Ontario

Aggregate Resources Inventory of

Prince Edward County

Ontario Geological Survey
Aggregate Resources Inventory
Paper 172

1999

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Paper 172

By Jagger Hims Limited and Staff of the Sedimentary Geoscience Section,
Ontario Geological Survey

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Contents

CHARTS

TABLES

FIGURES

GEOLOGICAL MAPS (back pocket)

Abstract

This report includes an inventory and evaluation of sand and gravel and bedrock resources for Prince Edward County. It is based on a detailed field assessment undertaken in the summer of 1997 and on previous studies in the area. The investigation was conducted to delineate aggregate deposits in the county and determine its quality and quantity. Such information will help ensure that sufficient aggregate resources are available for future use. The report is part of the Aggregate Resources Inventory Program for areas designated under the *Aggregate Resources Act* (ARA) 1989.

In general, Prince Edward County contains only limited resources of sand and gravel. Three small Selected Sand and Gravel Resources Areas have been identified at the primary level of significance, with a resource potential of approximately 10.4 million tonnes. The aggregate contained in these areas is suitable for a range of road building and construction products. These areas occupy approximately 104 hectares. Selected Sand and Gravel Resource Areas of secondary and tertiary significance have also been identified.

Prince Edward County is underlain by bedrock of the Verulam Formation and the upper and lower members of the Lindsay Formation. These units have been quarried mainly to produce lime for cement manufacture and other chemical uses. The formations do not meet Ministry of Transportation specifications for many road building and construction aggregates. These formations can produce non-specification aggregate for local use. No areas have been selected for possible resource protection.

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.

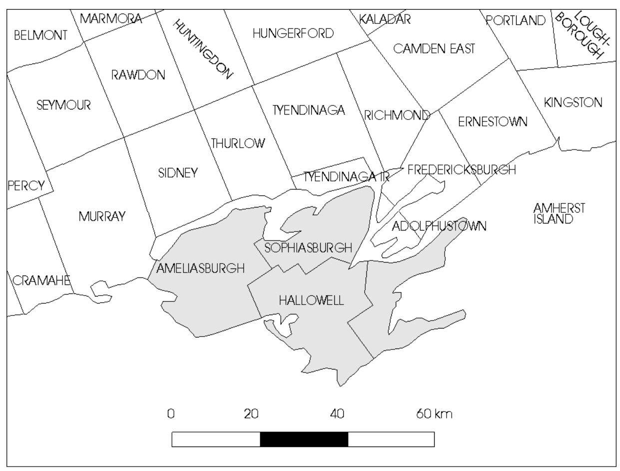

Figure 1. Key map showing the location of Prince Edward County.

Aggregate Resources Inventory of Prince Edward County

By Staff of Jagger Hims Limited and the Ontario Geological Survey

Project Supervisors: C.L. Baker and D.J. Rowell; field work by R. Jelly, K. Antoniuk and A.J. Cooper; compilation and drafting by staff of Jagger Hims Limited, Proctor and Redfern Limited and the Ontario Geological Survey. Assistance with review provided by the Resident Geologist, Ministry of Northern Development and Mines, Tweed, Ontario; the Soils and Aggregate Section, Ontario Ministry of Transportation, Downsview, Ontario; and the Mineral Resources Staff, Peterborough Office, Ministry of Natural Resources.

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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 quantities of these materials are used each year throughout the Province. For example, in 1996, the total tonnage of mineral aggregates extracted in Ontario was 141 million tonnes, greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1996).

Although mineral aggregate deposits are plentiful in 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 areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in many areas, especially urban areas where demand is the greatest.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Unfortunately, in some cases, the best aggregate resources are found in or near areas of environmental sensitivity, resulting in the requirement to balance the need for the different natural resources. Therefore, planning 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 Program is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies. 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 an area's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential for bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I - Inventory Methods

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) as well as field examination of potential resource areas. 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 (MTO), the Ontario Geological Survey (OGS), and by Regional, District and Area Offices of the Ontario Ministry of Natural Resources (MNR). Observations made at pit sites included estimates of the total face height and the proportion of gravel- and sand-sized materials in the deposit. Observations regarding the shape and lithology of the particles were also made. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting.

Deposits with potential for further extractive development or those where existing data are scarce, were studied in greater detail. Representative sections in these deposits were evaluated by taking 11 to 45 kg samples from existing pit faces or from test pits. The samples were tested for grain size distribution, and in some cases the Los Angeles abrasion and impact test, absorption, Magnesium Sulphate soundness test and petrographic analyses are carried out. Analyses were performed in the laboratories of the Ontario Ministry of Transportation.

The field data were supplemented by pit information on file with the Geotechnical Section of the Ontario Ministry of Transportation. Data contained in these files includes field estimates of the depth, composition and "workability" of deposits, as well as laboratory analyses of the physical properties and suitability of the aggregate. Information concerning the development history of the pit and acceptable uses of the aggregate is also recorded. The locations of additional sources were obtained from records held by Regional, District and Area Offices of the Ontario Ministry of Natural Resources. In addition, reports on geological testing for type, quantity and quality of aggregates were also obtained from numerous aggregate licence applications on file with the MNR, and with specific individuals and companies. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, were used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records were used 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 base map, also at a scale of 1:50 000. These base maps are prepared with information taken from maps of the National Topographic System by permission of Natural Resources Canada, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

Sand and Gravel Resources

Once the interpretative boundaries of the aggregate units have been established, 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 hectares (ha). 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 test holes and water well records. Tonnage values can then be calculated by multiplying the volume of the deposit by 17 700 (the density factor). This factor is approximately the number of tonnes in a 1 m thick layer of sand and gravel, 1 ha in extent, assuming an average density of 1770 kg/m^3.

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 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of hectares unavailable because of 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, unlicenced and abandoned pits are included in this category). The remaining figure is the area of the deposit potentially 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 17 700), to give an estimate of the sand and gravel tonnage (Column 7) potentially available for extractive development and/or resource protection. It should be noted however, that recent studies (Planning Initiatives Ltd. 1993) have shown that anywhere from 15 to 85% of this last figure in any resource area may be further constrained or not accessible because of such things as environmental considerations (e.g., floodplains, environmentally sensitive areas), lack of landowner interest, resident opposition or other matters.

Resource estimates are calculated for deposits of primary significance. Resource estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however, the aggregate potential of these deposits is discussed in the report.

Bedrock Resources

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 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 (Table 4). The measured extent of such areas is then multiplied by the estimated quarriable 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 18 m is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tonnes of a 1 m thick section of rock, 1 ha in extent).

Resources of limestone and dolostone are calculated using a density factor of 2649 kg/m^3, sandstone resources are calculated using a density estimate of 2344 kg/m^3, and shale resources are calculated with a factor of 2408 kg/m^3 (Telford, Geldart, Sheriff and Keys 1980).

Units and Definitions

The measurements and other primary data available for resource tonnage calculations are given in Metric units in the text and on the tables which accompany the report. Data are generally rounded off in accordance with the Ontario Metric Practices Guide (Ontario Interministerial Committee on National Standards and Specifications 1975).

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

Part II - Data Presentation and Interpretation

Two maps, each portraying a different aspect of the aggregate resources in the report area, accompany the report. Map 1, "Sand and Gravel Resources", gives a comprehensive inventory and evaluation of the sand and gravel resources in the report area. Map 2, "Bedrock Resources", shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments and identifies the Selected Bedrock Resource Areas.

MAP 1: SAND AND GRAVEL RESOURCES

Map 1 shows the extent and quality of sand and gravel deposits within the study area and an evaluation of the aggregate resources. The map is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete.

The present level of extractive activity is also indicated on Map 1. Those areas which are licenced for extraction under the *Aggregate Resources Act* 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/operator and licenced hectarage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or pits operating on demand under authority of a wayside permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

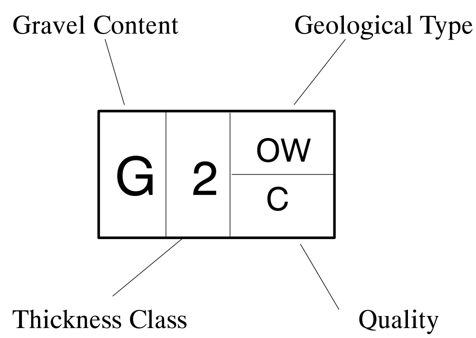
Deposit Symbol

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 every deposit shown on Map 1.

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 (greater than 4.75 mm) makes up less than 35% of the whole deposit. "G" indicates that the deposit contains more than 35% gravel.

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.

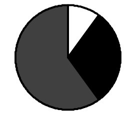
Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C), and the lower series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



For example, the above symbol identifies an outwash deposit 3 to 6 m thick containing more than 35% gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

Texture Symbol

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30% gravel, 60% sand and 10% silt and clay.



SELECTED SAND AND GRAVEL RESOURCE AREAS

All the Selected Sand and Gravel Resource Areas are first delineated by geological boundaries and then classified into 3 levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by dark shading on Map 1.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units. They represent areas in which a major resource is known to exist, and may be reserved wholly or partially for extractive development and/or resource protection. In many of the recently approved local and Regional/County Official Plans primary, and in some cases resources of secondary significance, are identified and protected.

Deposits of secondary significance are indicated by medium shading on Map 1. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are indicated by light shading. They are not 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 or extraction under a wayside permit but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of 2 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 report area 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 resources in the rest of the project area. Generally, deposits in Class 1 (greater than 6 m thick), and containing more than 35% gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in areas with low total resources.

AGGREGATE QUALITY

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

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

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35% gravel in addition to a minimum of 20% material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10% may impede drainage in road subbase 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% oversize material (greater than 10 cm in diameter) may also have use limitations. The oversize component is unacceptable for uncrushed road base, so it 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.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types 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 such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L", or any combination of these indicators, the quality of the deposit is considered to be reduced for some aggregate uses. No attempt is made to quantify the degree of limitation imposed. Assessment of the 4 indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation (MTO) and the Sedimentary Geoscience Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of MTO quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendixes B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular A and Granular B Type 1; Hot-Laid Asphaltic Sand Nos. 1, 2, 3, 4 and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

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 natural, environmental 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 (Column 3).

In addition to man-made and cultural features, certain natural features, such as provincially significant wetlands, may prove to be contraints. In this report such constraints have not been outlined and the reader is advised to consult with municipal planning staff and the local office of the MNR for information on these matters. Depending on the number and type of constraints, anywhere from 15 to 85% of the total resources in a municipality can become inaccessible when these or other specific local constraints are considered (Planning Initiatives Ltd. 1993).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. Since the approval under the Planning Act of the Mineral Aggregate Resource Policy Statement (MARPS) in the mid 1980s and the Comprehensive Set of Policy Statements, including MARPS, in March 1995, many of the more recently approved local and regional Official Plans now contain detailed policies regarding the location and operation of aggregate extraction activity and should be consulted at an early date in regard to considering the establishment of an aggregate extraction operation. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent office of MNR, and regional and local planning officials.

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 roughly at the same level. In most cases, however, the market demand for aggregate products, especially in urban areas, is greater than the amount of production found within the local market area. Consequently, conflicts often arise between the increasing demand for aggregates in such areas and the frequent pressures to restrict aggregate operations, especially in the near urban areas.

The aggregate resources in the region surrounding a project area should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, an area that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Areas 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 2: BEDROCK RESOURCES

Map 2 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment (MOE), oil and gas well data from the Non-Renewable Resources Section, Ontario Ministry of Natural Resources, and from geotechnical test hole data from various sources. Map 2 is based on concepts similar to those outlined for Map 1.

The geological boundaries of the Paleozoic bedrock units are shown by dashed lines. Isolated Paleozoic outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 1 m of drift, areas of 1 to 8 m of drift, and areas of 8 to 15 m of drift. The extent of these areas of thin drift are shown by 3 shades of grey. The darkest shade indicates where bedrock outcrops or is within 1 m of the ground surface. These areas constitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 8 m thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 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 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 deposits).

Other inventory information presented on Map 2 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the *Aggregate Resources Act* 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/operator, licenced hectarage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 2 and described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness in metres, is shown beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock, in metres, shown beside it. The test holes may be further described in Table 7.

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. The main characteristics and uses of the bedrock units 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. 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 are 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. First, quality and quantity variations within a specific geological formation are gradual. Second 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, and third, 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 Selected Areas, if present, are shown on Map 2 by a line pattern and the calculated potential tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 2 are not permanent, single land use units. They represent areas in which a major bedrock resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection, within an Official Plan.

Part III - Assessment of Aggregate Resources in Prince Edward County

LOCATION AND POPULATION

Prince Edward County occupies 104 820 ha along Lake Ontario south of Belleville and includes the townships of: Ameliasburgh, Hillier, Sophiasburgh, Hallowell, Athol, North Marysburgh and South Marysburgh (Figure 1). The county encompasses parts of the Consecon (30 N/13), Wellington (30N/14), Duck Island (30N/15), Bath (31C/2), Belleville (31C/3) and Trenton (31C/4) 1:50 000 scale map sheets of the National Topographic System (NTS).

The population of Prince Edward County was 22 746 in 1994 (Ontario Ministry of Municipal Affairs and Housing 1997), representing an increase of less than 2.2% from 1991 (Ontario Ministry of Municipal Affairs 1992)(Chart A). The Town of Picton is located in the east central portion of the county, while the villages of Bloomfield and Wellington are situated near the centre and in the western part of the county, respectively. The cities of Belleville and Trenton are located just north of the study area. The area is mostly farmland as well as a cottage and tourist destination.

Highway 33, which generally trends easterly, provides a transportation corridor between Trenton and Picton. Highways 62 and 49 trend southerly and provide access to the county from Highway 401. Numerous county and township roads provide vehicle access throughout the study area.

SURFICIAL GEOLOGY AND PHYSIOGRAPHY

Prince Edward County is an irregularly shaped peninsula of land comprised of a plain of limestone which projects into the eastern part of Lake Ontario. It is almost separated from the mainland by the Bay of Quinte. The shoreline is irregular as a number of deep valleys dissect the limestone and thus form long bays. The surface of the plain has a slight gradient toward the southwest and the western and southern shores have very low relief. The northern and eastern shorelines are often precipitous limestone bluffs rising 30 m or more. More than half of the county has shallow soils with less than a metre of unconsolidated material over the bedrock (Chapman and Putnam 1984). Over 10 000 ha of the county's ground surface is covered by marsh and other organic soils. Marshes border most lakes and lagoons in the county and many small areas of muck are found in the shallow depressions on the rock plain.

During the Pleistocene Epoch, all of Ontario was covered by a succession of ice sheets. There were definitely 2 and probably more major ice advances, each separated by interglacial periods. The last glacial substage, referred to as the Late or Classical Wisconsinan, began approximately 23 000 years before present (BP) (Barnett 1992). Glacial ice initially moved across the study area from the north-northeast followed by a younger readvance from the southeast out of the St. Lawrence Valley.

Glacial ice was primarily erosional in the study area, producing streamlined bedrock features such as the rock drumlin at McMahon Bluff (Leyland 1982). A thin sandy silt to silty sand till with a moderate stone content was deposited in the area. This till, after deposition, was partly eroded and modified by glaciolacustrine activity. Generally, till in the study area is less than 1 m thick except in isolated pockets where it comprises drumlinoid and drumlin landforms. Most of these landforms are located between Picton and West Lake.

Chart A - Area and Population
Prince Edward County

Municipality	Area (ha)	1991 Population	1994 Population
Town of Picton	404	4 067	4 077
Village of Bloomfield	194	669	667
Village of Wellington	655	1 340	1 540
Ameliasburgh Twp.	19 635	5 154	5 235
Athol Twp.	10 224	1 235	1 290
Hallowell Twp.	19 290	4 168	4 101
Hillier Twp.	13 750	1 651	1 700
North Marysburgh Twp.	9 759	1 180	1 165
Sophiasburgh Twp.	20 083	1 954	2 067
South Marysburgh Twp	10 826	847	904
County Total	**104 820**	**22 265**	**22 746**

As the ice retreated, a small number of ice-contact deposits were formed close to the ice margin. These deposits originated in a variety of depositional environments. Eskers were formed by glacial meltwater flowing and depositing sediment in tunnels under the ice or in reentrants in the ice front. Ice-contact deposits range in grain size from silt and sand to coarse gravel and cobbles. These deposits have been an important local source of aggregate in the area. Stratified ice-contact deposits of sand and gravel occur in 3 northeast trending esker ridges in the Cherry Valley area, Picton to West Lake area and in the Hallowell area. Associated with these esker ridges are outwash sands. Nearshore glaciolacustrine sands in most places overlie these outwash deposits.

Glaciolacustrine sediments, predominantly silty fine sand, were deposited in the shallower parts of glacial lakes. These sands occur primarily in topographically low areas and are generally too fine to produce most aggregate products. Raised shoreline features are present in the area at elevations between 84 and 91 m asl. These shoreline features are moderately well developed and probably represents a water level following the high level glacial Lake Iroquois stage.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates deposits that contain granular materials. These deposits occupy a total of 5545 ha and contain an original resource tonnage of 337.4 million tonnes (Table 1). **These figures represent a comprehensive inventory of all granular materials in the map area, although much of the material included in the estimate has no potential for use in aggregate products**. Many of these deposits have limited potential for extraction because of the small size of the deposit, the poor quality of the material and/or restricted access.

Deposits selected at the primary level contain aggregate resources considered potentially suitable for the production of road subbase. Deposits selected at the secondary level are generally sand deposits that are considered potentially suitable for at least the production of Select Subbase Material (SSM).

Three small deposits, outlined on Map 1, have been selected as areas of primary significance for protection and possible extraction. The 3 areas occupy a total of 232 ha with an available extractive area of 104 ha. The potential aggregate resource available is 10.4 million tonnes (Table 3).

EXTRACTIVE ACTIVITY

Forty-eight sand and gravel pits were identified in Prince Edward County (Table 2). The majority of these have been developed in ice-contact and glaciolacustrine deposits. At the time of writing, there were 18 pits licenced under the *Aggregate Resources Act*, occupying a total of 208.48 ha. Average aggregate production from 1994 to 1996 was 1 969 695.4 tonnes (Chart B) (Ontario Ministry of Natural Resources 1994, 1995, 1996).

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 is located in the west part of Hallowell Township, just east of Wellington (Map 1). One shallow abandoned pit has been developed in this esker. Pit No. P36 is overgrown with a 2 m face exposing sand and gravel.

During the field investigation, a sample was taken from the pit face and various aggregate quality tests were

Chart B - Extractive Activity
Prince Edward County

Municipality	1994 Production (Tonnes)	1995 Production (Tonnes)	1996 Production (Tonnes)
Ameliasburgh/Athol	86 985.3	82 329.2	51 076.1
Hallowell	137 600.6	104 488.7	140 864.0*
Hillier/N. & S. Marysburgh	33 753.0	70 100.1*	
Sophiasburgh	1 669 178.2	1 937 201.0	1 588 043.7
South Marysburgh			7 466.2*
County Total	**1 927 517.1**	**2 194 119.0**	**1 787 450.0**

* In 1994 and 1995 Hillier, North and South Marysburgh townships were reported together. In 1996 South Marysburgh was separated and Hillier and North Marysburgh were reported with Hallowell Township.

performed. The aggregate is considered of sufficient quality for the production of granular base and subbase material. The results of the quality testing for the most part fall within Ministry of Transportation specification limits for these products. The material from this deposit is unacceptable for HL and concrete products. The results of these tests are listed in Table 9 and Figures 2A and 2B.

This small esker occupies approximately 28 ha and has an estimated resource volume of 2.2 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 2

A large esker, located along Ridge Road and trending southwest from Picton for approximately 9 km, represents Selected Sand and Gravel Resource Area 2. Eleven pits have been developed in this feature. Pit faces range in height from 1 m to 20 m, exposing material ranging from fine to medium sand to sandy gravel. Generally, the material is coarser near the core of the ridge and becomes finer in the flanks.

Material from this deposit has reportedly been used for the production of HL4, 16 mm crushed, Granular A and B and select subbase (SSM). During the field investigation, a sample was taken from Pit No. P17 for magnesium sulphate soundness and Micro-Deval abrasion tests. The results confirm that material from the deposit is suitable for the production of the above-noted applicable uses. The results are presented in Table 9 and Figures 2A and 2B.

This deposit occupies approximately 152 ha but since Ridge Road is located along the top of the esker, only about 52 ha would be potentially available for extractive activity. The 52 ha have an aggregate resource potential of 5.5 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 3

Selected Sand and Gravel Resource Area 3 is an esker deposit located in Cherry Valley, south of Picton. Two pits (Pit Nos. P44 and P45) have been developed in this feature. Pit faces range in height from 3 m to 12 m, exposing material ranging from gravelly sand to sand and gravel. Generally, the material becomes finer from the centre of the esker ridge.

Material from this deposit has reportedly been used as HL4, 16 mm crushed and Granular A and B. During the field investigation, a sample was taken from Pit No. P45 and aggregate quality tests were performed. The quality tests included petrographic analysis, magnesium sulphate soundness, absorption and freeze-thaw soundness. The aggregate is considered of sufficient quality for the various granular base and subbase material, HL4 and HL8. The results of the quality testing for the most part fall within specification limits for these products. The results of these tests are presented in Table 9 and Figures 3A and 3B.

The deposit has an areal extent of approximately 52 ha but since this esker ridge runs through a developed area, only about 25 ha would be available for extractive activity. The 25 ha has an aggregate resource potential of 2.7 million tonnes (Table 3).

Resource Areas of Secondary Significance

A small area of ice-contact material located in the north-central part of Ameliasburgh Township, has been selected at the secondary level of significance. Houses and a county road restrict development in this area. No pits have been developed in this deposit.

A small glaciolacustrine beach deposit located at the southwest end of Selected Sand and Gravel Resource Area 2 southwest of Picton, has been selected at the secondary level of significance. Abandoned Pit No. P42 was established in this deposit and much aggregate has been removed. Pit faces expose sandy material with some gravel.

A sandy outwash deposit is located at the northeast end of Selected Sand and Gravel Resource Area 2 near Picton, has also been selected at the secondary level of significance. Licenced Pit Nos. P21 to P24 have been established in this deposit. Pit faces expose a fine to medium sand with a minor amount of gravel. Most of the deposit is licenced for extraction.

A sandy glaciolacustrine plain deposit adjacent to Selected Sand and Gravel Resource Area 3 has been selected at the secondary level of significance. Pit No. P45, located in Selected Sand and Gravel Resource Area 3, has southern faces extending into this sand deposit. These pit faces expose sand with a minor amount of gravel. The majority of the deposit is undeveloped to the east of the 2 existing pits.

Another sandy glaciolacustrine plain deposit located south of Milford in South Marysburgh Township has been selected at the secondary level of significance. Licenced Pit No. P48 has been established in this deposit. Pit faces expose up to 11 m of medium sand.

Resource Areas of Tertiary Significance

There are a number of glaciolacustrine plain and beach deposits that could supply sand and fill for low-specification purposes. Some of these deposits cover large expanses of the county, particularly surrounding the large esker deposit southwest of Picton. The beach deposits have many small abandoned pits which expose material composed of a silty sand and gravel. The shallow water sand plains are generally composed of fine sand with very little gravel and are usually 1 to 3 m thick.

BEDROCK GEOLOGY AND RESOURCE POTENTIAL

A succession of limestones and shales of Ordovician age, including the Lindsay and Verulam formations, underlie Prince Edward County. Excluding 2 small inliers, a

Precambrian (granitic) inlier and an Ordovician aged Bobcaygeon Formation inlier, the oldest Paleozoic unit in the map area is the Verulam Formation.

The Verulam Formation consists of interbedded limestones and shales and has an upper and lower member (Liberty 1969). The lower member, ranging from 23 to 68 m in thickness, consists of interbedded dark grey to grey, fossiliferous, fine- to coarse-grained limestone and green shale. The upper member is a medium- to coarse-grained, buff to tan coloured, cross-bedded, bioclastic limestone, ranging from 2 to 9 m in thickness. The upper member is not widely present in the study area.

The Lindsay Formation is the youngest Paleozoic unit in the study area and underlies most of the southern part of the county. The formation can be divided into 2 members. The lower member, approximately 30 m in thickness, consists of medium grey and bluish grey, fine- to medium-crystalline limestone. The limestone occurs in beds 3 to 10 cm thick separated by thin shaly seams and partings (Carson 1981). The upper member of the Lindsay Formation consists of pale to medium grey, sublithographic to fine-crystalline, nodular and shaly limestone. The thickness of the upper member is estimated to be 60 m.

Portions of the Verulam Formation can be used in the production of aggregate products, however, the Verulam is not generally suitable for the production of crushed products for road building or construction which meet the Ministry of Transportation specifications. Shale content of some beds tend to make the rock soft, and shaly zones have poor freeze-thaw resistance. Although drift cover is less than 8 m throughout most of the county, no resource areas have been selected. Although this rock unit does not meet Ministry of Transportation specifications for aggregate products, the material can produce non-specification aggregate material for local use.

Both members of the Lindsay Formation have been quarried for lime production, but they are generally unsuitable for road building or concrete aggregate which meets Ministry of Transportation specifications. The rock of this formation is soft and not resistant to weathering, making the aggregate produced from it unsuitable for load-bearing uses. Since the county has a lack of high quality aggregate reserves, rock from this formation is used for local road building and construction purposes. Although drift cover is less than 8 m throughout most of the county, no areas have been selected for possible resource protection (Chart C).

During the field investigation, 3 quarry stockpiles were sampled from 3 separate quarries each in a different bedrock unit. Quarry Q2 is extracting the lower member of the Lindsay Formation; Quarry Q35 is extracting the upper member of the Lindsay Formation and Quarry Q22 is mining in the Verulam Formation. The quality tests performed on the samples included petrographic analysis, magnesium sulphate soundness, absorption, Los Angeles Abrasion, freeze-thaw, accelerated mortar bar expansion and Micro-Deval Abrasion. The aggregate from Q2 and Q35 is considered of sufficient quality for Granular B and select subbase material (SSM) only. Material from Quarry Q22 (Verulam Formation) does not meet specifications for these uses. The results of these tests are presented in Table 9.

Within the study area, there are 13 quarries currently licenced under the *Aggregate Resources Act,* occupying a total of 531.49 ha (Table 5). Of this total area, approximately 60% (318.87 ha) is under one licenced property currently operated by Essroc Canada Inc. (Quarry No. Q19). At this quarry, all quarried rock (Verulam and Lindsay formations) is used in the production of cement. Of the remaining licenced quarries, 3 are in the Verulam Formation, 8 are in the lower member of the Lindsay Formation and one is in the upper member of the Lindsay Formation. Aggregate materials produced from the licenced quarries are generally limited to Granular B and select subbase material (SSM). There are 35 abandoned quarries in the study area. Most of these quarries are in the lower member of the Lindsay Formation.

Selected Bedrock Resources

Bedrock formations in Prince Edward County are generally of poor quality for aggregate uses, but some of the horizons are useable for select purposes. Due to the lack of aggregate reserves in the county, rock from the Verulam and Lindsay formations are used for local road building and construction purposes. No bedrock resource areas have been selected for possible extractive development in view of the limited quality of the material and the fact that extensive areas of bedrock are available for potential extraction.

SUMMARY

Three sand and gravel deposits have been selected for possible resource protection in Prince Edward County. The 3 eskers contain locally important resources of crushable gravel and other aggregate products. Other deposits of secondary and tertiary significance are also available in the county, however, these deposits generally contain material suitable for use as fill or low specification uses only.

The bedrock in Prince Edward County is not considered to be a suitable source of high quality crushed stone for aggregate. However, stone has been quarried in the county to produce lime for cement manufacture, particularly from the Verulam Formation. Although neither of the bedrock formations present in the county exhibit the potential to manufacture Ministry of Transportation specification aggregate, the units have the potential to manufacture non-specification products to meet local aggregate needs.

Enquiries regarding the Aggregate Resources Inventory of Prince Edward County may be directed to the Sedimentary Geoscience Section, Ontario Geological Survey, Ministry of Northern Development and Mines, 7th Floor, 933 Ramsey Lake Road, Sudbury, Ontario, P3E 6B5; the Resident Geologist Office, Ministry of Northern Development and Mines, Tweed, Ontario; or the Ministry of Natural Resources, Peterborough Office.

CHART C - BEDROCK RESOURCES SUMMARY PRINCE EDWARD COUNTY

FORMATION	ROCK TYPE	APPROXIMATE THICKNESS (m)	SUITABILITY AGGREGATE	OTHER	OCCURRENCE	NOTES
Lindsay	Lower member is interbedded, fine- to coarse-grained limestone with shaly partings. Upper member is interbedded, dark grey shale with petroliferous limestones.	25 to 65	Yes (Lower specification uses	-	Occurs throughout the study area and underlies most of the southern part of the county.	Has been used for aggregate in Eastern Ontario. In central Ontario, the Lindsay Formation has been used in the production of cement. May be suitable or unsuitable for use as concrete and asphalt aggregate.
Verulam	Fossiliferous, pure to argillaceous limestone interbedded with calcareous shale.	30 to 65	Yes (Lower specification uses	-	Occurs throughout the study area.	Has been used for aggregate elsewhere in the Province. Can be used in the manufacture of cement. May be unsuitable for use as aggregate in some areas because of its high shale content.
Bobcaygeon	Subdivided into upper, middle and lower members. Homogeneous, massive to thin bedded, fine-crystalline limestone with numerous shaly partings.	5 to 90	Yes (Lower specification uses	-	Occurs as a single inlier.	Quarried throughout Ontario for use as granular base course and for use in asphalt and concrete. Certain layers are silica alkali-reactive when used in Portland cement concrete.

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES PRINCE EDWARD COUNTY			
1 Class No.	**2 Deposit Type**	**3 Areal Extent (Hectares)**	**4 Original Tonnage (Million Tonnes)**
1	G-E	280	29.7
	G-LB	14	1.5
	S-LD	8	0.8
	S-LB	24	2.5
	S-LP	118	12.5
	S-OW	32	3.4
2	G-E	28	2.2
	S-IC	12	1.0
	S-LB	4	0.3
	S-LP	2708	215.7
	S-WD	14	1.1
3	G-LP	274	10.9
	G-IC	6	0.2
	S-LB	86	3.4
	S-LD	52	2.1
	S-LP	944	37.6
4	G-LB	18	0.2
	S-AL	133	1.8
	S-LB	4	0.1
	S-LD	25	0.3
	S-LP	148	2.0
	S-WD	613	8.1
COUNTY TOTAL		**5545**	**337.4**

Minor variations in all tables are caused by rounding of data.

The above figures represent a comprehensive inventory of all granular materials in the map area. Some of the material included in the estimate has no aggregate potential and some is unavailable for extraction due to land use restrictions.

TABLE 2 - SAND AND GRAVEL PITS
PRINCE EDWARD COUNTY

Pit No.	Owner/Operator	Licenced Areas (Hectares)	Face Height (Metres)	% Gravel	Remarks
AMELIASBURGH TOWNSHIP					
Licenced Pits					
P1	Roger Redner and Barbara Gray	24.06	6-8	10-50	Rehabilitated
Unlicenced Pits					
P2	-	-	6-8	20-80	Depleted
P3	-	-	4-6	10-60	Depleted
P4	-	-	2-3	10-30	Overgrown
P5	-	-	2-6	10-50	Depleted
P6	-	-	3-4	10-60	Landfill site
P7	-	-	3-5	50	Overgrown
P8	-	-	3	20	Depleted
SOPHIASBURGH TOWNSHIP					
Licenced Pits					
P9	Roy Longwell	2.53	4	-	
Unlicenced Pits					
P10	-	-	2	10	Overgrown
HILLIER TOWNSHIP					
Unlicenced Pits					
P11	Wright	-	9	1	Depleted
P12	Grossman	-	2	10-30	Depleted
P13	Hillier Township	-	2	10-30	Landfill Site
HALLOWELL TOWNSHIP					
Licenced Pits					
P14	Anthony Grootheest	23.00	8	10-20	Overgrown
P15	Raymond Moore	3.80	3-7	10-40	Mostly Sand
P16	Paul Greer	8.07	-	-	Unopened
P17	Township of Hallowell	15.55	5-15	20-70	
P19	Monika Amos/Gord Amos	14.58	2-8	10-20	Below water extraction
P20	Prince Edward County	5.20	5-14	30-70	Overgrown
P21	Prince Edward County	7.01	10	10	Overgrown
P22	Peter Hennessy	5.05	5	10-30	
P23	Power Concrete Products	1.30	10-15	10	
P24	Miller Paving Ltd.	4.45	8-10	10	
Unlicenced Pits					
P18	-	-	6-15	20-60	Overgrown
P25	-	-	6-8	10-30	Overgrown
P26	-	-	-	-	Unopened
P27	-	-	-	-	Unopened
P28	-	-	-	60	Unopened
P29	-	-	4-12	20-60	Depleted
P30	-	-	3-10	10-60	Water on floor
P31	-	-	-	-	Unopened
P32	-	-	-	-	Unopened
P33	-	-	-	-	Unopened
P34	-	-	2-6	20-60	Rehabilitated

TABLE 2 - SAND AND GRAVEL PITS PRINCE EDWARD COUNTY					
Pit No.	**Owner/Operator**	**Licenced Areas (Hectares)**	**Face Height (Metres)**	**% Gravel**	**Remarks**
P35	-	-	6-7	10	Overgrown
P36	-	-	2	30-50	Overgrown small pit
P37	-	-	-	-	Unopened
P38	-	-	-	-	Unopened
P39	-	-	20	30-70	Depleted
P40	-	-	-	-	Unopened
P41	-	-	20	10-50	Sloughed & overgrown
P42	-	-	4-6	10-30	Overgrown
P43	-	-	-	-	Rehabilitated
ATHOL TOWNSHIP					
Licenced Pits					
P44	Prince Edward County	2.70	5	30-50	
P45	C.B. Fennell Ltd.	60.70	3-12	30	Large Pit
NORTH MARYSBURGH TOWNSHIP					
Licenced Pits					
P46	Gerald McAuley	8.09	6-8	<10	
SOUTH MARYSBURGH TOWNSHIP					
Licenced Pits					
P47	William Creasy	4.61	-	-	Filled with water
P48	County of Prince Edward	8.04	8-11	10	Overgrown

TABLE 3 - SELECTED SAND AND GRAVEL RESOURCE AREAS
PRINCE EDWARD COUNTY

1 Deposit No.	2 Unlicenced Area (Hectares)*	3 Cultural Setback (Hectares)**	4 Extracted Area (Hectares)***	5 Available Area (Hectares)	6 Estimated Deposit Thickness (Metres)	7 Possible Aggregate Resources (Million Tonnes)****
1	28	0	1	27	4.5	2.2
2	152	90	10	52	6	5.5
3	52	27	0	25	6	2.7
COUNTY TOTAL						
	232	**117**	**11**	**104**		**10.4**

Minor variations in all tables are caused by rounding of data.

* Excludes areas licenced under the Aggregate Resources Act.

** Cultural setbacks include heavily populated urban areas, roads (including a 100 m wide strip centred on each road), water features (e.g., lakes, streams), 1 ha for individual houses. NOTE: this provides a preliminary and generalized constraint application only. Additional environmental and social constraints will further reduce the deposit area.

*** Extracted area is a rough estimate of areas that are not licenced but due to previous extractive activity, largely depleted.

**** Further environmental, resource, social and economic constraints will greatly reduce the selected resource quantity realistically available for potential extraction.

TABLE 4 - TOTAL BEDROCK RESOURCES PRINCE EDWARD COUNTY				
1 Drift Thickness (Metres)	**2 Formation**	**3 Estimated Deposit Thickness (Metres)**	**4 Areal Extent (Hectares)**	**5 Original Tonnage (Million Tonnes)**
0 - 1	Lower Lindsay	18	45578	21732.5
1 - 8	Lower Lindsay	18	7008	3341.6
8 - 15	Lower Lindsay	18	320	152.6
> 15	Lower Lindsay	18	80	38.1
0 - 1	Upper Lindsay	18	19659	9373.8
1 - 8	Upper Lindsay	18	6291	2999.7
8 - 15	Upper Lindsay	18	2394	1141.5
> 15	Upper Lindsay	18	440	209.8
0 - 1	Verulam	18	13275	6329.8
1 - 8	Verulam	18	9256	24413.4
8 - 15	Verulam	18	117	55.8
> 15	Verulam	18	102	48.6
0 - 1	Bobcaygeon	18	180	85.8
COUNTY TOTAL			**104700**	**69923**

The above figures represent a comprehensive inventory of all bedrock resources in the map area. Some of the material included in the estimate has no aggregate potential and some is unavailable for extraction due to land use restrictions.

TABLE 5 - QUARRIES PRINCE EDWARD COUNTY				
Quarry No.	Owner/Operator	Licenced Areas (Hectares)	Face Height (Metres)	Remarks
AMELIASBURGH TOWNSHIP				
Licenced Quarries				
Q1	Roger Redner & Barbara Gray	24.06	6-8	Pit and quarry
Q2	Tarmac Canada Inc.	15.75	18-20	Mountain View Quarry
Unlicenced Quarries				
Q3	-	-	1	Filled with water
Q4	-	-	2-3	Filled with water
Q5	-	-	1	Filled with water
Q6	-	-	5-8	Overgrown
Q7	-	-	-	Unopened
Q8	-	-	-	Unopened
Q9	-	-	-	Shaley Limestone
HILLIER TOWNSHIP				
Licenced Quarries				
Q10	Tarmac Canada Inc.	35.10	7-8	Consecon Quarry
Unlicenced Quarries				
Q11	-	-	2	Overgrown
Q12	-	-	-	Rehabilitated
Q13	-	-	-	Filled with water
Q14	-	-	2	Filled with water
Q15	-	-	3	Overgrown
Q16	-	-	-	Rehabilitated
Q17	-	-	3	Overgrown
Q18	-	-	4-7	Overgrown
SOPHIASBURGH TOWNSHIP				
Licenced Quarries				
Q19	Essroc Canada Inc.	318.87	51	Three Lifts
Q20	Wimpy Minerals Canada	4.86	7	
Q21	Miller Paving Ltd.	47.60	7-8	One Lift
Q22	Anderson Farms	26.98	10	One Lift
Q23	R. Anderson	7.70	10	One Lift
Q24	Township of Sophiasburgh	6.57	4.5	Water on floor
Q25	John E. Fox	21.30	0.5	Shallow quarry
Unlicenced Quarries				
Q26	-	-	-	Unopened
Q27	-	-	1-9	Filled with water
Q28	-	-	1	Filled with water
Q29	-	-	3	Overgrown
Q30	-	-	3	Overgrown
Q31	-	-	3	Filled with water
Q32	-	-	1	Filled with water
Q33	-	-	1	Filled with water
Q34	-	-	-	Filled with water

TABLE 5 - QUARRIES PRINCE EDWARD COUNTY				
Quarry No.	**Owner/Operator**	**Licenced Areas (Hectares)**	**Face Height (Metres)**	**Remarks**
HALLOWELL TOWNSHIP				
Licenced Quarries				
Q35	Foster Quarry	9.79	7-9	One Lift
Unlicenced Quarries				
Q36	-	-	1-2	Filled with water
Q37	-	-	3	Overgrown
Q38	-	-	4	Filled with water
Q39	-	-	10-20	Landfill site
ATHOL TOWNSHIP				
Unlicenced Quarries				
Q40	-	-	1	Filled with water
Q41	-	-	6	Overgrown
Q42	-	-	4	Overgrown
NORTH MARYSBURGH TOWNSHIP				
Unlicenced Quarries				
Q43	-	-	4-5	Filled with water
Q44	-	-	2-3	Overgrown
SOUTH MARYSBURGH TOWNSHIP				
Licenced Quarries				
Q45	William Creasy	4.61	7-9	Pit and quarry
Q46	William Creasy	8.30	1-2	Filled with water
Unlicenced Quarries				
Q47	-	-	1	Filled with water
Q48	-	-	1	Filled with water

TABLE 6 - SELECTED BEDROCK RESOURCES PRINCE EDWARD COUNTY							
1 Area No.	2 Depth of Overburden (Metres)	3 Area (Hectares)*	4 Cultural Setbacks (Hectares)**	5 Extracted Area (Hectares)***	6 Possible Resource Area (Hectares)	7 Estimated Workable Thickness (Metres)	8 Possible Bedrock Resources**** (Million Tonnes)
NONE							

TABLE 7 - SUMMARY OF TEST HOLE DATA PRINCE EDWARD COUNTY
NONE

TABLE 8 - SUMMARY OF GEOPHYSICAL DATA PRINCE EDWARD COUNTY
NONE

TABLE 9 - RESULTS OF AGGREGATE QUALITY TESTS
PRINCE EDWARD COUNTY

COARSE AGGREGATE									FINE AGGREGATE
Sample No. (Pit/ Quarry)	Petrographic Number: Granular & 16 mm Crushed	Petrographic Number: Hot Mix & Concrete	Magnesium Sulphate Soundness (% Loss)	Absorption (%)	Los Angeles Abrasion* (% Loss)	Freeze-Thaw (% Loss)	Accelerated Mortar Bar Expansion (% Expansion)	Micro Deval Abrasion (% Loss)	Micro Deval Abrasion (% Loss)
Pit No. P17			14						13.4
Pit No. 36	199	283	21	1.545	28	13	0.047	24.2	18.2
Pit No. P45	130	138	10	0.737		12			13.3
Q2	143	167	23	0.672	22	9	0.222	27.0	
Q22	190	229	27	1.006	21	17	0.099	35.6	35.2
Q35	148	244	33	0.721		21	0.229	29.2	

* Note - Los Angeles Abrasion no longer accepted, however, included for comparison purposes.

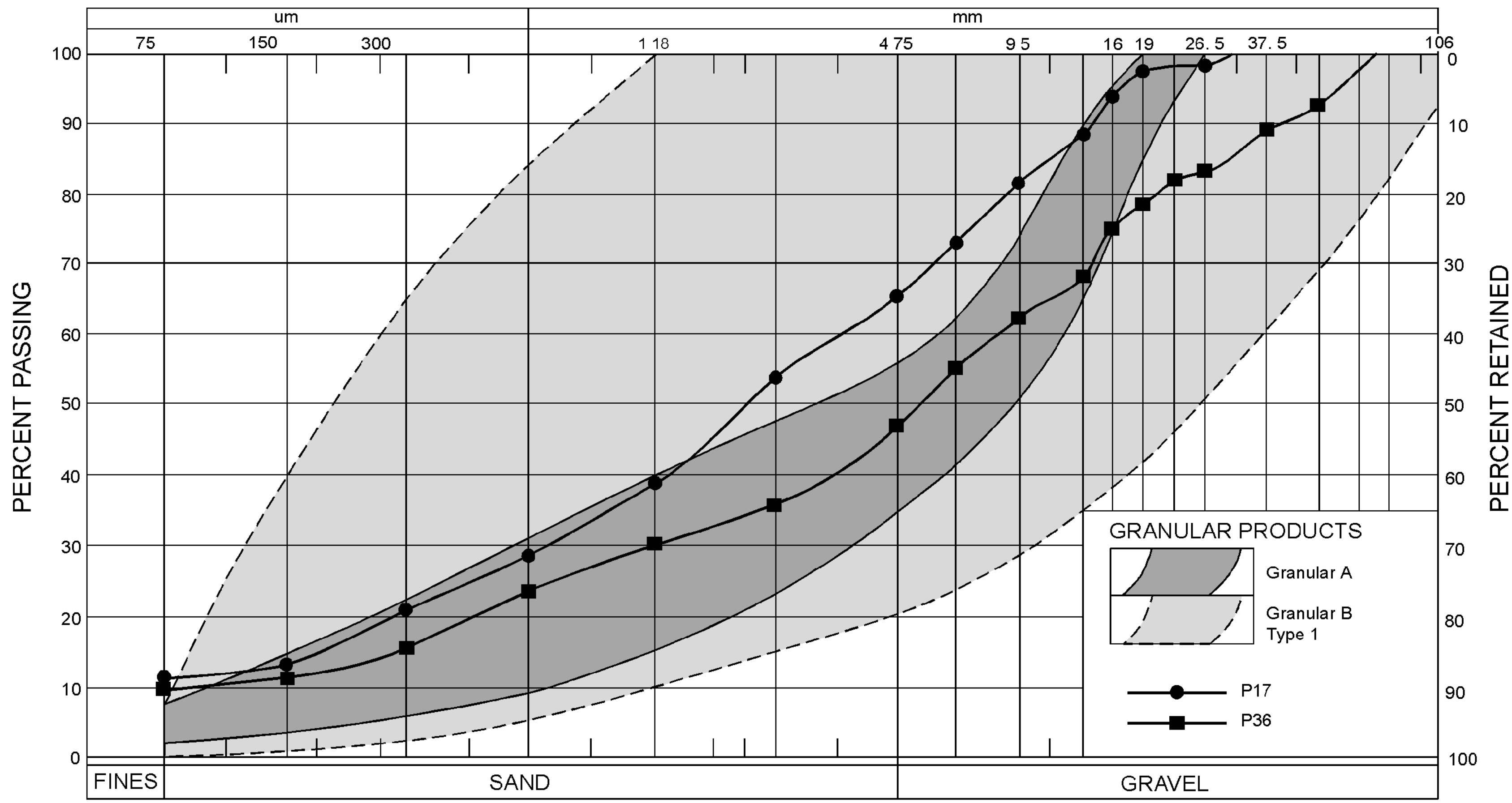


FIGURE 2A AGGREGATE GRADING CURVES, PRINCE EDWARD COUNTY.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

NOTE:
Information portrayed by grading curves refers stictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

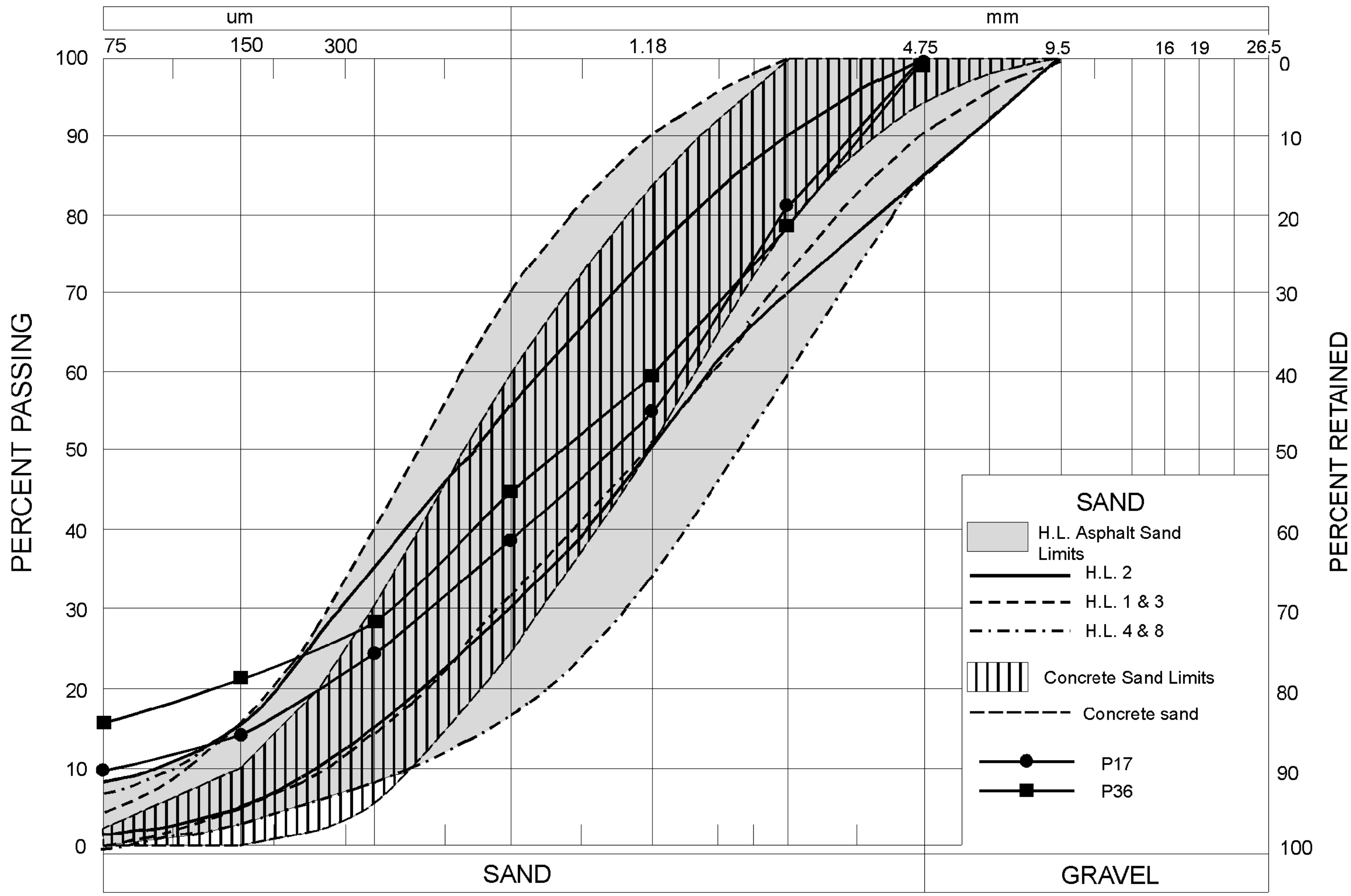


FIGURE 2B AGGREGATE GRADING CURVES, PRINCE EDWARD COUNTY.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1002, 1988 and 1003, 1988).

NOTE:
Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

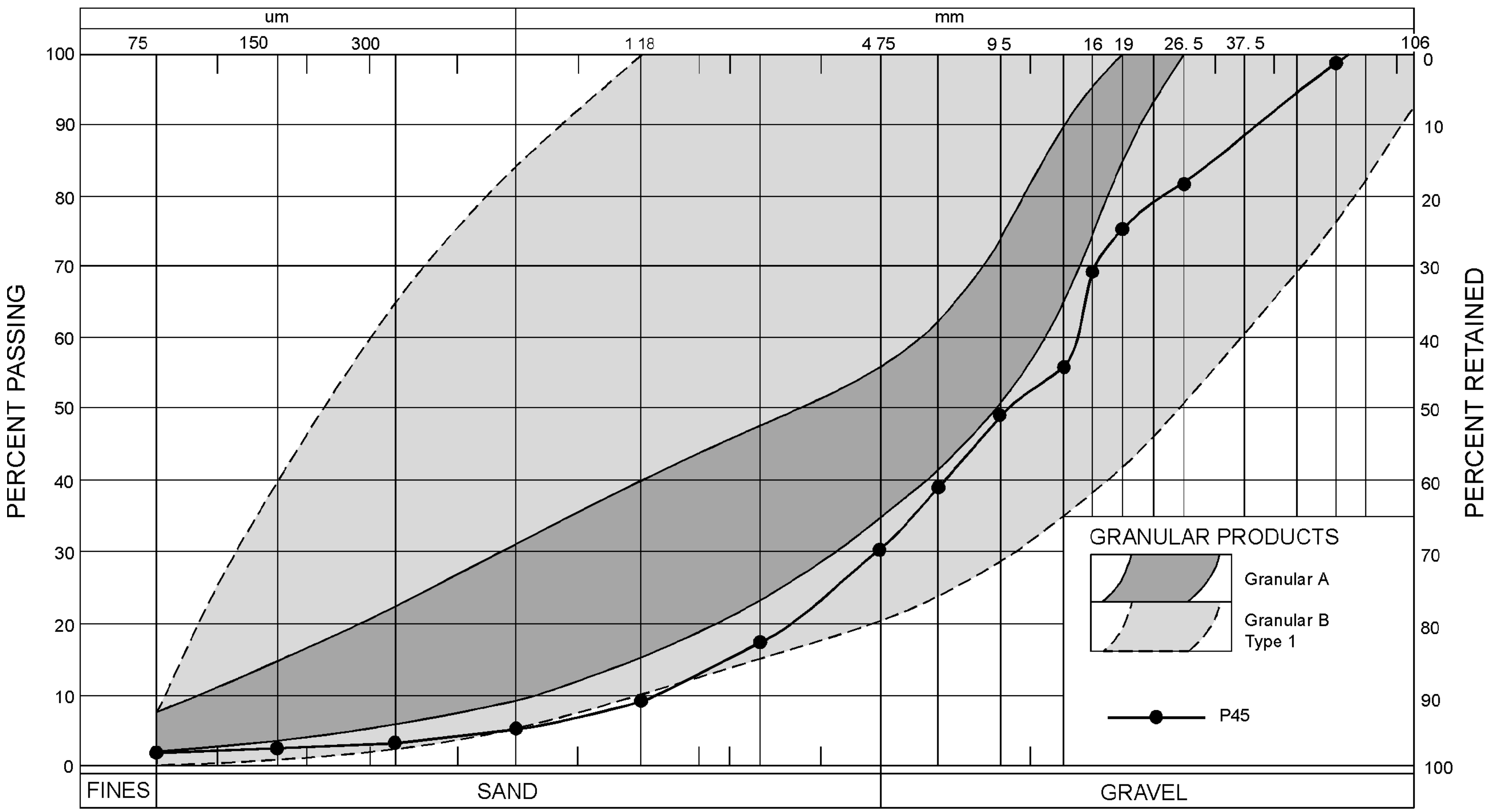


FIGURE 3A AGGREGATE GRADING CURVES, PRINCE EDWARD COUNTY.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1010, 1988).

NOTE:
Information portrayed by grading curves refers stictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

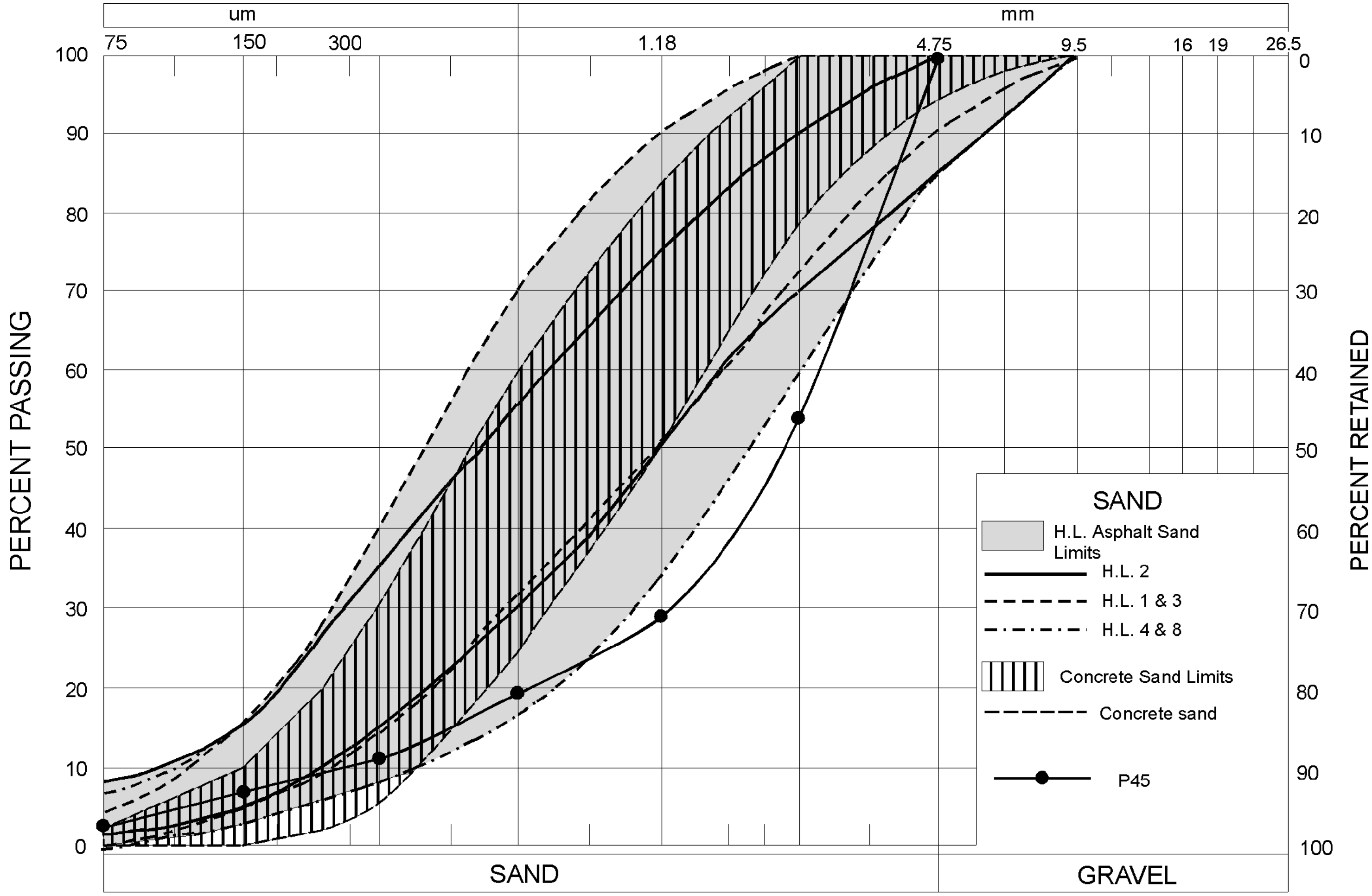


FIGURE 3B AGGREGATE GRADING CURVES, PRINCE EDWARD COUNTY.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standard Specifications OPSS 1002, 1988 and 1003, 1988).

NOTE:
Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix B - Glossary

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.

Acid-Soluble Chloride Ion Content: This test measures total chloride ion content in concrete and is used to judge the likelihood of re-bar corrosion and susceptibility to deterioration by freeze-thaw in concrete structures. There is a strong positive correlation between chloride ion content and depassivation of reinforcing steel in concrete. Depassivation permits corrosion of the steel in the presence of oxygen and moisture. Chloride ions are contributed mainly by the application of de-icing salts.

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.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desirable.

Alkali-aggregate reaction: A chemical reaction between the alkalies of Portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing, or classification. Heavy media separation, jigging, or application of special crushers (e.g., "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: The density of a material related to water at 4^{o}C and atmospheric pressure at sea level. An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 505 million years age. The Cambrian precedes the Ordovician Period.

Chert: Amorphous silica, generally associated with limestone. Often occur as irregular masses or lenses but can also occur finally disseminated through limestones. It may be very hard in unleached form. In leached form, it is white and "chalky" and is very absorptive. It has deleterious effect for aggregates to be used in Portland cement concrete due to reactivity with alkalies in Portland cement.

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

Crushable Aggregate: Unprocessed gravel containing a minimum of 35% coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20% greater than the 26.5 mm sieve.

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 Paleozoic Era thought to have covered the span of time between 408 and 360 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest Paleozoic rocks in Ontario.

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 formed 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 (0.075 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 then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in Ontario.

Gneiss: A coarse-textured metamorphic rock with the minerals arranged in parallel streaks or bands. Gneiss is relatively rich in feldspar. Other common minerals found in this rock include quartz, mica, amphibole and garnet.

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	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granite: A coarse-grained, light-coloured rock that ordinarily has an even texture and is composed of quartz and feldspar with either mica, hornblende or both.

Granular Base and Subbase: Components of a 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. Four types have been defined: Granular A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular B which is usually pit-run or other unprocessed aggregate; Granular M is a shouldering and surface dressing material with quality requirements similar to Granular A; Select Subgrade Material has similar quality requirements to Granular B and it provides a stable platform for the overlying pavement structure. (For more specific information the reader is referred to Ontario Provincial Standard Specification OPSS 1010).

Heavy Duty Binder: Second layer from the top of hot mix asphalt pavements, used on heavily travelled (especially by trucks) expressways, such as Highway 401. Coarse and fine aggregates are to be produced from high quality bedrock quarries, except when gravel is permitted by special provisions.

Hot-laid (or Asphaltic) Paving Aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (HL 1, 3 and 4), or as binder course (HL 2, 4 and 8) used to bind the surface course to the underlying granular base.

Limestone: A carbonate sedimentary rock consisting chiefly of the mineral calcite. It may contain the mineral dolomite up to about 40%.

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

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium Sulphate Soundness Test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Medium Duty Binder: Second layer from the top of hot mix asphalt pavements used on heavily travelled, usually four lane highways and municipal arterial roads. It may be constructed with high quality quarried rock or high quality gravel with a high percentage of fractured faces or polymer modified asphalt cements.

Meltwater Channel: A drainage way, often 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 505 and 438 million years ago.

Paleozoic Era: One of the major divisions of the geologic time scale thought to have covered the time period 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.

Petrographic Examination: An aggregate quality test based on known field performance of various rock types. In Ontario the test result is a Petrographic Number (PN). The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the “Great Ice Age”.

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abrasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible Resource: Reserve estimates based largely on broad knowledge of the geological 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, but do not take into account many site-specific natural and environmental constraints that could render the resource unaccessible.

Precambrian: The earliest geological period extending from the consolidation of the earth’s crust to the beginning of the Cambrian Period.

Sandstone: A clastic sedimentary rock consisting chiefly of sand-sized particles of quartz and minor feldspar, cemented together by calcareous minerals (calcite or dolomite) or by silica.

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.

Siltstone: A clastic sedimentary rock consisting chiefly of silt-sized particles, cemented together by calcareous minerals (calcite and dolomite) or by silica.

Silurian: An early period of the Paleozoic era thought to have covered the time between 438 and 408 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 period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of 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 Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and 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 because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of 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 crossbedded, 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. Eskers 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 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 because of 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. The deposits 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.

Subaqueous Fans (SF): Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment-laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan- or lobe-shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels which may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay which settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

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 they have generally low value because of the presence of excess silt- and clay-sized material. There are few 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 Ontario. Well developed lacustrine beaches are usually less than 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 source 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 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 Plains (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 because of 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 subbase aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines 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 areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (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 Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

Appendix D - Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure D1) and, where known, the potential uses of the various bedrock formations. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure D2) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey (e.g. Johnson et al. 1992) and the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness and uses of the formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data are available, the data have been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use. The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 14 m. USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: part of the Potsdam Group. COMPOSITION: thin- to massive-bedded quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 30 m. USES: suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, $MgSO_4$ = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 6 to 64 m. USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate. Suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, $MgS0_4$ = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaly interbeds. THICKNESS: 61 to 102 m. USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, $MgSO_4$ = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 125 m. USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario - the basal unit of the Ottawa Group; central Ontario - overlain by the Simcoe Group. COMPOSITION: in eastern Ontario - silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario - conglomerates, sandstones, and shales. THICKNESS: eastern Ontario - 2 to 3 m; central Ontario - 0 to 12 m. USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In eastern Ontario the formation is subdivided into upper and lower members; in central Ontario it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 7.5 to 136 m. USES: quarried in the Lake Simcoe, Kingston, Ottawa and Cornwall areas for crushed stone. Rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 7 to 87 m. USES: quarried at Brechin, Marysville, and in the Ottawa area for crushed stone. Generally suitable for use as granular base course aggregate. Rock from certain layers has been found to be alkali-reactive when used in Portland cement concrete (alkali-silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 32 to 65 m. USES: quarried at Picton and Bath for use in cement manufacture. Quarried for aggregate in Ramara Township, Simcoe County and in the Belleville–Kingston area. May be unsuitable for use as aggregate in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle Upper Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: eastern Ontario - the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; central Ontario – Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 25 to 67 m. USES: eastern Ontario - lower member is used extensively for aggregate production; central Ontario - quarried at Picton, Ogden Point and Bowmanville for cement. May be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47, LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario – Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario – Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: Blue Mountain Formation - blue-grey, noncalcareous shales; Billings Formation - dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation - 43 to 61 m; Billings Formation - 0 to 62 m. USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: central Ontario – Georgian Bay Formation composed of interbedded limestone and shale; eastern Ontario – Carlsbad Formation composed of interbedded shale, siltstone and bioclastic limestone. THICKNESS: Georgian Bay Formation - 91 to 170 m. Carlsbad Formation - 0 to 186 m. USES: Georgian Bay Formation - used by several producers in Metropolitan Toronto area to produce brick and structural tile, as well as for making Portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate. Carlsbad Formation - used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 45 to 335 m. USES: There are several large quarries developed in the Queenston Formation in the Toronto–Hamilton region and one at Russell, near Ottawa. All extract shale for brick manufacturing. The Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Peninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 - 8 m. USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff-brown dolomitic limestones and dolostones. THICKNESS: 0 to 25 m. USES: extracted for crushed stone in St. Vincent and Sarawak townships, Grey County, and for decorative stone on Manitoulin Island.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs in subsurface throughout southwestern Ontario and outcrops along the length of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 10 to 39 m. USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile. Extraction limited by lack of suitable exposures.

Grimsby Formation (Lower Silurian)

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 15 m. USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 2 - 3 m. USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION: dark-grey to green shale with minor interbedded limestone. THICKNESS: 0 to 2 m. USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 7.5 m. USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 15 m. USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: occurs on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff-brown, micro- to medium-crystalline, thin- to medium-bedded dolostone. THICKNESS: 0 to 25 m. USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-2, LA = 19-21, Absn = 0.6-0.7, BRD = 2.78-2.79, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation - fine- to coarse-crystalline dolostone with high silica content; Reynales Formation - thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation 6 to 26 m; Reynales Formation 0 to 3 m. USES: both formations quarried for aggregate with overlying Amabel and Lockport Formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4$ = 41, LA = 29, Absn = 4.1, BRD = 2.45, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION:

massive, coarse-crystalline crinoidal limestone. THICKNESS: 0 to 2 m. USES: not utilized extensively.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 5 to 24 m. USES: not utilized extensively. AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Asbn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 5 m. USES: too shaley for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members, and an informal member (the "Vinemount shale beds"); the approximately equivalent Amabel Formation, found from Waterdown to Cockburn Island, has been subdivided into Lions Head, Wiarton/Colpoy Bay and Eramosa Members. On the Bruce Peninsula and in the subsurface of southwestern Ontario the Eramosa Member is considered to be part of the overlying Guelph Formation. COMPOSITION: Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone with reef facies developed near Georgetown and on the Bruce Peninsula. The Eramosa Member is thin bedded and bituminous. THICKNESS: (Lockport/Amabel) 3 to 40 m. USES: both formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: exposed south and west of the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, medium- to thick-bedded, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. THICKNESS: 4 to 100 m. USES: some areas appear soft and unsuitable for use in the production of load-bearing aggregate. This unit requires additional testing to fully establish its aggregate suitability. Main use is for dolomitic lime for cement manufacture. Quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; only rarely exposed at surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic-rich material with up to eight units identifiable. THICKNESS: 113 to 330 m. USES: gypsum mines at Hagersville, Caledonia and Drumbo. Salt is mined at Goderich and Windsor and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, rarely outcrops in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville and Akron Members. COMPOSITION: medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. THICKNESS: 14 to 28 m. USES: quarried for crushed stone on the Niagara Peninsula; shaly intervals are unsuitable for use as high specification aggregate because of low freeze-thaw durability. Has also been extracted for lime. AGGREGATE SUITABILITY TESTING: PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.8, BRD = 2.61-2.78, PN (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick- to massive-bedded, coarse-grained, grey-yellow sandstone. THICKNESS: 0 to 5 m. USES: has been quarried for silica sand, building stone and armour stone. May be acceptable for use as rip rap, and well-cemented varieties may be acceptable for some asphaltic products. AGGREGATE SUITABILITY TESTING: (of a well-cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSITION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 3 to 40 m. USES: quarried at Hagersville, Cayuga and Port Colborne for crushed stone. Material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (Asphalt & Concrete) = 102-290.

Onondaga Formation (Lower - Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence and Moorehouse Members. COMPOSITION: medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone. THICKNESS: 8 to 25 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 use as concrete aggregate and asphaltic concrete. Has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Lower - Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Peninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone with grey chert nodules; Formosa Reef Limestone - high purity (calcium-rich) limestone; Sylvania Sandstone Member - quartz sandstone. THICKNESS: 0 to 60 m; Formosa Reef Limestone - up to 26 m. USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock–Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminus laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone and locally, sandy limestone. THICKNESS: 40 to 75 m. USES: most important source of high-purity limestone in Ontario. Used as calcium lime for metallurgical flux and for the manufacture of chemicals. Rock of lower purity is used for cement manufacture, agricultural lime and aggregate. Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn = 1.1-6.5, BRD = 2.35-2.40, PN (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, brownish-grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. THICKNESS: 15 to 45 m. USES: quarried near Port Dover and on Pelee Island for crushed stone. Used at St. Marys as a raw material for Portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern USA, pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 12 m. USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no outcrop in Ontario. COMPOSITION: soft, blue and grey calcareous shale. THICKNESS: 0 to 14.5 m. USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 6 m. USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. THICKNESS: 5 to 37 m. USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 2 m. USES: suitable for some crushed stone and fill with selective quarrying.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 21 m. USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse grained, grey-brown, bioclastic limestone. THICKNESS: 2 to 14 m. USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a northwest-trending band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 75 m. USES: possible source of material for use as sintered lightweight aggregate or fill.

Bedford Formation (Upper Devonian or Mississippian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 30 m. USES: no present uses.

Berea Formation (Upper Devonian or Mississippian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine- to medium-grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 60 m. USES: no present uses.

Sunbury Formation (Upper Devonian or Mississippian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 20 m. USES: no present uses.

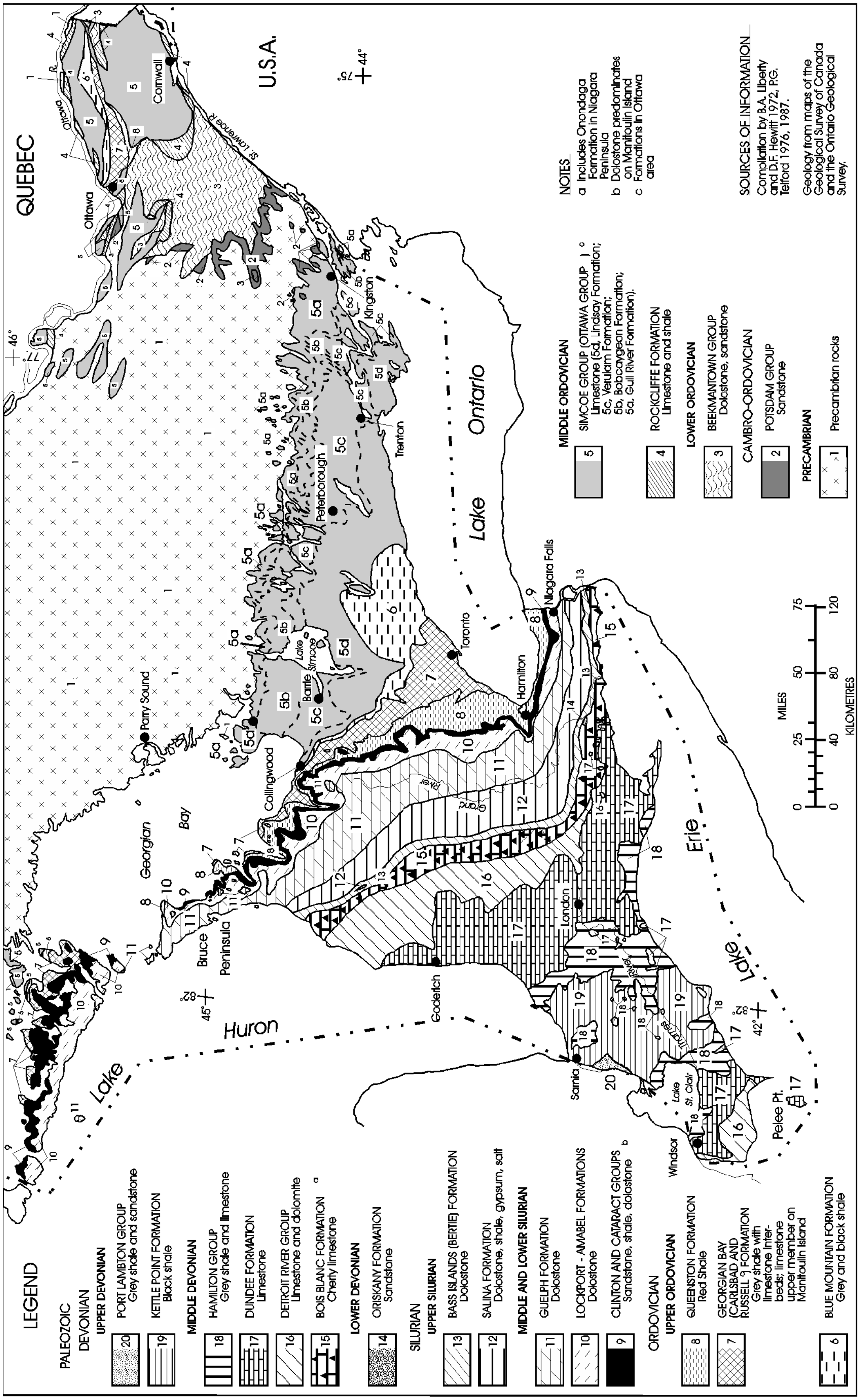

Figure D1. Bedrock geology of southern Ontario.

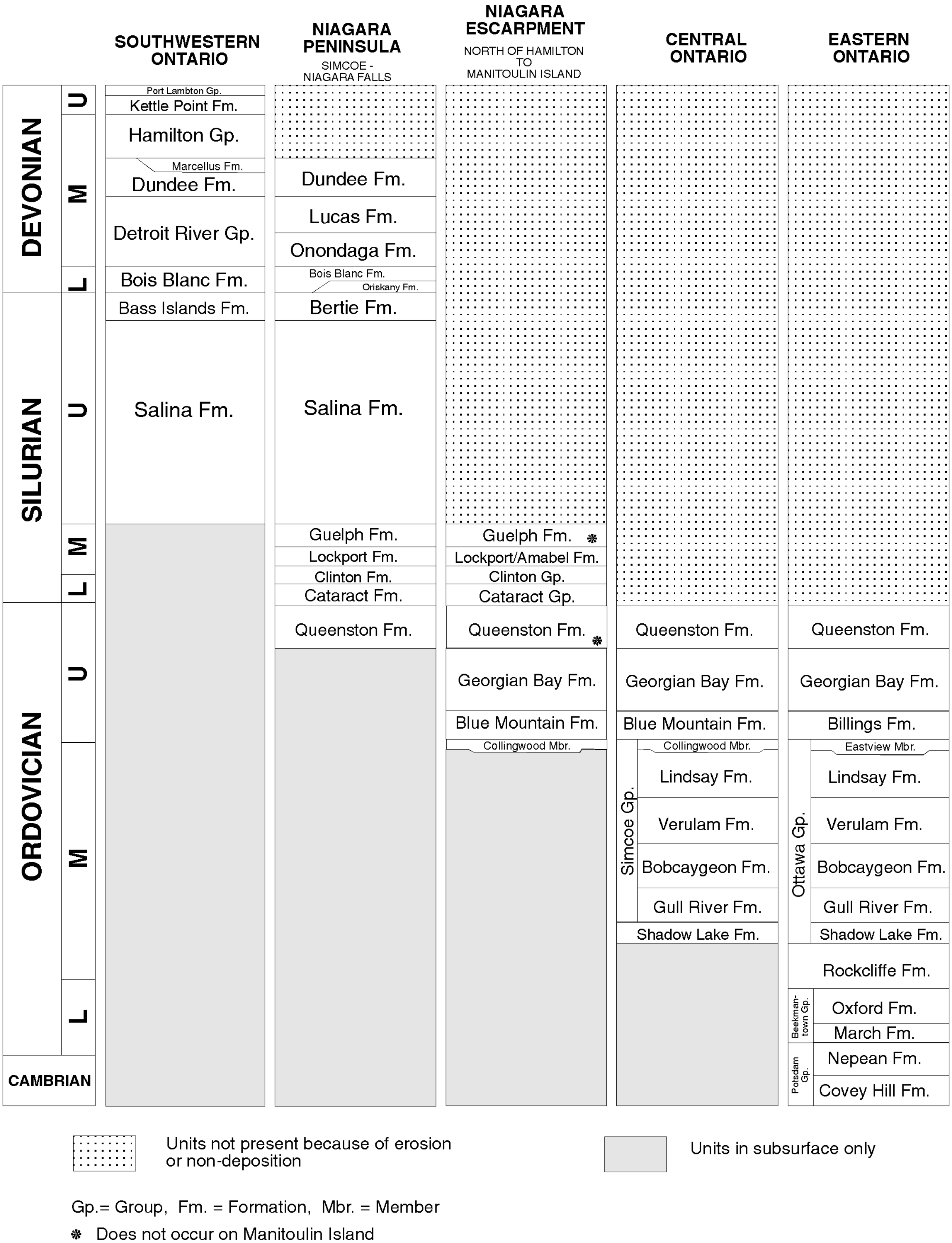

Figure D2. Exposed Paleozoic stratigraphic sequences in southern Ontario (*adapted from*: Bezys, R.K. and Johnson, M.D. 1988. The geology of the Paleozoic formations utilized by the limestone industry of Ontario; The Can. Mining and Metallurgical Bulletin,v.81, no. 912, p.49-58.)

Appendix E – Aggregate Quality Test Specifications

Six types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description and the specification limits for each test are included in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the six tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Ontario Ministry of Transportation.

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. This test is conducted in conjunction with the determination of the sample's relative density.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium Sulphate Soundness Test: This test is designed to simulate the action of freezing and thawing on aggregate. Those aggregates which are susceptible will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Micro-Deval Abrasion Test: The Micro-Deval Abrasion test is an accurate measure of the amount of hard, durable materials in sand-sized particles. This abrasion test is quick, cheap and more precise than the fine aggregate Magnesium Sulphate Soundness test that suffers from a wide multilaboratory variation. The maximum loss for HL 1/HL 3 is 20%, for HL 2 and HL 4/HL 8 it is 25% and for structural and pavement concrete it is 20%. It is anticipated that this test will replace the fine aggregate Magnesium Sulphate Soundness test.

Mortar Bar Accelerated Expansion Test: This is a rapid test for detecting alkali-silica reactive aggregates. It involves the crushing of the aggregate and the creation of standard mortar bars. For coarse and fine aggregates, suggested expansion limits of 0.10 to 0.15% are indicated for innocuous aggregates, greater than 0.10% but less than 0.20% indicates that it is unknown whether a potentially deleterious reaction will occur, and greater than 0.20% indicates that the aggregate is probably reactive and should not be used for Portland cement concrete. If the expansion limit exceeds 0.10% for coarse and fine aggregates, it is recommended that supplementary information be developed to confirm that the expansion is actually because of alkali-reactivity. If confirmed deleteriously reactive, the material should not be used for Portland cement concrete unless corrective measures are undertaken such as the use of low- or reduced-alkali cement.

Petrographic Examination: Individual aggregate particles in a sample are divided into categories good, fair, poor and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Table E1. Selected quality requirements for major aggregate products.

TYPE OF TEST						
COARSE AGGREGATE					FINE AGGREGATE	
TYPE OF MATERIAL	**Petrographic Number Maximum**	**Magnesium Sulphate Soundness Maximum% Loss**	**Absorption Maximum%**	**Los Angeles Abrasion Maximum% Loss**	**Micro-Deval Abrasion Maximum % Loss**	**Magnesium Sulphate Soundness Maximum % Loss**
Granular A	200	-	-	60		-
Granular B Type 1	250*	-	-	-		-
Granular B Type 2	250	-	-	60		-
Granular M	200	-	-	60		-
Granular S	200	-	-	-		-
Select Subgrade Material	250	-	-	-		-
Open Graded Drainage Layer (1)	160	15	2.0	35		-
Hot Mix-HL 1, DFC, OFC	See OPSS 1149 and Special Provision No. 313S10					
Surface Treatment Class 1	135	12	1.75	35		-
Surface Treatment Class 2	160	15	-	35		-
Surface Treatment Class 3	160	12	2.0	35		-
Surface Treatment Class 4	-	-	-	-		20
Surface Treatment Class 5	135	12	1.75	35		-
Hot Mix - HL 1	100	5	1.0	15	20	16
Hot Mix - HL 2	-	-	-	-	25	20
Hot Mix - HL 3	135	12	1.75	35	20	16
Hot Mix - HL 4	160	12	2.0	35	20	20
Hot Mix - HL 8	160	15	2.0	35	25	20
Structural Concrete, Sidewalk, Curb, Gutter and Base	140	12	2.0	50	20	16
Pavement Concrete	125	12	2.0	35	20	16

*** requirement waived if the material has more than 80% passing the 4.75 mm sieve**
(1) Hot mix and concrete petrographic number applies
(Ontario Provincial Standard Specifications OPSS 304, OPSS 1002, OPSS 1003, OPSS 1010 and OPSS 1149)

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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Ontario

Ontario Geological Survey

Aggregate Resources Inventory

PRINCE EDWARD COUNTY

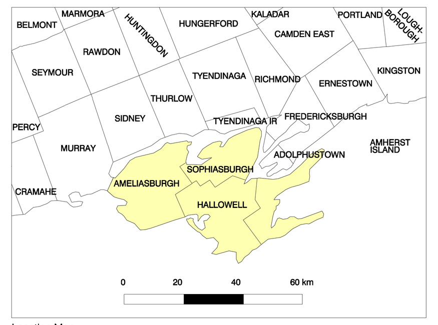
ARIM MAP 172-1

SAND AND GRAVEL RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS reference: 30N/13, 30N/14, 30N/15, 31C/2, 31C/3, 30C/4



Location Map

LEGEND

(Some map units and symbols may not apply to this map)

- Selected sand and gravel resource area, primary significance; deposit number; see Table 3.
- Selected sand and gravel resource area, secondary significance.
- Sand and gravel deposit, tertiary significance.
- Other surficial deposits or exposed bedrock.

SYMBOLS

- Township boundary
- Project area boundary
- Park, reserve boundary
- Geological and aggregate thickness boundary of sand and gravel deposits
- Buried geological and aggregate thickness boundary of sand and gravel deposits
- Licenced property boundary: Property number: see Table 2
- Unlicenced sand or gravel pit*. Property number: see Table 2
  *Abandoned pit or wayside pit operating on demand under authority of a permit
- DF-DS-18 Test hole location: Identification number (see Table 7)
- DF-SS-1 Selected sample site: Identification number
- 2.4 / 31S Selected water well location. Layers of materials are described by reported thickness of material (in m) reported type of material (number only - overburden. G - gravel, S - sand, C - clay, T - till, B - boulders, Bk - bedrock, Hpan - hardpan, Stn - stones, Silt - silt)
- Moraine
- Texture symbol: see below
- G 1 IC c·o Deposit symbol: see below

TEXTURE SYMBOL

Fines: silt and clay (<.075 mm)

Sand (.075 - 4.75 mm)

Gravel (>4.75 mm)

The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

DEPOSIT SYMBOL

Gravel Content → G 1 IC c·o ← Geological Type

Thickness Class → ← Quality Indicator

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e., material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per hectare. Geological Type refers to geological origin. Quality indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel
S	Less than 35% gravel

Thickness Class

Class	Average Thickness in Metres	Tonnes per Hectare
1	greater than 6	greater than 106 000
2	3 - 6	53 000 - 106 000
3	1.5 - 3	26 500 - 53 000
4	less than 1.5	less than 26 500

Geological Type

AL	Older Alluvium	LB	Lacustrine Beach
E	Esker	LD	Lacustrine Delta
M	Moraine	LP	Lacustrine Plain
IC	Undifferentiated Ice-Contact Stratified Drift	OW	Outwash
ICT	Ice-Contact Terrace	SF	Subaqueous Fan

(see Appendix C for descriptions of Geological Types.)

Quality Indicator

	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.

SOURCES OF INFORMATION

This map is based on information taken from the National Topographic System map sheet numbers 30N/13, 30N/14, 30N/15, 31C/2, 31C/3, 31C/4 @ her Majesty the Queen in right of Canada with permission of Energy, Mines and Resources Canada.

Licence data from the Ontario Ministry of Natural Resources.
Aggregate suitability data from the Ontario Ministry of Transportation.
Test hole data from Ontario Geological Survey, Ontario Ministry of Northern Development and Mines
Selected drilling data from the Ontario Ministry of the Environment

Geology by:
Leyland 1982, 1982a
Leyland and Russell 1983

Compilation by: staff of Jagger Hims Limited and Sedimentary Geoscience Section, Ontario Geological Survey.

Drafting by: I. Prediger, Proctor and Redfern Limited and S.Tait, Sedimentary Geoscience Section.

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This map is to accompany O.G.S. Aggregate Resources Inventory Paper 172.

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Ontario

Ontario Geological Survey

Aggregate Resources Inventory

PRINCE EDWARD COUNTY

ARIM 172-2

BEDROCK RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 30N/13, 30N/14, 30N/15, 31C/2, 31C/3, 31C/4

LEGEND

(Some units and symbols may not apply to this map.)

BEDROCK UNITS
PALEOZOIC
ORDOVICIAN
MIDDLE AND UPPER ORDOVICIAN
SIMCOE GROUP
LINDSAY FORMATION
Limestone and Shale
MIDDLE ORDOVICIAN
SIMCOE GROUP
VERULAM FORMATION
Limestone and Shale
BOBCAYGEON FORMATION
Limestone

DRIFT THICKNESS

- Paleozoic bedrock outcrop (see Table 4); areas of exposed bedrock partially covered by a thin veneer of drift. Drift thickness is generally less than 1 m. (3 feet)
- Paleozoic bedrock covered by drift (see Table 4); drift thickness is generally 1 to 8 m. (3 to 25 feet) Bedrock outcrops may occur.
- Paleozoic bedrock covered by drift (see Table 4); drift thickness is generally 8 to 15 m. (25 to 50 feet) Isolated bedrock outcrops may occur.
- Paleozoic bedrock covered by drift; drift thickness is generally greater than 15 m. (50 feet)
- Undifferentiated Precambrian bedrock; predominantly bedrock covered by thin drift. Bedrock outcrops are common and localized areas of thick overburden may occur in bedrock depressions.

SYMBOLS

- Township boundary
- Project area boundary
- Park, reserve boundary
- Geological formation boundary
- Geological formation member boundary
- Formation thickness boundary (see text)
- 15 — Drift thickness contour. (1 m, 8 m and 15 m contours are shown)
- 1 — Selected bedrock resources area; Deposit number: see Table 6.
- EW-SS-1 — Selected sample sites
- 2 — Licenced quarry boundary: Property number: see Table 5
- Q5 — Unlicenced quarry*; Property number: see Table 5
  *Abandoned quarry or wayside quarry operating on demand under authority of a permit
- × — Isolated bedrock outcrop
- 8 — Selected water well location; reported depth to bedrock (in metres)

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Aggregate suitability data from the Ontario Ministry of Transportation.
Selected drilling data from the Ontario Ministry of the Environment.

Geology by: D.M. Carson 1980, 1981, 1982
Additional Geology by: K.B. Antoniuk and R. Jelly, Jagger Hims Limited

Compilation by: Staff of Jagger Hims Limited and the Sedimentary Geoscience Section, Ontario Geological Survey.
Drafting by: L.Prediger, Proctor and Redfern Limited and S. Tait, Sedimentary Geoscience Section, Ontario Geological Survey.

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