraints in the form of houses and local roads pose significant limitations on extraction. Former extractive activity is indicated by the presence of one unlicenced quarry. The total area thus available is calculated to be 140 acres (57 ha). Assuming a workable thickness of 50 feet (15 m), total possible resources in Area 2 are estimated to be 25 million tons (23 million tonnes).

SUMMARY

The Fonthill Kame deposit is a very important regional source for sand and gravel and careful planning should be undertaken to preserve as much of the aggregate as possible for future extraction. Three areas within the complex have been selected as resource areas of primary significance. The Areas cover an unlicenced 2030 acres (820 ha) and have total possible resources of 95 million tons (86 million tonnes).

Much of the land in the Selected Sand and Gravel Resource Areas is well suited for fruit crops, and orchards are currently cultivated throughout the area. Careful planning is required to make the best use of the land's extractive and agricultural capabilities.

Resources of crushed stone suitable for road and building construction in the Town of Pelham come from the extreme northern portion of the area and are restricted to limestones and dolostones of the Lockport Formation. Two areas have been selected for possible resource protection. These Areas have a total of 390 acres (158 ha) and have presently available resources of 63 million tons (57 million tonnes). Stone in these Areas is suitable for the production of building stone and lime for cement, as well as for a wide range of crushed products.

If, for any reason, significant portions of the two Selected Areas are unavailable for extraction, consideration should be given to ensuring resource protection for those areas in the northern portion of the town, where the Eramosa and Gasport Members of the Lockport Formation are overlain by 25 to 50 feet (8 to 15 m) of overburden. Although development costs for extraction would be greater in these areas, a greater flexibility in selecting resource areas would be possible.

Enquiries regarding the Aggregate Resources Inventory of The Town of Pelham should be directed to the Ontario Ministry of Natural Resources either at the Niagara District Office, Fonthill, Ontario, L0S 1E0, (Tel. 892-2656) or at the Central Region Office, Richmond Hill, Ontario, L4C 3C9, (Tel. (416) 884-9203).

TABLE 1 | TOTAL SAND AND GRAVEL RESOURCES, TOWN OF PELHAM

1	2	3	4
CLASS NO.	**DEPOSIT TYPE** (See Appendix C)	**AREAL EXTENT** Acres (Hectares)	**ORIGINAL TONNAGE** Millions of Tons (Tonnes)
1	G-IC-LB	380 (154)	74 (67)
	G-IC-LD	1510 (610)	112 (102)
	S-IC-LP	8400 (3400)	1480 (1340)
2	G-IC-LD	30 (12)	1 (1)
4	S-IC-LP	160 (65)	2 (2)
	S-LP	100 (40)	1 (1)
	G-LB	20 (8)	<1 (<1)
		10,600 (4300)	1670 (1520)

TABLE 2 | SAND AND GRAVEL PITS, TOWN OF PELHAM

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS*							
1	N3-32	Mrs. E.M. Bishop	7	8	6.5 (2.6)	30 (9)	10
2	N3-1 N3-39	Moyer Sand Division of Steed & Evans Ltd.	10-11	7	135.0 (54.6)	30 (9)	–
3	N3-28	Moyer Sand Division of Steed & Evans Ltd.	12	7	27.0 (10.9)	–	10-20
4	–	Moyer Sand Division of Steed & Evans Ltd.	12	8	42.0 (17.0)	25 (8)	10
5	–	Moyer Sand Division of Steed & Evans Ltd.	8,9	7	48.0 (19.4)	–	50
6	N3-28	TCG Materials Ltd.	7,8,9	7	128.0 (51.8)	35 (11)	50
7	N3-26	TCG Materials Ltd.	9	7	76.0 (30.8)	35 (11)	50
					462.5 (187.2)		
UNLICENCED PITS							
8	N3-12	Moyer Sand	3	7	–	–	–

*Sites 2,3,4 and 5 (above) are under a single licence issued by the Ontario Ministry of Natural Resources.
Sites 6 and 7 (above) are also under a single licence.
Site 5 has been recently depleted of aggregate reserves (1979).

TABLE 3 | SELECTED SAND AND GRAVEL RESOURCE AREA, TOWN OF PELHAM

1 **DEPOSIT NO.**	2 **UNLICENCED AREA** Acres (Hectares)	3 **CULTURAL SETBACKS** Acres (Hectares)	4 **EXTRACTED AREA** Acres (Hectares)	5 **AVAILABLE AREA** Acres (Hectares)	6 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	7 **AVAILABLE AGGREGATE** Millions of Tons (Tonnes)
1	385 (156)	95 (38)	20 (8)	270 (109)	60 (18)	41 (37)
2	1290 (520)	450 (182)	310 (126)	530 (214)	30 (9)	40 (36)
3	355 (144)	65 (26)	0 (0)	290 (117)	20 (6)	14 (13)
	2030 (820)	610 (247)	330 (134)	1090 (440)		95 (86)

TABLE 4 TOTAL IDENTIFIED BEDROCK RESOURCES, TOWN OF PELHAM

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **WORKABLE THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
	A. LOCKPORT FORMATION GASPORT MEMBER			
0-3 (0-1)		50 (15)	15 (6)	2 (2)
3-25 (1-8)		50 (15)	375 (152)	68 (62)
25-50 (8-15)		50 (15)	2050 (830)	370 (340)
			(2440) (990)	440 (400)
	B. LOCKPORT FORMATION ERAMOSA MEMBER			
25-50 (8-15)		30 (9)	1990 (800)	215 (195)
	C. CLINTON AND CATARACT GROUPS			
0-3 (0-1)		60 (18)	6 (2)	<1 (<1)
3-25 (1-8)		60 (18)	114 (46)	24 (22)
25-50 (8-15)		60 (18)	350 (142)	75 (68)
			470 (190	100 (91)
			4900 (1980)	755 (685)

TABLE 5 QUARRIES, TOWN OF PELHAM

1 NO.	2 MTC NO.	3 OWNER/OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
		LICENCED QUARRIES				
		- NONE-				
		UNLICENCED QUARRIES				
Q1	-	-	4	1	-	25 Approx. (8)

TABLE 6 | SELECTED BEDROCK RESOURCE AREAS, TOWN OF PELHAM

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE TONNAGE Millions of Tons (Tonnes)
1	3-25 (1-8)	225 (91)	15 (6)	0 (0)	210 (85)	50 (15)	38 (34)
2	0-25 (0-8)	165 (67)	23 (9)	2 (1)	140 (57)	50 (15)	25 (23)
		390 (158)	38 (15)	2 (1)	350 (142)		63 (57)

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ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE

Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

CAMBRIAN

The first Period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago; the Cambrian precedes the Ordovician Period.

CLAST

An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

DELETERIOUS LITHOLOGY

A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone, and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN

A Period of the geological past thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DIRT

See fines.

DOLOSTONE

A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT

A general term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN

A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN

Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES

A general term used to describe the size fraction of an aggregate which passes (is finer than) the No.200 mesh screen (0.074 mm). Also described informally as "dirt", these particles are in the silt- and clay-size range.

GLACIAL LOBE

A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced and retreated numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GRADATION

The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder		>-256 mm
Gravel	cobble	64-256 mm
Gravel	pebble	4-64 mm
Gravel	granule	2-4 mm
Sand	coarse	.5-2 mm
	medium	.25-.5 mm
	fine	.074-.25 mm
Silt, clay		< .074 mm

GRANULAR BASE COURSE

Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability, and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

H.L. (HOT-LAID OR ASPHALTIC AGGREGATE)

Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3, and 4), or as binder course (H.L. 2, 6, and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY

The description of rocks on the basis of such characteristics as color, structure, mineralogic composition, and grain size. Generally, the description of the physical character of a rock.

MELTWATER CHANNEL

A drainage way, usually terraced, produced by water flowing away from a melting glacier margin.

ORDOVICIAN

An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA

One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago. The Paleozoic Era (or Ancient Life Era) is subdivided into six geologic Periods, of which only four (Cambrian, Ordovician, Silurian, and Devonian) can be recognized in southern Ontario.

PLEISTOCENE

An Epoch of the recent geological past including the time from approximately 1.8 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity.

POSSIBLE RESOURCE

Reserves estimates based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

SHALE

A fine-grained, sedimentary rock formed by the consolidation of clay, silt, or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone, and mudstone.

SILURAIN

An early Period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS

The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL

Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN

Pertaining to the last glacial stage of the Pleistocene Epoch in North America. It began approximately 85,000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

APPENDIX C-GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 7000 to 85 000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and they can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

ICE-CONTACT TERRACES (ICT)

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley, The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain-size distribution.

KAMES (K)

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good-quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt-and clay-sized particles).

ESKERS (E)

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. They vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout southern Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

UNDIFFERENTIATED ICE-CONTACT STRATIFIED DRIFT (IC)

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain-size variability. They are given a qualitative rating based on existing pit and other subsurface data.

OUTWASH (OW)

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. They occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain-size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

ALLUVIUM (AL)

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

GLACIOLACUSTRINE BEACH DEPOSITS (LB)

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

GLACIOLACUSTRINE DELTAS (LD)

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

GLACIOLACUSTRINE PLAIN (LP)

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

END MORAINES (EM)

These are belts of glacial drift deposited at, and parallel to, glacier margins. They commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best resource areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

WINDBLOWN FORMS (WD)

Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on , pre-existing lacustrine sand plain deposits. Windblown sediments are almost invariably composed of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

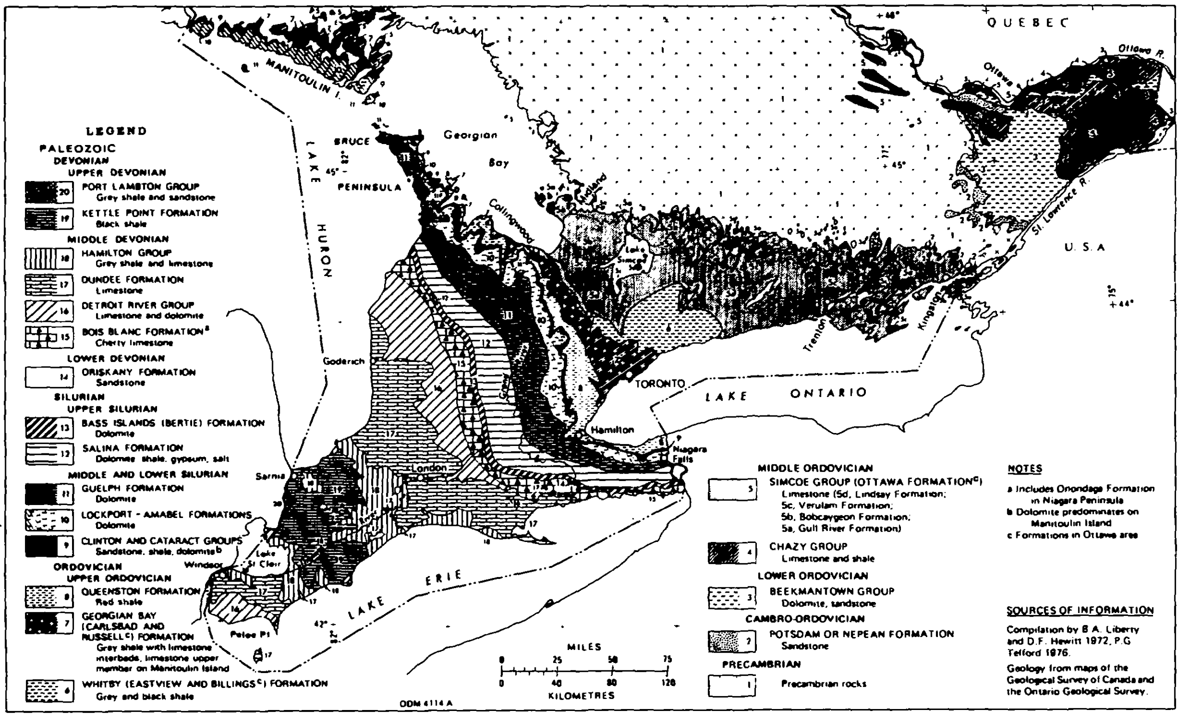


Figure 3 - Bedrock Geology of Southern Ontario

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

BASS ISLANDS FORMATION (UPPER SILURIAN)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11-18m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate due to high soundness losses.

BOBCAYGEON FORMATION (MIDDLE ORDOVICIAN)

Composition: Compact, homogeneous, medium- to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

BOIS BLANC FORMATION (LOWER-MIDDLE DEVONIAN)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High chert content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion

Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

DUNDEE FORMATION (MIDDLE DEVONIAN)

Composition: Fine- to medium-crystalline, brown ish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

GULL RIVER FORMATION (MIDDLE ORDOVICIAN)

Composition: Member A: thin-to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield, Victoria County, and Uthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

LOCKPORT AND AMABEL FORMATIONS (MIDDLE SILURIAN)

Composition: Amabel Formation (Georgetown to the Bruce Peninsula): massive, fine crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Georgetown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, and building stone throughout their area of occurrence, and are a valuable aggregate resource. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

ONONDAGA FORMATION (MIDDLE DEVONIAN)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliffe Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey brown, fine-grained, very cherty limestone having an estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for concrete aggregate.

OTTAWA FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137–145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of lime for cement production and agricultural uses.

OXFORD FORMATION (LOWER ORDOVICIAN)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES.

DETROIT RIVER GROUP (MIDDLE DEVONIAN)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change). Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces 80% of Ontario's cement. Its dolomitic reefal facies is also important for lime production to the north. It is generally unsuitable for crushed stone. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

GRENVILLE MARBLE (PRECAMBRIAN)

Composition: Recrystallized white limestone and dolostone, fine- to coarse-grained, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazo chips, poultry grit, decorative stone, and building stone.

GUELPH FORMATION (MIDDLE SILURIAN)

Composition: Aphanitic- to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. The Guelph Formation and the underlying Amabel Formation have a combined thickness of 200 feet (61 m) on the Niagara Peninsula and more than 400 feet (122 m) on the Bruce Peninsula. Uses: The main use is for dolomitic lime in the construction industry. It is quarried at Glen Christie and Guelph.

LINDSAY FORMATION (MIDDLE ORDOVICIAN)

Composition: Lower Member: fine-crystalline, rubbly, nodular, weathering limestone. Upper Member: grey calcareous claystone with shaly partings and bioclastic layers. The rock is "soft" and weathers to rubble. Both members are characterized by low dolomite content and by numerous clayey partings. Uses: Quarried at Picton, Ogden Point, Colborne, and Bowmanville for lime. It is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

VERULAM FORMATION (MIDDLE ORDOVICIAN)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200-300 feet (61-91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for lime. It is unsuitable for crushed stone due to clay impurities and many clayey interbeds, low abrasion resistance, high soundness losses and poor freeze-thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

GEORGIAN BAY FORMATION (UPPER ORDOVICIAN)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas). Composition: Soft, fissile, blue grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Five producers in Metro Toronto and Cooksville produce brick and structural tile (Guillet 1967). Lightweight aggregate is also produced at Streetsville by heat expansion of the shale.

HAMILTON GROUP (MIDDLE DEVONIAN)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The Group has six formations. Only the Arkona is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile and brick.

QUEENSTON FORMATION (UPPER ORDOVICIAN)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are 12 large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa (Guillet 1967). All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

NEPEAN (POTSDAM) FORMATION (CAMBRO-ORDOVICIAN)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

SALINA FORMATION (UPPER SILURIAN)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amhertsburg, Windsor, and Sarnia.

WHITBY FORMATION (UPPER ORDOVICIAN)

(Formerly known as Collingwood Shale near Toronto). Composition: Brown to black fissile shale. Uses: Quarried at Bowmanville for use in cement production. Testing indicates that the Whitby Formation may produce satisfactory lightweight expanded aggretage.

Ontario

Ministry of Natural Resources

Hon. James A.C. Auld
Minister

Dr. J.K. Reynolds
Deputy Minister

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

THE TOWN OF PELHAM

REGIONAL MUNICIPALITY OF NIAGARA

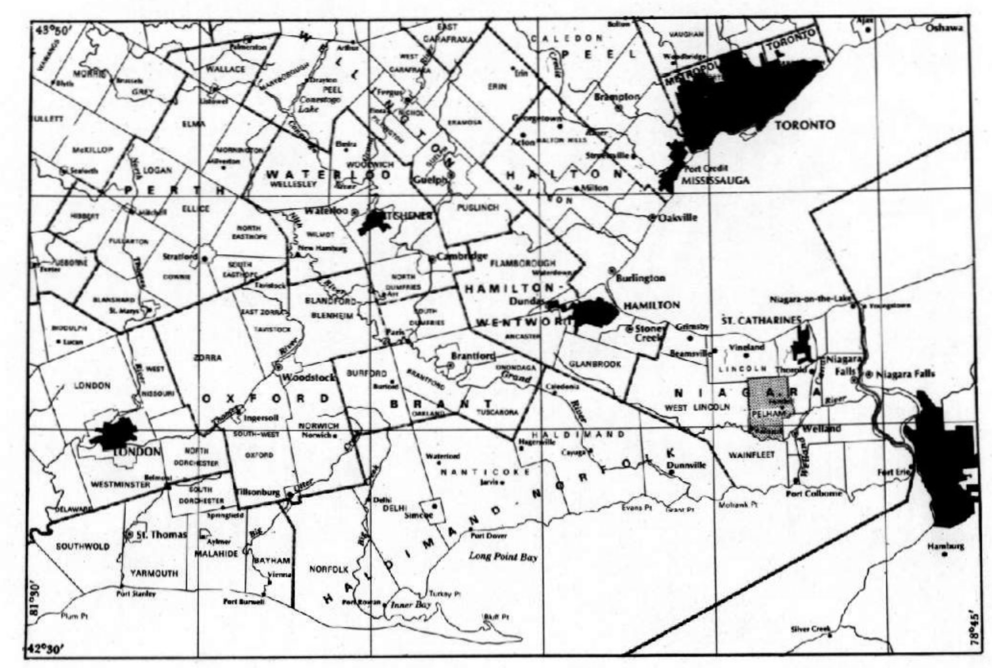
MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

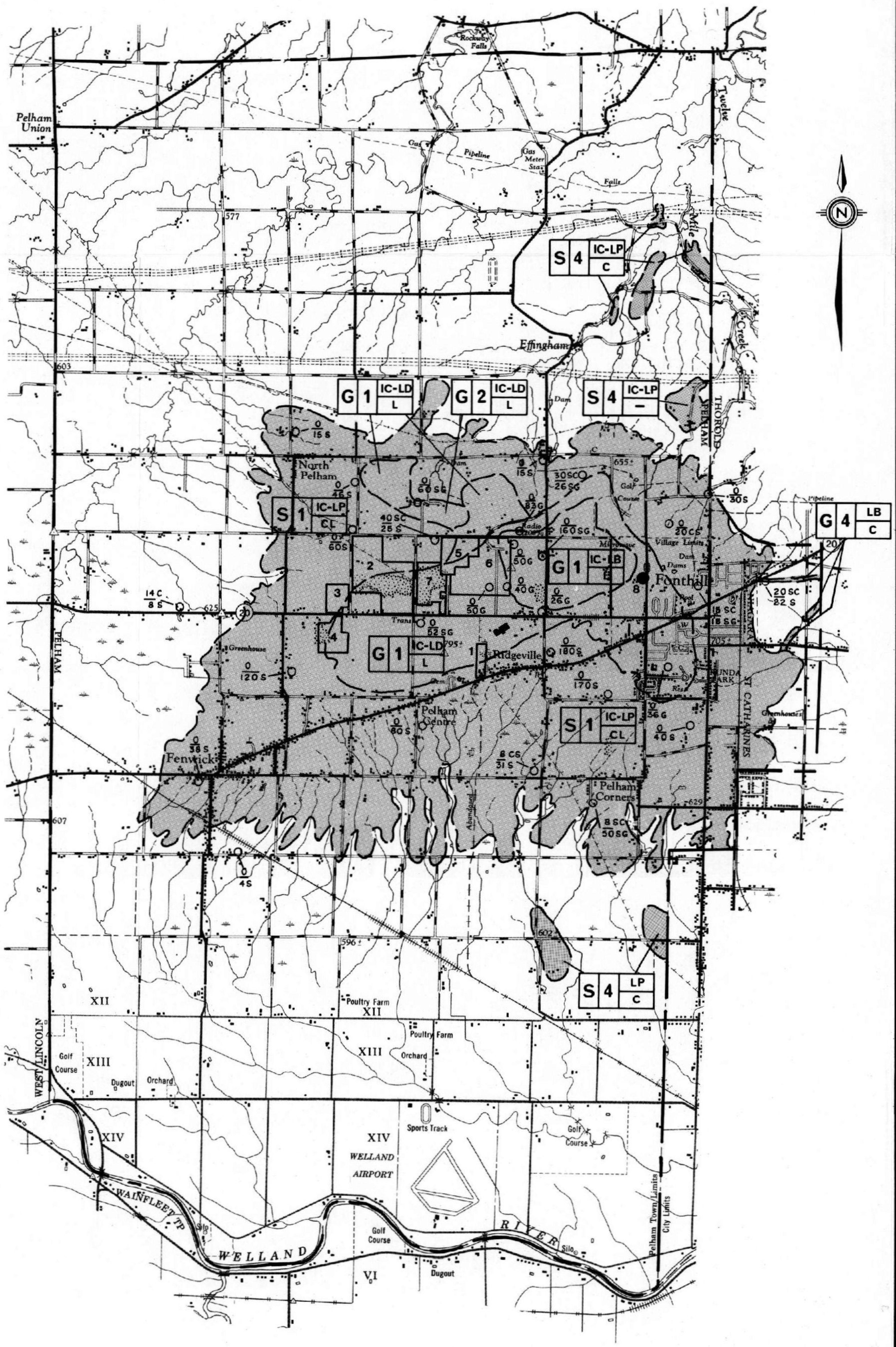
Scale: 1:50,000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference. 30 L/14, 30 M/3





PELHAM

SYMBOLS

(shaded area)	Geological and aggregate thickness boundary. Shading indicates deposit area.
S1 IC/CLO	Deposit symbol: see below.
3	Licenced property boundary; Property number: see Table 2.
●4	Unlicenced sand or gravel pit; Property number: See Table 2.
○ 6/23	Selected drilling location indicating thickness of overburden overlying reported thickness of granular materials (in feet). (Note: S-sand, G-gravel, C-clay, T-till)

DEPOSIT SYMBOL

Deposits are identified by gravel content, thickness class, deposit type and quality indicators. Gravel content is expressed as percentage of crushable material. Classes are based on potential aggregate tonnage per acre and are designated numerically. Type refers to geologic origin. Quality modifiers indicate variations in grain size distribution and lithology.

Gravel Content	Thickness Class	Geological Type
		Quality Indicators

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.
?	Requires investigation

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (> 18 500)
2	10-20 (3-6)	25,000-50,000 (9 000-18 500)
3	5-10 (1.5-3)	12,500-25,000 (4 500-9 000)
4	less than 5 (< 1.5)	less than 12,500 (< 4 500)

Geological Type

IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
ICT	Ice-Contact Terrace	LB	Lacustrine Beach
K	Kame	LP	Lacustrine Plain
E	Esker	LD	Lacustrine Delta
EM	End Moraine	AL	Older Alluvium
		WD	Windblown Forms

(see Appendix C for descriptions of Geological Types.)

Quality Indicators

	If blank, no known limitations present
C	Clay and/or silt (fines) present in objectionable quantities
L	Deleterious lithologies present
O	Oversize particles or fragments present in objectionable quantities
–	Requires investigation

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected drilling data from the Ontario Ministry of the Environment and the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by B.H. Feenstra, 1972, 1975.
P.G. Telford, B.A. Liberty and B.H. Feenstra, 1976.
P.G. Telford and G.A. Tarrant, 1975.

Compilation and drafting by E.T. Harvey

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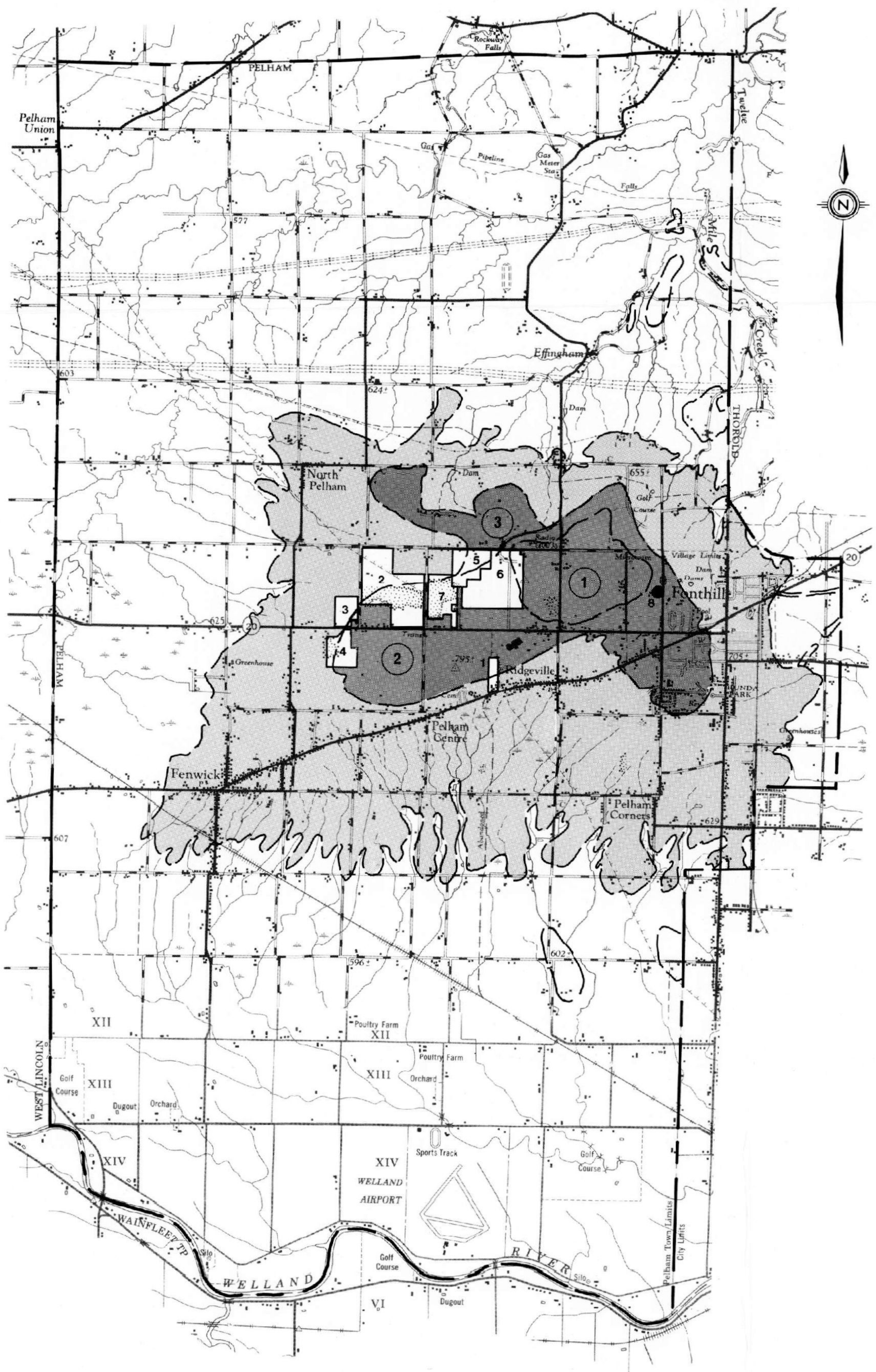
This map is to accompany O.G.S. Aggregate Resources Inventory Paper 4.



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THE TOWN OF PELHAM

REGIONAL MUNICIPALITY OF NIAGARA

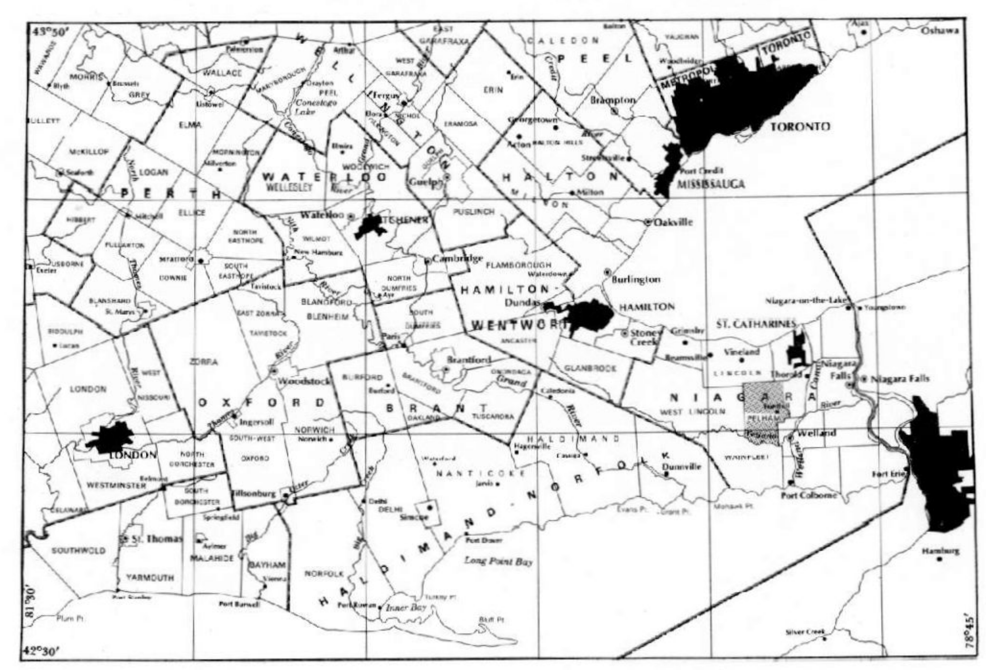
MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale: 1:50,000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 30 L/14, 30 M/3



SYMBOLS
(Some symbols may not apply to this map)

- Geological and aggregate thickness boundary.
- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area; Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- Licenced property boundary; Property number: see Table 2.
- Unlicenced sand or gravel pit; Property number: See Table 2.

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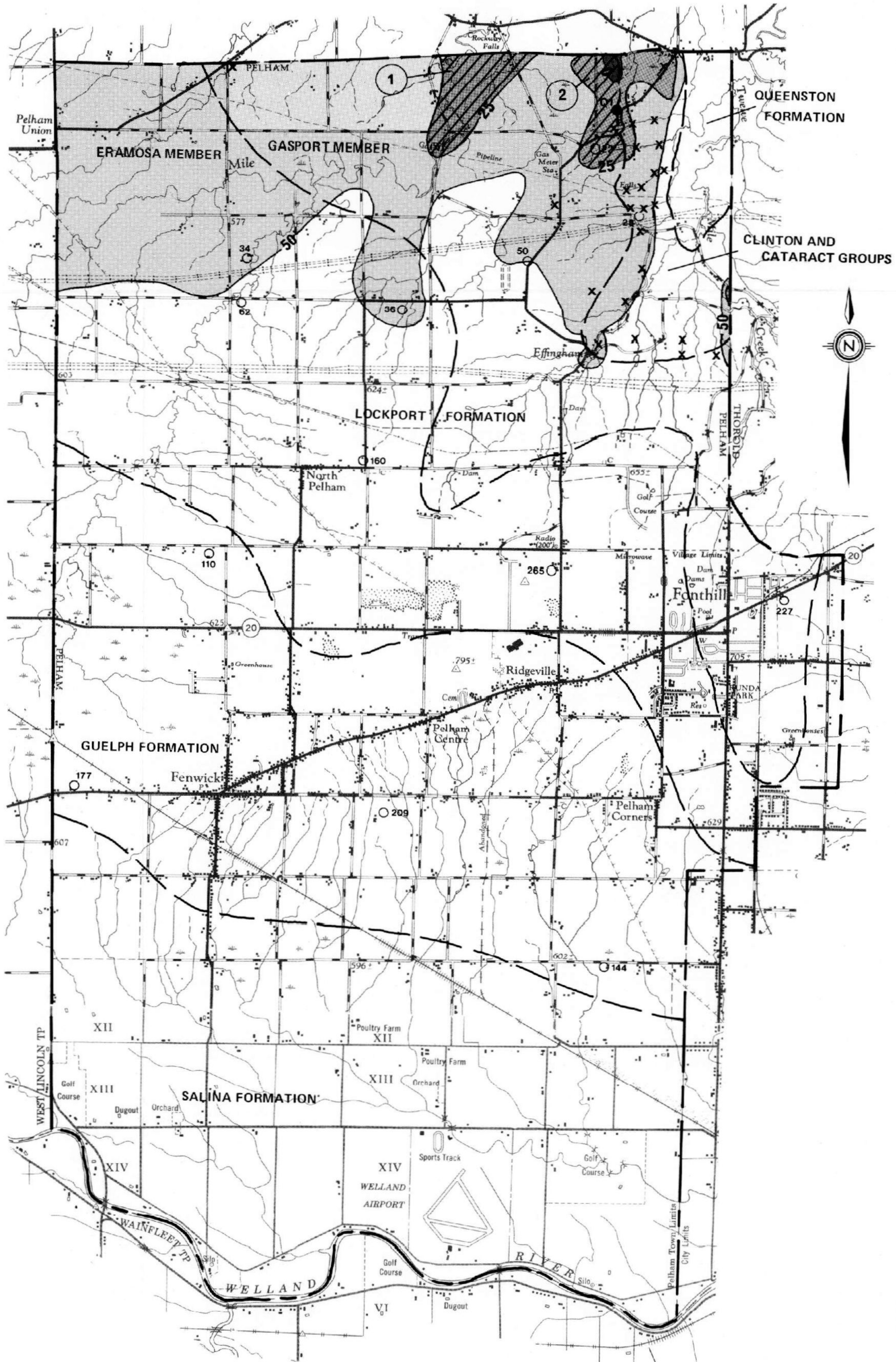

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THE TOWN OF PELHAM

REGIONAL MUNICIPALITY OF NIAGARA

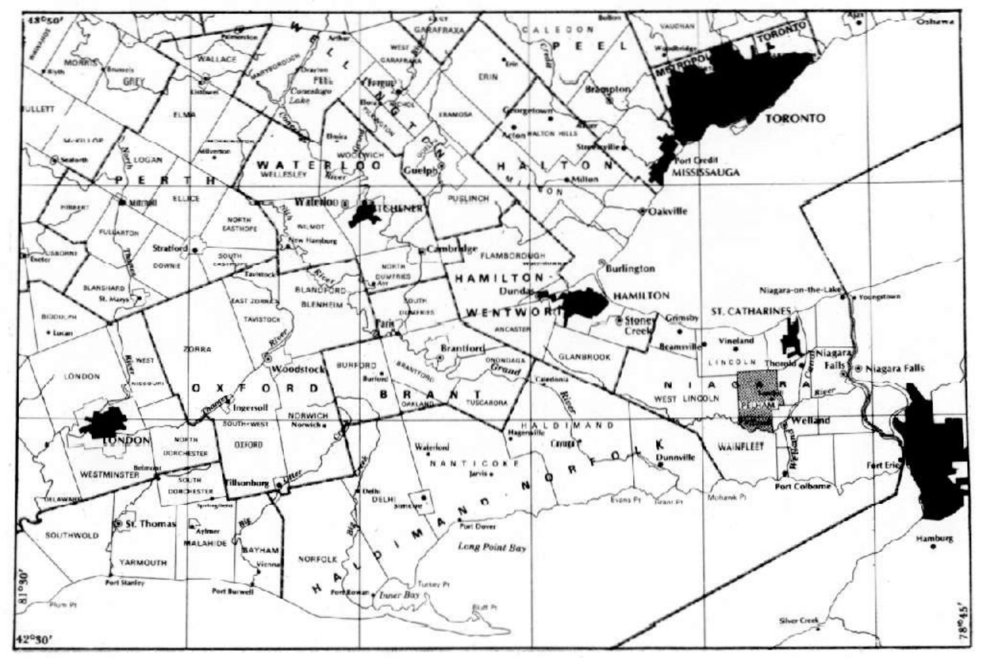
MAP 3
BEDROCK RESOURCES

Scale: 1:50,000

Mile 1 — 0 — 1 Mile

Metres 1000 — 0 — 1 Kilometre

NTS Reference: **30 L/14, 30 M/3**



LEGEND

PALEOZOIC

SILURIAN

UPPER SILURIAN

SALINA FORMATION
Dolostone shale, gypsum, salt

MIDDLE AND LOWER SILURIAN

GUELPH FORMATION
Dolostone

LOCKPORT-AMABEL FORMATIONS
Dolostone

CLINTON AND CATARACT GROUPS
Sandstone, shale, dolostone

ORDOVICIAN

UPPER ORDOVICIAN

QUEENSTON FORMATION
Red shale

SYMBOLS

(Some symbols may not apply to this map)

- Geological boundary.
- Drift thickness contour line (25 foot (8 m) interval).
- Isolated bedrock outcrop.
- Bedrock within 3 feet (1 m) of surface: see Table 4.
- Bedrock covered by 3 to 25 feet (1 m to 8 m) of overburden: see Table 4.
- Bedrock covered by 25 to 50 feet (8 m to 15 m) of overburden: see Table 4.
- Selected bedrock resource area; Deposit number: see Table 6.
- Licenced property boundary; Property number: see Table 5.
- Quarry property number: see Table 5.
- Selected drilling location indicating reported depth to bedrock (in feet).

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P.G. Telford and G.A. Tarrant, 1975.

Compilation by E.T. Harvey

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