Ontario

Aggregate Resources Inventory of

Wellington County

Townships of Minto, Arthur, West Luther, Maryborough, Peel, West Garafraxa, Pilkington, Nichol, Guelph, Eramosa, Erin, Puslinch and the City of Guelph

Ontario Geological Survey
Aggregate Resources Inventory
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By Planning & Engineering Initiatives Ltd. and Staff of the Sedimentary Geoscience Section, Ontario Geological Survey

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Abstract

This report includes an inventory and evaluation of sand, gravel and bedrock resources for Wellington County. Within Wellington County, a total of 40 primary selected sand and gravel resource areas have been identified. These selected sand and gravel resource areas occupy 13 030 hectares (ha), exclusive of licenced areas. Once cultural, environmental and other constraints have been taken into account, an estimated 10 373 ha are possibly available for extraction. The total possible aggregate resources available for Wellington County is 1094.5 million tonnes.

The sand and gravel resources within the northern part of Wellington County are found within a number of small outwash, esker and ice-contact stratified drift deposits located throughout the area. Larger outwash and ice-contact stratified drift deposits are found in the most northerly part of the county, especially Minto Township. Much of the remaining part of northern Wellington County is covered by the Elma and Mornington till. In this till dominated area, the main sand and gravel resources are found within eskers that are limited in size and geographic extent. Although a large area of primary significance is located within the outwash and ice-contact deposits in Minto Township, north of the town of Harriston, much of this area is covered by wetlands.

In south Wellington County, Puslinch and Erin townships are the most important in terms of aggregate production. In particular, the outwash deposits along Highways 6 and 401 have accounted for as much as 40% of the county's total sand and gravel production. In Erin Township, the most important natural aggregate deposit is an outwash deposit located south and east of the Village of Erin.

With respect to bedrock resources suitable for crushed stone, northern Wellington County has limited resources. Only one area of bedrock having a thin cover of glacial drift was identified near the village of Monck in West Luther Township. No quarrying activity is currently undertaken in north Wellington County.

In south Wellington County, 9 selected bedrock resource areas have been identified for protection. However, at present, the only municipalities within which quarrying is actively taking place are the City of Guelph and Puslinch Township.

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.

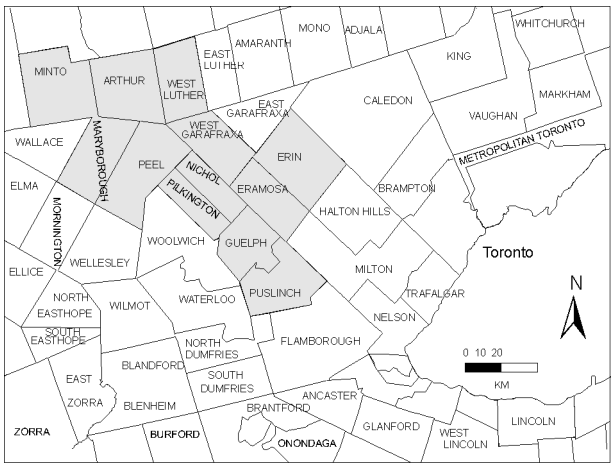


Figure 1. Key Map Showing the Location of Wellington County.

Aggregate Resources Inventory of Wellington County Townships of Minto, Arthur, West Luther, Maryborough, Peel, West Garafraxa, Pilkington, Nichol, Guelph, Eramosa, Erin, Puslinch and the City of Guelph

By Planning & Engineering Initiatives Ltd. and Staff of the Sedimentary Geoscience Section, Ontario Geological Survey

Project Supervisors: C. L. Baker; fieldwork and report by D. A. Stewart, Z. L. Katona, P. F. Puopolo, and A.G. McLellan; compilation and drafting by staff of Planning & Engineering Initiatives Ltd. and staff of the Sedimentary Geoscience Section, Ontario Geological Survey. Assistance with review provided by the Cambridge District Office, Ministry of Natural Resources.

Manuscript accepted for publication by, and published with the permission of, C. L. Baker, Senior Manager, Sedimentary Geoscience Section, Ontario Geological Survey, 1999.

Introduction

Mineral aggregates, which include bedrock-derived crushed rock as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1993, the total tonnage of mineral aggregates extracted in Ontario was 131 million tonnes, greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1995).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, non-renewable 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 in 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 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

This report provides a consolidation and update of the previously released Aggregate Resource Inventory Reports for the townships of Minto, Arthur, West Luther, Maryborough, Peel, West Garafraxa, Pilkington, Nichols, Guelph, Eramosa, Erin, Puslinch and the City of Guelph (Ontario Geological Survey 1980a, 1980b, 1980c, 1981a-g, 1982, 1985). The contents of existing reports were reviewed in detail. All of the resource areas of primary significance and some of the resource areas of secondary significance that had been originally outlined were field checked. As necessary, field samples were collected and tested for gradation and were also petrographically analysed. Data was also collected from the Ontario Ministry of Transportation (MTO) files and from testing companies involved in licencing procedures under the *Aggregate Resources Act*, 1989. The collected information was compiled, analysed and incorporated with the data found within the existing Aggregate Resource Inventory Reports.

All previously Selected Sand and Gravel Resource Areas of primary and secondary significance were examined considering the following: 1) licencing that has occurred since the original inventory was conducted; 2) discussions with the appropriate staff of the Ministry of Natural Resources; 3) review of available public and private research reports; 4) reports prepared for licences under the *Aggregate Resources Act*, 1989, and other documents; and 5) personal knowledge of the staff involved in completion of the project.

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 were 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 were 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 Limited 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

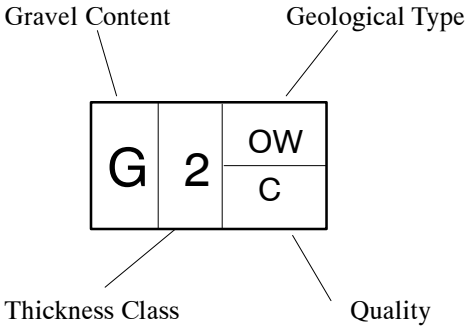
Map 1 shows the extent and quality of sand and gravel deposits within the study area and an evaluation of the aggregate resources. The map is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete.

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. These components are illustrated by the following example:



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.

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.

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 constraints. 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 a minimum of 15 to 85% of an individual licence or resource area 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 (MNR), 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 are 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 Wellington County

LOCATION AND POPULATION

Wellington County occupies an area of approximately 265 931 ha in Southern Ontario (Figure 1). The study area is covered by parts of the Brampton (30M/12), Cambridge (40P/8), Guelph (40P/9), Conestogo (40P/10), Palmerston (40P/15), Orangeville (40P/16), Dundalk (41A/1) and Durham (41A/2) 1:50 000 scale map sheets of the National Topographic System (NTS).

In 1994, the population of Wellington County was approximately 162 851 (Ontario Ministry of Municipal Affairs and Housing and the Association of Municipal Clerks and Treasurers of Ontario 1997), representing a 5.6% increase from 1991 population data (Ontario Ministry of Municipal Affairs 1992) (Chart A).

Wellington County is largely rural in character. The dominant urban centres include the City of Guelph, the towns of Arthur, Elora, Fergus, Erin and a number of smaller villages and settlement areas.

Road access throughout the study area is provided by a network of county and local township roads. Highway 401 traverses the southern part of Wellington County in a westerly direction, providing a direct link to other major market areas of southern Ontario including the western part of the Greater Toronto Area (GTA). Highways 6, 7, 9, 10 and 25 also provide relatively direct access to the northwestern part of the GTA from the northern and eastern portions of the county.

SURFICIAL GEOLOGY AND PHYSIOGRAPHY

The physiography and distribution of unconsolidated surficial materials within Wellington County are largely the result of glacial activity that took place in the late Wisconsinan substage of the Pleistocene Epoch about 23 000 to 10 000 years ago. The onset of this period was marked by lobes or sub–masses of the continental ice sheet advancing out of the Great Lake basins and joining to cover south-

CHART A - AREA AND POPULATION
WELLINGTON COUNTY

Municipality	Area (ha)	1991 Population	1994 Population
City of Guelph	6 875	85 625	93 400
Town of Fergus	716	7 657	8 008
Town of Harriston	335	1 946	1 900
Town of Mount Forest	692	4 095	4 164
Town of Palmerston	291	2 273	2 400
Village of Arthur	417	2 033	1 960
Village of Clifford	241	746	722
Village of Drayton	234	1 156	1 333
Village of Elora	303	3 119	3 116
Village of Erin	439	2 400	2 414
Twp. Of Arthur	27 016	2 456	2 472
Twp. Of Eramosa	18 860	5 789	5 764
Twp. Of Erin	29 411	7 263	7 468
Twp. Of Guelph	11 801	3 122	3 045
Twp. Of Maryborough	23 061	2 565	2 573
Twp. Of Minto	28 970	2 297	2 357
Twp. Of Nichol	10 881	3 907	3 999
Twp. Of Peel	30 422	4 238	4 294
Twp. Of Pilkington	12 341	2 337	2 400
Twp. Of Puslinch	23 108	4 843	4 607
Twp. Of West Garafraxa	18 940	3 147	3 341
Twp. Of West Luther	20 577	1 095	1 114
Total	**265 931**	**154 109**	**162 851**

ern Ontario. The latter part of this period was characterized by the repeated advance and retreat of these glacial lobes. During the late stages of glacial activity in the report area, the northwestern and northeastern townships of Wellington County were covered by glacial ice of the Huron-Georgian Bay lobe (Cowan 1979). The margin of this lobe advanced to the south and southeast over these townships and deposited a thick layer of glacial till over the bedrock surface and the pre-existing sediments. In most of the townships, this till is composed of clayey silt with few pebbles and is termed the Tavistock Till (Cowan 1979, Karrow 1971, 1986). This till is not generally suited for use as aggregate because of its fine texture, but is well suited for agriculture when it is drained.

Subsequently, minor retreat and re-advance of the Huron-Georgian Bay lobe first deposited the Mornington Till, which is exposed in Maryborough and Peel townships, followed by the Elma Till, which occurs in Maryborough, Minto and Arthur townships. As a warming climate caused the margin of the glacial lobe to melt back, eskers, outwash and ice-contact deposits of sand and gravel were laid down in Minto Township. The esker deposits in Minto Township have been extensively worked at numerous small pits and remain a good aggregate source for the township. A halt in the retreat of the Huron-Georgian Bay lobe margin in the northern portion of Minto Township is marked by extensive deposits of ice-contact stratified drift and outwash sand and gravel. These ice-contact deposits form a large area of hummocky topography known as the Saugeen Kames (Chapman and Putnam 1984, Cowan 1979). These deposits contain large amounts of sand and gravel which are worked in numerous pits. In many areas the deposits underlie wetland areas. In the other townships of northern Wellington County (Arthur, West Luther, Maryborough and Peel townships), sites of commercial aggregate extraction are generally limited to the long sinuous esker ridges that occur in the area. These deposits contain moderate amounts of crushable gravel and have been traditional sites for extraction. The material extracted from the eskers forms an important component of the local resource base. Other small ice-contact stratified drift deposits associated with the esker systems have also been utilized as a source of aggregates in the northern part of Wellington County.

During the middle part of the late Wisconsinan the southern part of Wellington County was affected by glacial ice of the Ontario lobe. Glacial ice of this lobe advanced across the southern part of Wellington County depositing a thick layer of till over the bedrock surface and the pre-existing sediments in the area. This till, known as the Port Stanley Till, is composed of silt and sand with minor stone content (Cowan 1976). In addition, long, rounded drumlins occur throughout the southern portion of the townships forming a physiographic region known as the Guelph Drumlin Field. This region occupies an area of 83 000 ha in Wellington County (Chapman and Putnam 1984). The till has little value as aggregate because of its high silt content.

After deposition of the Port Stanley Till, the margin of the ice lobe began to recede from this area. Several eskers and kames were deposited in the southern and central portions of the county. These deposits contain small amounts of sand and gravel suitable for extraction. In Pilkington Township, additional ice-contact deposits and one large kame deposit are located in the northern portion of the township, north of Pentland Corners. These deposits contain large amounts of stratified sand with scattered lenses of coarse aggregate.

The southern portion of West Garafraxa Township is covered by the southwesterly trending Orangeville Moraine (Cowan 1976). The moraine formed in an interlobate position between glacial ice of the Huron-Georgian Bay and Ontario lobes. High relief and hummocky topography are characteristic of the moraine. It consists of a lower glaciofluvial layer of gravel and an upper glaciolacustrine unit of fine sand, silt and some varved sand and clay.

After the deposition of the Orangeville Moraine, the margin of the Huron-Georgian Bay lobe melted back toward the northwest. Some of the meltwater that flowed from the ice front formed an ice-marginal channel in which outwash gravel was deposited. The channel is now occupied by the Grand River and Lake Belwood and the outwash now forms a series of terraces along the northwestern shore of the lake. This deposit contains large resources of sand and crushable gravel and is an important local resource.

The City of Guelph, Guelph Township and Eramosa Township are characterized by extensive areas of Port Stanley Till, and the Guelph Drumlin Field and Paris Moraine physiographic regions. In the report area the Port Stanley Till (Karrow 1974) is a moderately stoney, sandy silt till. The Guelph Drumlin Field, which covers much of Guelph Township and the central portions of Eramosa and central western Erin townships, consists of streamlined mounds of till. The southwest trending Paris Moraine complex is located in the southern parts of these townships. Associated with the moraine are kame deposits and northwest trending eskers. The Eramosa, Ariss and Guelph eskers provided an early source of coarse aggregate, but are now largely depleted or inaccessible.

Ice marginal spillways containing meltwaters seeking an outlet to the south and west also deposited stratified sands and gravels in these townships. As the retreating Ontario lobe halted at the Paris Moraine (Puslinch Township) a major spillway or valley outwash system developed along the present Speed River valley. Variable thicknesses of uniform outwash materials, in places burying drumlins, were deposited. These terraced deposits provide the best quality aggregate sources for the Guelph area and contain materials suitable for a variety of crushed products.

The Eramosa Esker (Karrow 1968) is the best developed esker within Eramosa Township. The esker, situated in the southern portion of the township, consists of a narrow, east trending ridge. Ice-contact stratified drift deposits in the township contain large amounts of stratified sand and usually small amounts of gravel. These deposits provide good sources of fine-grained aggregate.

A large channel which trends through central Erin Township was formed by meltwaters flowing southward

along the margin of the Ontario lobe. Outwash sand and gravel deposited by the meltwaters cover a large area near the Town of Erin near the eastern boundary of the township. The deposit, known as the Caledon Outwash, contains large resources of aggregate and is an important component of Erin Township's resource base. Smaller gravel deposits are found further to the west.

The most southerly, and most significant township in Wellington County in terms of aggregate production, is Puslinch Township. It contains 3 physiographic areas: the Guelph Drumlin Field; the Horseshoe Moraines and the Flamborough Plain (Chapman and Putnam 1984).

The Guelph Drumlin Field is located in the northwestern portion of the township. The physiographic region of the Horseshoe Moraines consists of 2 major glacial features, those being the Paris and Galt moraines. Together they form a belt 6 to 8 km wide (Karrow 1968) extending through Puslinch Township from north to southwest. The Paris Moraine is situated to the north and west of the Galt Moraine; both are composed primarily of sandy Wentworth Till. The Paris Moraine was formed at the margin of the Ontario ice lobe as it retreated into the Lake Ontario basin and the Galt Moraine was deposited during a minor readvancement of the margin.

The Flamborough Plain, located in the southeast part of the area, is an isolated tract of shallow drift that consists of bouldery glacial till or sand and gravel (Chapman and Putnam 1984). The Flamborough Plain constitutes an area of about 39 000 ha. In some places the limestone bedrock has been exposed and washed bare by wave action associated with glacial lakes.

Related to the Paris and Galt moraines is an integrated system of spillways with broad gravel and sand terraces (Chapman and Putnam 1984). Excellent cross-sections of the Horseshoe Moraines area can be seen along Highway 6 between Guelph and Puslinch, and along Highway 401. Portions of the Horseshoe Moraines area are very hilly with a local relief of more than 30 m (Chapman and Putnam 1984). Kettles and kettle lakes (e.g., Puslinch Lake) are also prominent.

An extensive outwash plain between Killean Station and Aberfoyle separates the Galt and Paris moraines. This outwash plain was apparently fed by glacial meltwaters when ice of the Ontario lobe stood at the Galt Moraine. Coarse aggregate deposits of the spillway channel are concentrated southwest of Aberfoyle where the material is now extracted in several pits. To the north of the Paris Moraine are gravel terraces of the Speed and Eramosa rivers. Numerous extractive operations exist in this area.

Several other aggregate operations are found in the kame, esker and beach gravels that are located southeast of the Galt Moraine. After its brief halt at the Galt Moraine, the margin of the Ontario lobe retreated from Puslinch Township, thus marking the end of glacial activity in the area. Postglacial erosional and depositional processes have since been of minor importance in modifying the physiography of the township and the land still shows the strong influence of the glacial ice.

EXTRACTIVE ACTIVITY

At the time of writing there were 92 licenced sand and gravel pits and 4 quarry operations in Wellington County (Table 2). Nearly 50% of the aggregate activity occurs within Puslinch and Erin townships. Average annual aggregate production within Wellington County over the 5 year period from 1989 to 1993 was approximately 5.8 million tonnes, with the largest average annual production coming from the Township of Puslinch (1.57 million tonnes per year) (Chart B).

During the last 5 year period Puslinch Township has produced as much as 2.87 million tonnes per year of aggregate (Planning Initiatives and Associates Ltd. 1993) and has frequently been one of the top 10 aggregate producing municipalities in the province. One of the main reasons for this is the presence of high quality aggregate resources located in the area immediately adjacent to Highway 401, which provides a direct route to the largest market in Ontario, the Greater Toronto Area (GTA). Should further restrictions to extraction be placed on other high quality aggregate resources near the GTA (e.g., the Niagara Escarpment or Oak Ridges Moraine) Puslinch Township can be expected to be placed under increased pressure to extract increasing amounts of the high quality resources. As of mid May, 1995, an additional 7 licence applications have been formally submitted for approval within Puslinch Township. In the future, similar pressures are likely to be exerted upon Erin Township given its proximity and relatively easy access to parts of the GTA.

Wellington County has provided aggregates for the construction industry for over 50 years. Over this time period commercial extraction of aggregates has occurred in Puslinch, Guelph, the eastern part of Erin and the northern part of Minto townships. In the remainder of the county aggregate extraction has occurred mainly to supply local needs.

QUALITY OF AGGREGATES

The quality of aggregate from sand and gravel deposits in Wellington County is not uniform. Acceptable aggregate for the production of Granular A, B and M can be found in all parts of the county. However, sources of sand and gravel acceptable for high quality uses are limited. Sand and gravel in the central and southern parts of the county are, in general, of good quality. In the townships of Puslinch, Guelph, Pilkington, Eramosa and in the northeastern part of Minto commercial sources are capable of producing very high quality aggregates, including fine and coarse aggregates suitable for use with Portland cement. In the outwash deposits of Puslinch Township sources are capable of producing Heavy Duty and Medium Duty Binder asphalt paving aggregates from those parts of the deposits containing a high percentage of coarse gravel.

The suitability of the aggregate in the county is affected by 3 main factors: 1) the presence of chert-cherty carbonates; 2) the presence of siltstone; and 3) the coarseness of gravel.

The Bois Blanc Formation forms a 10 to 20 km wide, northwesterly trending band that underlies the glacial drift

Chart B - EXTRACTIVE ACTIVITY
WELLINGTON COUNTY

Municipality	Average Annual Aggregate Production (1989-1993)	Number of Licences		Total Licenced Area	
		Pits	Quarries	Pits	Quarries
Minto	270 00	17	-	469.48	-
Arthur	280 000	13	-	121.55	-
Maryborough	136 000	5	-	111.09	-
Peel		4	-	76.05	-
West Garafraxa	484 000	2	-	20.23	-
West Luther		1	-	14.78	-
Pilkington	951 000	9	-	234.99	-
Nichol	-	-	-	-	-
Guelph	638 000	3	2	45.54	192.94
Eramosa	247 000	8	-	169.27	-
Erin	1 181 000	9	-	430.55	-
Puslinch	1 569 000	21	2	1037.41	140.29
Total	**5 756 000**	**92**	**4**	**2730.94**	**333.23**

in the western part of Minto, Maryborough and Peel townships. The formation consists primarily of thin- to medium-bedded, cherty limestone with local dolostone. Many chert-rich nodules were derived from this formation and incorporated into the local surficial aggregate deposits through glacial activity associated with the Huron-Georgian Bay lobe. A high concentration of chert-cherty carbonates are found in deposits situated in the western part of Minto, Maryborough and Peel townships. Elsewhere, chert-rich clasts may be present, however, not in significant quantities. In general, the chert-cherty carbonate content decreases in an easterly direction from about 20% in the west to 1 to 3% in Guelph and Puslinch townships. This trend has been demonstrated by previous work (Ingham and Dunikowska-Koniuszy 1965).

The effect of the presence of chert is threefold. Firstly, the white coloured "chalky" leached chert can "pop-out" from Portland cement structural and paving concrete and from surface course hot-mix asphalt pavements due to its high water absorption and resultant frost susceptibility. Secondly, the presence of chert, even in small amounts, can make a gravel or sand unsuitable for Portland cement concrete aggregate due to reactivity with the alkalis in Portland cement. Thirdly, a high percentage of unleached chert (approximately 20%) may require use of anti-stripping additives in asphalt cement for hot-mix asphalt paving.

The coarseness of aggregate clasts containing chert may also pose quality problems as noted by Ingham and Dunikowska-Koniuszy (1965). One of the findings in this paper was that the greatest percentage of chert in the gravels is concentrated between the 1.18 mm and 50 mm sizes. Therefore, if a deposit in the chert-rich zones contains mainly fine gravel size particles, the effect of areal predominance of chert and the concentration of cherty particles in the fine gravel sized particles can make the gravel unacceptable for hot-mix asphalt paving and Portland cement concrete uses. While the presence of chert mainly influences the quality of coarse aggregate, it can also render fine aggregates unsuitable for the same uses. This is caused by the high percentage of chert in the coarser particle sizes of the fine aggregate fraction.

The presence of siltstone is also the result of glacial and glaciofluvial action. The westerly advancing Ontario ice lobe eroded siltstones and shales from formations in the Clinton-Cataract Group at the base of the Niagara Escarpment. These lithologies were incorporated into the glacial tills that were deposited across Erin, Eramosa and surrounding townships to the north and east. As the ice margin retreated, glacial meltwaters washed out, transported and deposited the siltstones in outwash deposits located west and southwest of the ice margin. During this process most of the shale disintegrated. While the siltstone content in the eastern and northern parts of Erin Township is about 15% the content in Eramosa and West Garafraxa townships is reduced to about 3%.

While the siltstone content does not have any affect on the suitability of gravels for Granular A, B and M, it can influence acceptability for hot-mix paving and concrete aggregates. The siltstone tends to be hard, however, in pavement, repeated frost action can break up siltstone clasts along bedding planes.

Fortunately, the effect of chert and siltstone content on aggregate quality occurs only locally within Wellington County. Research conducted by the MTO (Ingham and Dunikowska-Koniuszy 1965), records from MTO Mineral Aggregate Inventory data files, examination of MTO contract Aggregate Sources Lists (ASLs) and recent sampling

indicate that the highest concentrations of chert are found in the eskers located in the western corner of Minto Township, the southern half of Maryborough Township and small outwash deposits in the western corner of Peel Township. Within these areas, the aggregates are unsuitable for hot-mix paving and Portland cement concrete coarse and fine aggregates. They do, however, meet requirements for Granular A, B Type I and M.

The influence of siltstone on aggregate usage can be observed in the northern half of Erin Township. In general, aggregates in the Orangeville Moraine area are unsuitable for hot-mix asphalt and Portland cement concrete coarse and fine aggregates. In the central and eastern portion of this township, the aggregates are not acceptable for high quality HL3 hot-mix paving aggregates, but are acceptable for lower quality HL4 aggregates. In general, the remainder of the county can provide, with appropriate processing, aggregates acceptable for high quality uses, including Portland cement concrete coarse and fine aggregates. Hot-mix asphalt paving sands often require blending to correct grain size distribution deficiencies. This is a normal procedure for these uses. There are no quality limitations for Granular A, B and M and sand products used by the construction industry, other than possible grain size distribution problems.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Maps 1A and 1B show the surficial deposits that contain sand and gravel in Wellington County. In the county, the total area occupied by selected sand and gravel deposits is approximately 13 030 ha. When constraints such as areas depleted by previous or current extraction, urban areas, provincial parks and conservation areas, as well as physical constraints like roads, railways, rivers, lakes and ponds are considered the area possibly available for extraction is reduced to approximately 10 373 ha (Table 3). It must be noted, however, that further restrictions on the area actually available or accessible for extraction may occur because of provincially or regionally significant wetlands or other sensitive natural heritage features that are not taken into account in this report. The most significant resource areas are shown on the maps and are described in detail below.

Selected Sand and Gravel Resources Area 1, 2, 3, and 4

Selected Sand and Gravel Resource Areas 1, 2, 3, and 4 are dealt with together due to the fact that they are all outwash deposits and form part of the Saugeen Kames physiographic region (Chapman and Putnam 1984). The genesis, thickness, texture and quality of these deposits are much the same.

Cowan (1979) describes the outwash deposits as follows. The most extensive deposits of outwash gravel occur within the Saugeen Kames as belts of braided outwash between ridges of morainic deposits. With regard to the texture and quality of the aggregate Cowan (1979) notes that these gravels range for the most part from 2 to 6 m in thickness although more than 15 m has been reported locally. The gravels contain 25 to 60% gravel of which most is medium- to very-coarse pebble gravel.

Selected Sand and Gravel Resource Area 1 is an irregular 311 ha area of outwash sand and gravel situated east of Clifford. Local topography indicates the existence of erosional remnants of older fluvial landforms. No licenced properties are located within this resource area. A previously licenced pit situated north of the resource area exposed a 4 m face containing up to 70% of well stratified gravel. An unlicenced pit (Pit No. 23) located south of the resource area has 2 to 4 m face heights that show mainly gravel (45 to 75%). Based on 289 ha being potentially available for extraction and assuming a deposit thickness of 5 m, the deposit could contain up to 25.6 million tonnes of aggregate (Table 3).

Selected Sand and Gravel Resource Area 2 consists of an irregular belt of braided outwash channels in the north-central part of Minto Township. The surface of the deposit is relatively flat but marshy depressions are frequent, indicating high water table conditions. One presently licenced source (Pit No.1) exposes 3 to 6 m of sandy aggregate that contains up to 45% crushable material. Below water extraction is now occurring in this pit. Other exposures indicate generally less than 3 to 5 m of sandy aggregate. Selected Resource Area 2 occupies a total of 716 ha. Approximately 543 ha are potentially available for extraction. Assuming an average deposit thickness of 4 m, the potentially available sand and gravel resources are estimated to be 38.4 million tonnes (Table 3). Competing land uses may pose future constraints on extraction. High water table levels and significant wetlands may limit development of large parts of the area. Road access to the deposit is provided by gravel-surfaced township and county roads. Rail access is provided by a line of the Canadian National Railway.

Selected resource area 3 is a small outwash deposit located at the eastern boundary of Minto Township, near the South Saugeen River. No subsurface data are available for the resource area, but it is probable that it resembles the other outwash deposits with respect to average thickness and aggregate quality. Selected Sand and Gravel Resource Area 3 occupies 89 ha, of which 70 ha are potentially available for extraction. Assuming an average deposit thickness of 5 m throughout the resource area, possible sand and gravel resources are estimated to be 6.2 million tonnes (Table 3).

Selected resource area 4 forms a large area of flat to undulating topography on the southwest side of Pike Lake in Minto Township. Several marshy depressions in the central part of the resource area suggest a high water table. Selected resource area 4 occupies a total of 640 ha, of which 534 ha are potentially available for extraction. Assuming an average thickness of 5 m throughout resource area 4, the potential sand and gravel resources are estimated to be 47.3 million tonnes (Table 3). Wetland constraints on extraction are likely to be significant as the

Provincial Wetland Policy Statement prohibit any development within designated Class 1, 2 and 3 Wetlands. At the eastern end of the resource area, recreational land use development is also taking place along the shores of Pike Lake. Access to resource area 4 is provided by Highway 89 and by county and township roads.

Future development in parts of these 4 resource areas is likely to be affected by the designation of portions of these areas as Provincially Significant Wetlands by the Province.

MTO records and recent field research indicates that the aggregate material within these deposits is not suitable for high quality uses such as for hot-mix paving and concrete, due to the high chert content. The materials are, however, suitable for Granular A, B Type I and M.

Selected Sand and Gravel Resource Area 5

Selected Sand and Gravel Resource Area 5 is an extensive deposit of ice-contact stratified drift located near Pike Lake in the northeastern corner of Minto Township. The topography of the area is characteristically irregular and hummocky, and a series of depressions, several of which now form small lakes, suggest the melting out of ice blocks during deglaciation. This portion of the selected area appears to be associated with the very extensive Riverstown Esker that extends southeast to Riverstown in Arthur Township. The portion of the Riverstown Esker in Arthur Township has also been selected for possible resource protection at the primary level of significance.

At present 2 licenced sand and gravel pits are situated within resource area 5 (Pit Nos. 3 and 8). Faces in these 2 pits range from 5 to 7 m in height and expose sandy, irregularly stratified material with a crushable gravel content of 35 to 50%. Excess fines pose a problem in parts of the deposit and because of excessive chert the stone quality is locally considered unsuitable for high quality uses such as road-surfacing aggregates (Deike 1978a). The materials are, however, suitable for Granular A, B Type I and M.

Selected Sand and Gravel Resource Area 5 occupies a total area of 855 ha, exclusive of the licenced properties. Approximately 657 ha are potentially available for extraction prior to taking into account any other constraints. Assuming an average thickness of 5 m throughout the deposit, possible resources of sand and gravel are estimated to be 58.1 million tonnes (Table 3). The resource area is accessible by road and rail and is located in close proximity to local demand areas, but may be further constrained by wetland and water table considerations.

Selected Sand and Gravel Resource Area 6

Selected Sand and Gravel Resource Area 6 is an outwash deposit located in the northeastern corner of Minto Township. The topography of the area is relatively flat, except where dissected by the South Saugeen River and associated small tributaries. Presently the area contains 3 licenced pits (Pit Nos. 4, 5 and 6) that contain from 35 to 70% gravel (Davis 1994). A large licenced pit, (Pit No. 5) in the resource area is described by Cowan (1979). In the pit, up to 8 m of material was exposed although the gravels are reported to be 21 m thick. In general, a coarse upper unit of weakly stratified, poorly sorted, rounded gravel, containing 60 to 70% stone, overlies a cross-bedded medium- to coarse-sand unit containing as much as 15% gravel. The coarse unit was observed to range from 2 to 6 m in thickness. These gravels may contain up to 10% fines and many of the pebbles and cobbles had a silt coating on their surface. Most of the aggregate extracted from this pit is used for pre-mix concrete although a full range of granular products is also supplied from the pit (Cowan 1979).

Recent licencing reports for the newest pit (Pit No. 4) (Gamsby Mannerow Limited 1993) and MTO records indicate that the material is suitable for Granular A, B Type I and M. This source is also approved for hot-mix HL4 paving and concrete coarse and fine aggregates.

Resource area 6 occupies 43 ha, excluding licenced areas. An estimated 22 ha are possibly available for extraction. Assuming an average thickness of 7 m throughout the resource area, possible sand and gravel resources suitable for a range of road-building and construction products are estimated to be 2.7 million tonnes (Table 3).

Access to Resource area 6 is provided by Highway 89 as well as by several county and township roads. Rail access is provided by a line of the Canadian National Railway. The resource area is located in close proximity to local demand centres such as Harriston and Mount Forest and is capable of supplying high-specification aggregate products both for housing and commercial construction.

Selected Sand and Gravel Resource Area 7

Selected Sand and Gravel Resource Area 7 consists of several esker segments, located in the southwestern corner of Minto Township. The deposits extend northwestward into Wallace Township in Perth County. In Minto Township the esker segments are single, sharply defined ridges with local relief of 6 to 15 m. The esker ridges have been deposited directly on the till plain and trend in a northwest direction. All of the deposits are shown as a single resource area because of their similarities in thickness, texture, quality and possible uses. Six pits (Pit Nos. 11, 12, 13, 14, 16 and 17) are currently licenced for extraction. Faces in the pits range from 2 to 6 m. The pits expose gravel and sand suitable for crushing and the production of granular base aggregate. The stone quality is too poor, because of chert content, to be used for hot-mix asphaltic aggregate or for concrete aggregate (Deike 1978a). This has been confirmed by recent field observations. Sandy deposits flanking the esker ridges have been selected for possible resource protection at the secondary level. These deposits contain small amounts of material suitable for granular subbase aggregate.

The individual esker segments which form Selected Sand and Gravel Resource Area 7 occupy a total of 141 ha of which an estimated 104 ha are possibly available for ex-

traction. Assuming an average thickness of 4 m in each of the esker segments, total possible sand and gravel resources are estimated to 7.4 million tonnes (Table 3).

Although the possible resource tonnage in the resource area is relatively low and individually the deposits are quite small, as a group they constitute a valuable local resource for a number of reasons. First, since the deposits are distributed over a large area they are well situated to supply local markets throughout the southern part of the township. Secondly, most of the deposits consist of crushable aggregate and are suitable for a range of products. Finally, since most of the aggregate lies above the level of the surrounding ground surface, extraction is made simple and rehabilitation is easily accomplished.

Selected Sand and Gravel Resource Area 8

Selected Sand and Gravel Resource Area 8 consists of a large esker and delta complex that trends northwest from the settlement of Riverstown in Arthur Township. Near Riverstown, one of the esker ridges broadens significantly into an irregular hummocky plateau with local relief of 15 to 23 m. The plateau consists of sandy deltaic material that was deposited into water at the mouth of the subglacial stream(s) which deposited the esker ridges. There are 6 licenced pits (Pit Nos. 35, 36, 38, 41, 42 and 43) distributed within the resource area. Pit faces range in height from 3 to 10 m, and expose well stratified, sandy aggregate with, locally, significant amounts of crushable gravel (40 to 80%). Granular A and B as well as asphaltic sand and stone have been produced from the pits, although sand control is required in places. The fine aggregate contains excess fines and occasional silt seams are encountered.

Deike (1978b) noted that the stone quality in Resource Area 8 is affected by the presence of significant amounts of shale and soft, porous limestone. However, recent work indicates that the aggregate is acceptable for the production of Granular A, B Type I and M and HL4 coarse and fine aggregates. Extensive deposits of ice-contact stratified sand and gravel flank the western portion of the resource area.

Selected Sand and Gravel Resource Area 8 occupies a total of 343 ha, excluding licenced areas. An estimated 294 ha are potentially available for extraction. Assuming an average thickness of 7 m throughout the deposit, possible sand and gravel resources are estimated to be 36.4 million tonnes (Table 3). Access to the resource area is provided by Highway 6 and a line of the Canadian Pacific Railway, both of which are located at the eastern end of the deposit. The area is also well situated with respect to the regional markets of Mount Forest and Arthur. The population in the vicinity of the resource area is low and there are few potential constraints on extraction. Resource area 8 is well suited for extraction and rehabilitation.

Selected Sand and Gravel Resource Area 9

Selected Sand and Gravel Resource Area 9 consists of an esker deposit, located in the northeastern portion of Arthur Township near the settlement of Derrynane. The esker extends into West Luther Township. The deposit consists of a long, narrow, sharply defined, single ridge with local relief of more than 15 m. Five pits have been developed in the ridge, 2 of which are presently licenced for extraction (Pit Nos. 34 and 40). Pit faces range in height from 6 to 15 m and expose coarse gravel and sand. The gravel is of high quality and is abundant, making the resource area well suited for the production of high specification aggregate products. The only quality limitations are the occasional presence of silt seams and excess silt content in the fine fraction of the aggregate. Pits in resource area 9 are given a moderate to high use rating by the MTO (Deike 1978b) with the material suitable for Granular A, B Type I, M and possibly HL4 coarse and fine aggregates.

The unlicenced portions of resource area 9 occupy a total of 168 ha, of which 129 ha are possibly available for extraction. Assuming an average deposit thickness of 10 m, the possible available sand and gravel resources are estimated to be 22.8 million tonnes (Table 3).

Cultural constraints on extraction, in the form of roads and houses, are minor. Esker deposits are generally well suited for extraction since most of the aggregate is situated at or above the surrounding land surface. Also, for this reason, post-extractive rehabilitation may be quickly and inexpensively accomplished.

Selected Sand and Gravel Resource Area 10

Selected Sand and Gravel Resource Area 10 is a large esker deposit situated in the north-central portion of West Luther Township. Currently, no licenced pits are present, however 2 previously worked sources are located in the northern part of the esker (Pit Nos. 55 and 56). Faces in these pits range from 3 to 6 m and expose poorly sorted, coarse gravel and sand. The aggregate has been used in the past for pit run and crusher run products and for hot-mix asphaltic sand and stone. Some oversize gravel has to be processed in order to use the aggregate as Granular A. In places the sand fraction may be coarse and contain excess fines which will require blending for some products. Pits in the resource area have been given a moderate to high use rating by the MTO.

Resource area 10 has a total area of 150 ha of which 118 ha are possibly available for extraction. Assuming an average deposit thickness of 5 m, the possible sand and gravel resources could be 10.4 million tonnes (Table 3). The southern part of the esker lies within the West Luther Marsh Wildlife Management Area, therefore, a considerable portion of it is likely to be constrained for extractive purposes. The resource area is accessible by road and is moderately well suited for extractive development.

Selected Sand and Gravel Resource Area 11

Selected Sand and Gravel Resource Area 11 consists of an ice-contact stratified drift deposit located in the central part of West Luther Township. One unlicenced pit, Pit No. 57, has been opened in the deposit, exposing a 6 m face. While the deposit is quite sandy, preliminary investigation has indicated that appreciable amounts of crushable gravel may be found and should be suitable for Granular A, B Type I and M. Cowan (1976) indicated that the probability of locating economic deposits in resource area 11 is moderate to high. Selected Sand and Gravel Resource Area 11 occupies a total of 47 ha, of which 42 ha could be available for extraction. Assuming an average deposit depth of 5 m, possible resources in the area total 3.7 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 12

Selected Sand and Gravel Resource Area 12, consists of an esker deposit located south of Luther Lake in West Luther Township, near the settlements of Damascus and Mount View. The esker is composed of a central ridge of coarse gravel that is surrounded by an extensive deposit of ice-contact stratified drift. The latter deposit has been selected as a sand and gravel resource area of secondary significance. At least 5 pits have been developed in the resource area, however, at present, only Pit No. 54, is licenced for extraction. Pit face heights range from 2 to 12 m and expose poorly sorted, coarse gravel and sand. The coarse aggregate is of exceptionally high quality and is suitable for many road-building and construction products. Also, the material may have potential for Portland cement concrete aggregates (Deike 1978c). The sand component of the deposit is of lower quality. An excess of fines in portions of the deposit prohibits the production of some types of hot-mix asphaltic sand. In addition, some oversize material is present in the deposit and may require processing. Several of the pits in the resource area have been given a moderate to high use rating by the MTO. Such pits contain aggregate generally suitable for Granular A and hot-mix HL4 asphaltic stone (Deike 1978c).

Resource area 12 occupies a total area of 71 ha, exclusive of licenced area. Cultural constraints reduce the area possibly available for extractive development to 49 ha. Assuming an average thickness of 5 m throughout the deposit, possible resources of sand and crushable gravel are estimated to be 4.3 million tonnes. The resource area is accessible by road and is well suited for extractive development.

Selected Sand and Gravel Resource Area 13

Selected Sand and Gravel Resource Area 13 consists of a small esker deposit located at the southern boundary of Arthur Township. The esker ridge extends south into Maryborough Township, where it has also been selected for possible resource protection at the primary level of significance. As with other eskers in Arthur Township, the deposit consists of a single, narrow, sharply defined ridge that is seldom more than 6 m in height. Information on the texture and quality of the material present indicates that sandy aggregate may predominate and that selection and sand control will be required for crushing.

The portion of the esker that extends into the northern part of Maryborough Township consists of a narrow central ridge that in places has relief of more than 12 m. The central ridge is flanked by a narrow deposit of sand. In places the central core of the esker has been removed entirely by previous extractive activity. The sandy flanking deposits have been selected as resource areas of secondary significance. At least 6 pits (Pit Nos. 52, 64, 65, 69, and 71) have been developed along the esker ridge. Pit Nos. 64 and 65 are presently licenced for extraction. The pit faces range in height from 3 to 12 m and expose primarily sandy aggregate, although considerable amounts of crushable aggregate are present in pockets. Approximately half of the pits contain sufficient amounts of coarse material to produce aggregate for Granular A and asphaltic hot-mix. For crushing purposes, selection to avoid silt seams and sand control is required throughout the resource area. All of the pits are capable of providing material acceptable for the production of lower specification aggregates such as Granular B and fill. Generally, pits in Resource Area 13 have been given a moderate to high use rating by MTO (Deike 1978d).

Selected Sand and Gravel resource area 13 occupies 54 ha. After considering cultural setbacks an estimated 44 ha are potentially available for extraction. Assuming an average usable aggregate thickness of 5 m throughout the deposit, possible available sand and gravel resources are estimated to be 3.9 million tonnes (Table 3). The deposit is accessible by Highway 9. Together with its northern extension into Arthur Township, the deposit forms a locally important source of aggregate. Agriculture is the major land-based activity in the area at present.

Selected Sand and Gravel Resource Area 14

Selected Sand and Gravel Resource Area 14 consists of 3 small outwash deposits located south of the settlement of Moorefield in the central portion of Maryborough Township. Numerous water well logs in this area indicate that significant amounts of sand and gravel may be present. Immediately east of the resource area indications are that portions of an older, much more extensive buried outwash deposit may be present. Water well records in this area indicate up to 5 m of clay overlies 2 to 7 m of gravel. For the purposes of this report, however, the resource area is restricted to the mapped extent of the exposed outwash deposit. Further investigation and testing of the area may expand the potential resource area.

The total extent of the mapped outwash unit in resource area 14 is 57 ha, of which 48 ha could be available for extraction. Assuming an average thickness of 4 m throughout the resource area, sand and gravel resources are

estimated to be 3.4 million tonnes (Table 3). The resource area is well situated with respect to road and rail transport routes.

Selected Sand and Gravel Resource Area 15

Selected Sand and Gravel Resource Area 15 consists of segments from 2 parallel esker ridges that are located in the west-central portion of Maryborough Township. The deposits consist of segmented, narrow ridges with relief of less than 6 m. Parts of the ridges have been removed through previous extraction.

One licenced pit (Pit No. 68) are present in the resource area. Pit faces range in height from 3 to 15 m and expose predominantly sandy aggregate, with scattered pockets of crushable aggregate. The presence of significant amounts of chert in the coarse aggregate fraction and excess silt in the fine fraction excludes the use of the material for higher specification products, however, the material is acceptable for Granular A, B and M. The pits are given a low use rating by MTO (Deike 1978d). Sample No. 95-ZLK-1006 (Table 9) taken at the south end of licenced Pit No. 68 provided a petrographic number of 208 for hot-mix and concrete uses and 101.8 for granular uses. The chert-cherty carbonate content is 53.1% and the shale content 0.2%. With the high chert-cherty carbonate content, the aggregate is not considered suitable for hot-mix or to be used with Portland cement. The fine aggregate tends to have an excess of fines for hot-mix paving and concrete fine aggregates.

After considering constraints, an original total resource area of 28 ha is reduced to 19 ha. Assuming an average usable material thickness of 9 m throughout the area, possible available sand and gravel resources are estimated to be 3 million tonnes (Table 3). Agriculture is the main land use in the vicinity of the resource area.

Selected Sand and Gravel Resource Area 16

Selected Sand and Gravel Resource Area 16 consists of several, small ice-contact stratified drift deposits located in east-central Peel Township. The deposits consist of irregular low ridges and mounds. One licenced property, Pit No. 77, occupies part of the area and contains reserves of predominantly sandy aggregate. This material may, in sections, be suitable for crushing to produce Granular A and B and hot-mix asphaltic stone (Deike 1978e). Material with similar use capabilities may be present in the unexcavated portions of the resource area.

Resource area 16 totals 29 ha, exclusive of licenced areas. After considering limited cultural constraints an estimated 22 ha are potentially available for extraction. Assuming an average usable material thickness of 4 m throughout the resource area, possible available sand and minor gravel resources are estimated to be 1.6 million tonnes (Table 3). The resource area is accessible by both road and rail and is close to local markets.

Selected Sand and Gravel Resource Area 17

Selected Sand and Gravel Resource Area 17, located in the south end of Peel Township, consists of 2 outwash terrace deposits situated along the Conestogo River. One unlicenced pit (Pit No. 84) is present in the more westerly deposit. Faces in the pit are approximately 3 m in height and expose sandy gravel. Material from the pit is unsuitable for high-specification products due to the high chert content, however, the material is suitable for granular base aggregate use. The presence of oversize material in the deposit requires processing (Deike 1978e).

Resource Area 17 occupies 39 ha, of which 29 ha is possibly available for extraction. Assuming an average deposit thickness of 3 m, the resource area has possible resources of 1.6 million tonnes (Table 3). Access to this area is provided by Highway 86.

Selected Sand and Gravel Resource Area 18

Selected Sand and Gravel Resource Area 18 consists of a large ridge of ice-contact stratified drift that is located on the west side of Carroll Creek in the northern part of Pilkington Township. The ridge has irregular to hummocky topography that, in places, produces local relief of more than 30 m. Only the central portion of the ridge contains large amounts of crushable gravel. The lower relief deposits which flank the main deposit contain considerable sand. Five pits have been developed in the resource area, 4 (Pit Nos. 85, 86, 87, and 88) of which are presently licenced for extraction. Face heights in the pits are variable, ranging from 6 to 10 m.

The crushable gravel content is variable throughout the area. The pits expose stratified sand and gravel with interbeds of silt and fine sand. The deposit also contains oversized material. Pits in the resource area have a moderate to high use rating and the material is acceptable for high specification roadbase and surfacing aggregate, such as Granular A, B Type 1 and M and hot-mix asphaltic sand and stone.

Selected Sand and Gravel Resource Area 18 occupies a total area of 145 ha, excluding licenced areas. An estimated 126 ha are potentially available for extraction. Assuming an average deposit thickness of 8 m, possible resources of sand and gravel are estimated to be 17.8 million tonnes (Table 3). The resource area is sparsely populated and the dominant land use activity is agriculture. The area is accessible by township roads and by County Road 17.

Selected Sand and Gravel Resource Area 19

Selected Sand and Gravel Resource Area 19 is an ice-contact stratified drift deposit that is located on the north side of Carroll Creek. It is surrounded by the outwash deposits that form resource area 20. The deposit is a single irregular knoll with relief of more than 15 m. The area currently contains 3 licenced pits (Pit Nos. 89, 90 and 91). Li-

cenced property (Pit No. 90) occupies the central portion of the area. Face heights at Pit No. 90 are approximately 9 m and expose stratified sand and gravel, with variable stone content. This pit can produce Granular A, B and M, hot-mix HL4 and Portland cement concrete coarse and fine aggregates. Crushable material is common, but its occurrence within the deposit is variable. Licenced Pit No. 89 is located on the west side of the deposit, adjacent to Pit No. 90. Pit No. 89 has a face height of 5 m and is located on the sandier flanks of the deposit. The gravel content at this site varies from 25 to 40%.

Resource area 19 occupies 52 ha exclusive of licenced areas. After dconsidering limited cultural constraints an estimated 36 ha are possibly available for extraction. Assuming an average thickness of 7 m, possible available sand and gravel resources are estimated to be 4.5 million tonnes (Table 3). Access to the area is provided by township and county roads.

Selected Sand and Gravel Resource Area 20

Selected Sand and Gravel Resource Area 20 consists of 2 portions of an outwash terrace deposit that lies in the valley of the Grand River. The resource area forms a broad terrace which is characterized by indistinct scarps that mark successively lower stages of water flow. A small ice-contact stratified drift deposit is located within the terrace and additional ice-contact stratified drift may underlie the outwash deposits. This ice-contact material may have formed the parent material from which the outwash was derived. Two small unlicenced pits (Pit Nos. 96 and 97) are located in the area. Face heights in the pits are 3 to 8 m and reveal gravel content ranging from 40 to 70%. The sand fraction tends to be dirty and field investigation of Pit No. 96 revealed the presence of some siltstone. Results of laboratory analysis for sample No. 95-ZLK-1004 (Table 9) collected from unlicenced Pit No. 97 which is located in a small ice contact deposit within the outwash material of selected area 20, indicate a petrographic number of 119.8 for hot-mix and concrete uses and 103.6 for granular use. The chert-cherty carbonate content of this sample is 8.1%. The material is acceptable for the production of Granular A, B and M, and HL4 coarse and fine aggregates.

Resource area 20 totals 440 ha, of which 371 ha are presently available for extraction. Assuming an average deposit thickness of 4 m, the possible available sand and gravel resources are estimated to be 26.3 million tonnes (Table 3). The lower portions of the resource area are located within the floodplain of the Grand River and extraction in these areas may not be feasible.

Selected Sand and Gravel Resource Area 21

Selected Sand and Gravel Resource Area 21 is a combination of esker and outwash deposits located along Swan Creek in both Pilkington and Nichol townships.

In Pilkington Township, the outwash terrace deposit is located on the north side of Swan Creek at its confluence with the Grand River. The terrace is narrower and slopes more steeply to the river level than the terrace deposits in resource area 20, however, the materials are similar in character.

South of Swan Creek, an esker deposit runs parallel with the creek. The esker consists of a single sharply defined ridge with local relief of 6 to 12 m. An unlicenced pit (Pit No. 98) is located in this part of the resource area. A 5 m pit face exposes gravel suitable for Granular A and B, as well as asphalt paving aggregate. The deposit covers 267 ha in Pilkington Township and is accessible by road and rail. The material at the west end of the deposit is acceptable for Granular A, B and M, and hot-mix HL4 coarse and fine aggregates. It is thought that the quality of the material continues to the east.

In Nichol Township the esker deposit continues as a single, narrow, segmented ridge that lies parallel to the course of Swan Creek. In general, the esker segments have relief of less than 6 m. No pits or other subsurface exposures are available in the esker or outwash deposits. Consequently, the texture and use suitability of the aggregate are unknown. The esker ridges are flanked by outwash terraces which were deposited in a glacial meltwater channel now occupied by Swan Creek. One water well drilled in the central portion of the terrace indicates that the deposit may be greater then 6 m thick.

The deposits within Nichol Township occupy a total of 173 ha. Generally, the deposits are thought to be suitable for crushed aggregate products. This is based on the few available water well records and on a basic understanding of the textural characteristics of esker and outwash deposits. The resource area is accessible by township and county roads and is reasonably close to local demand centres.

The resource area occupies a total of 440 ha of which approximately 336 ha could be available for extraction after considering limited constraints. Assuming an average deposit thickness of 5 m, possible resources of sand and gravel are estimated to be 29.7 million tonnes (Table 3). Although the area is accessible by road and rail, cultural constraints imposed by transport routes render a significant amount of the potential resource unavailable for extractive use. In addition, resources in the lower portions of the area may be unavailable for extraction due to their location on the floodplains of Swan Creek and the Grand River.

Selected Sand and Gravel Resource Area 22

Selected Sand and Gravel Resource Area 22 is made up of an outwash and an ice-contact stratified drift deposit located on the western boundary of Nichol Township, north of Elora.

Although no pits have been developed in this resource area, water well data indicates the presence of 7 to 14 m of coarse aggregate. Since no extraction has taken place, no texture or use suitability data are available. The resource area has been selected for protection because it may contain the greatest concentration of crushable aggregate in

Nichol Township. No other deposit in the township has comparable amounts of potentially crushable gravel.

The deposits which comprise the resource area occupy a total of 74 ha, of which 63 ha are possibly available for extraction. Assuming an average thickness of usable aggregate of 11 m throughout the 2 deposits, possible sand and gravel resources are estimated to be 12.3 million tonnes (Table 3). Portions of the resource area are unavailable for extraction due to its proximity to residential development in the community of Elora.

Selected Sand and Gravel Resource Area 23

Selected Sand and Gravel Resource Area 23 is a large outwash deposit located on the northwestern shore of Lake Belwood in West Garafraxa Township. The deposit forms part of an extensive series of outwash terraces that flank the Grand River throughout much of its length. This series of terraces is known as the Grand River Outwash (Cowan 1976). Numerous pits have been opened in the deposit under authority of wayside permits. The lands below the waters of Lake Belwood have also been the subject of a wayside permit by the Township of West Garafraxa, although no material has been removed to date. Currently only one pit is licenced for extraction (Pit No. 103) in the area. Depths of material are indicated as 8 to 13 m (Planning Initiatives Ltd. 1994a, Lotowater Ltd. 1995). Cowan (1976) notes that the deposits are 5 to 8 m thick. Gravel content ranges from 25 to 75% and much of it is suitable for crushing purposes, however, local presence of siltstone may affect quality. The currently licenced pit has pit faces of only 3 to 6 m. The material is acceptable for the production of Granular A, B Type 1 and M, and HL4 coarse and fine aggregates.

Resource area 23 covers 399 ha, exclusive of the licenced areas. After considering constraints an estimated 308 ha could be available for extraction. Assuming an average deposit thickness of 7 m, possible available sand and gravel resources are estimated to be 38.2 million tonnes (Table 3). Competing recreational and rural residential land uses, especially adjacent to county roads, and along the shoreline of Lake Belwood may restrict extractive development in parts of the resource area.

Selected Sand and Gravel Resource Area 24

Selected Sand and Gravel Resource Area 24, located in the southern part of West Garafraxa Township, consists of a thin sheet of outwash material that was deposited at the margin of the Orangeville Moraine during the time of its formation. No pits have been developed in the deposit and no subsurface information is available, however, it is thought that the deposit is similar in texture and thickness to Selected Sand and Gravel Resource Area 23.

Resource area 24 occupies 179 ha, of which 153 ha are possibly available for extraction. Assuming an average deposit thickness of 4 m, possible resources of sand and minor gravel are estimated to be 10.8 million tonnes (Table 3). Physical constraints on extraction are few and the resource area is well situated for local use.

Selected Sand and Gravel Resource Area 25

Selected Sand and Gravel Resource Area 25 consists of an outwash deposit located near the southern boundary of West Garafraxa Township, southeast of Lake Belwood. The outwash sands and gravels were deposited as irregular sheets along the flanks of the Orangeville Moraine. The deposit was mapped as gravel by Karrow (1968), however, data obtained from MTO for 2 pits that once operated in the deposit indicate the material has a low gravel content and is likely to be acceptable primarily for Granular B.

The resource area occupies 284 ha, of which 233 ha could be available for extraction. A power line right-of-way, several township roads and farms pose physical constraints on extraction. Assuming an average deposit thickness of 5 m, the possible sand and gravel resources are estimated to be approximately 20.6 million tonnes (Table 3). The resource area is accessible by township and county roads and by rail.

Selected Sand and Gravel Resource Area 26

Selected Sand and Gravel Resource Area 26 is an ice-contact stratified drift deposit located beside Selected Sand and Gravel Resource Area 25 in West Garafraxa Township and extends south-eastwards into Eramosa Township. The deposit forms part of the Orangeville Moraine, the bulk of which is located further to the east. Currently licenced Pit No. 104 is located in the resource area. There are two other pits (Pit Nos. 112 and 138), presently unlicenced, from which material was extracted in the past. Pit faces expose 2 to 5 m of well sorted, sand-rich aggregate with isolated lenses of crushable gravel. Because of the localized nature of the gravel detailed field testing would be required to identify those areas containing quantities of coarser aggregate. Granular A has been produced from the pits although extensive selection was required. The material is also suitable for Granular B and M.

The topography in Eramosa Township is rolling to irregular, with a maximum local relief of 46 m. The highest elevations occur on a small kame in the central portion of the resource area, where a now rehabilitated sand pit (Pit No. 138) had been developed. Faces reaching 5 to 6 m in height expose aggregate of variable quality which was extracted for hot-mix asphalt paving coarse and fine aggregate.

After considering limited constraints, 298 ha are potentially available for extraction. Assuming an average thickness of usable material of 5 m, possible resources are estimated to be 26.4 million tonnes (Table 3). Access to resource area 26 is provided by township and county roads.

Selected Sand and Gravel Resource Area 27

Selected Sand and Gravel Resource Area 27 is a well developed outwash fan deposit located in north-central Eramosa Township, near the settlement of Oustic. The material was deposited by water that flowed to the northwest from the margin of the Ontario ice lobe (Karrow 1968). The deposit has a relatively level surface and slopes gently to the northwest. Licenced Pit No. 130 is located in the northern part of the deposit. Faces in the pit range from less than 2 m to 6 m and expose moderately stratified sand and gravel. The material is of high quality and is acceptable for Granular A, B Type 1 and M, hot-mix HL4 and concrete coarse and fine aggregates.

The resource area occupies a total of 152 ha, of which 131 ha are possibly available for extraction. Assuming an average deposit thickness of 4 m, possible sand and gravel resources are estimated to be 9.3 million tonnes (Table 3). Access to the resource area is provided by township roads.

Selected Sand and Gravel Resource Area 28

Selected Sand and Gravel Resource Area 28, located in the south-central portion of Eramosa Township, forms part of an extensive glacial meltwater channel system that is now partially occupied by the Speed River and one of its tributaries. Resource area 28 has flat to undulating topography and slopes gently to the southeast. Water well data regarding subsurface materials are not available for this area, however, some information is provided by faces in 2 pits (Pit Nos. 143 and 145). Both sources expose a high percentage of coarse aggregate that is suitable for the production of Granular A, B and asphaltic hot-mix HL4 coarse and fine aggregate. Sand control may be required in the fine-grained portions of the deposit in order to produce crushed aggregates, while in other places, oversize material may need to be removed. Faces in the pits range between 3 and 5 m.

Selected Sand and Gravel Resource Area 28 occupies 263 ha of which 207 ha could be potentially available for extraction. Assuming an average thickness of 5 m in the resource area, possible resources of good-quality sand and gravel are estimated to be 18.3 million tonnes (Table 3). The population in the vicinity is sparse and agriculture is the main land use. Access is provided by gravel-surfaced township roads.

Selected Sand and Gravel Resource Area 29

Selected Sand and Gravel Resource Area 29 is an extensive outwash deposit located east and southeast of resource area 27. The topography of the area is rolling to irregular with isolated kettle depressions present on the surface of the outwash plain. No water well data are available for the resource area. Two unlicenced pits (Pit Nos. 140 and 141) have been previously worked in the deposit. Faces in the pits range from 3 to 5 m in height and expose coarse aggregate suitable for crushing.

Resource area 29 occupies a total of 589 ha, of which 467 ha are potentially available for extraction. Assuming an average usable material thickness of 4 m, the possible available resources are estimated to be 33 million tonnes (Table 3). The resource area is sparsely populated and is presently used for agriculture. As in resource area 27, access is provided by gravel-surfaced township roads.

Selected Sand and Gravel Resource Area 30

Selected Sand and Gravel Resource Area 30 consists of several esker segments that form the Eramosa Esker in the southern part of Eramosa Township. The esker trends westerly and consists of a single, narrow ridge, broken into numerous sections. The relief of the ridge is generally 3 to 6 m. Three licenced properties (Pit Nos. 133, 134 and 135) cover portions of the deposit. Faces in the pits are approximately 3 to 5 m high and expose sand and crushable gravel suitable for a range of road-building and construction products. The pits have been given a moderate to high use rating by the MTO.

The resource area occupies a total area of 56 ha. After considering limited constraints approximately 44 ha are possibly available for extraction. Assuming an average deposit thickness of 4 m, the possible remaining sand and gravel resources are estimated to be 3.1 million tonnes (Table 3). The resource area is well situated with respect to transport routes and local demand centres. As a result, it is an attractive site for local extractive development. In addition, esker deposits are generally well suited for rapid excavation and rehabilitation.

Selected Sand and Gravel Resource Area 31

Selected Sand and Gravel Resource Area 31 is an ice-contact stratified drift deposit consisting of a large hummocky area located south of Rockwood along Highway 7. The deposit forms part of the Paris Moraine.

One unlicenced pit (Pit No. 150) and one licenced source (Pit No. 136), are located in the resource area and expose 5 to 8 m of texturally variable aggregate. Pit data indicate that good quality crushable gravel is available in portions of the deposit. In other areas the deposit is primarily sand with a high silt content making the material unsuitable for most aggregate products. Testing of a site within this deposit (Ingham 1990) showed that up to 8 m of sand and gravel (20 to 50%) exist above the Amabel Formation dolostone. Water well records also indicate variable thicknesses of gravel, from 5 to 16 m, above bedrock. Further investigation of the deposit needs to be undertaken to identify those areas best suited for the production of crushed aggregates.

An additional potential resource exists in the Amabel Formation bedrock that underlies the resource area. The Amabel Formation is well suited for the production of many road-building and construction aggregates and

would be available for extraction beneath pits opened in the ice-contact stratified drift. For a description of the Amabel Formation and overlying surfical material, see the summary for test hole ER-TH-1 in Table 7.

Within Eramosa Township, this selected resource area includes 901 ha, however, after allowing for cultural and other constraints, approximately 889 ha are considered potentially available for sand and gravel extraction. Assuming an average deposit depth of 7 m the resource area could contain possible resources of up to 110.1 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 32

Selected Sand and Gravel Resource Area 32 is part of a large outwash deposit known as the Caledon Outwash. The main part of the Caledon Outwash is located in the Regional Municipality of Peel, east of Wellington County. Two pits have been developed in the deposit, one of which (Pit No. 157) is presently licenced (Ecological Services For Planning Ltd. and S.E.Yundt Limited 1992), with material being extracted from below water. This licence has recently been expanded to allow access to more resources located below water. Face heights in the pits are 4 to 5 m and expose stratified sandy gravel consisting of 65 to 80% gravel. Aggregate from the pits has been used for a range of granular base and subbase products. The material is also suitable for crushing, although in some areas poor quality of gravel may be a limiting factor for hot-mix paving uses. The pits are given a moderate to high use rating according to MTO standards.

Selected Sand and Gravel Resource Area 32 comprises 195 ha, excluding the licenced area. Previous extractive activity has been minimal and cultural features are primarily roads and watercourses. The area available for extraction is thus estimated to be 144 ha. Assuming an average deposit thickness of 5 m, total possible resources are approximately 12.7 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 33

Selected Sand and Gravel Resource Area 33 is located west of the village of Erin on the north side of the Credit River (Erin Branch), and represents an outwash terrace deposited in an extension of the Caledon Outwash meltwater channel system.

One unlicenced pit (Pit Nos. 168) has operated in the deposit during the past. Face heights range from 2 to 4 m and expose stratified sandy gravel with a crushable gravel content ranging from 35 to 60%. The aggregate from this pit has been used for Granular B Type 1 and for Select Subgrade Material (SSM). Due to high siltstone content the coarse aggregate fraction of crushed material is unsuitable for some products unless beneficiation is undertaken.

Resource area 33 covers an area of 296 ha. Some of this area is unavailable for extraction as Highway 24 stretches the length of the terrace and residential development is prevalent in some areas. Previous extractive activity has been minimal. The area remaining available for extraction is estimated to be 237 ha. Although water well data indicate as much as 18 m of gravel, a more conservative estimate of 8 m was used for resource calculation purposes. Possible resources in Resource area 33 are estimated to total approximately 33.6 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 34

Selected Sand and Gravel Resource Area 34 consists of a large portion of the Caledon Outwash situated at the eastern boundary of Erin Township. The material present in the deposit is described by Cowan (1976) as well-stratified, medium to coarse-textured with gravel content ranging from 25 to 75%. The deposit thickness ranges from 3 to 23 m. Overburden is up to 2 m thick. In addition, the water table has been encountered in several pits at depths of 9 to 15 m below ground surface.

Two licenced properties are located in the resource area (Pit Nos. 156 and 159). Face heights range from 5 to 15 m and expose stratified sandy gravel. The crushable material content ranges from 20 to 50%. Aggregate from the pits has been used for Granular A, B and M and for Select Subgrade Material. It is generally not suitable for higher specification uses. Undesirable quantities of siltstone and shale reduce the quality of the gravel and beneficiation must be undertaken to improve quality. Beneficiation procedures are used in large commercial pits developed in the Caledon Outwash in the Town of Caledon. The procedure is costly, however, the size of the deposit allows economies of scale that make the treatment economically viable. Pits in Area 34 have been given a low to moderate use rating (Deike 1976). Test results for sample 95-ZLK-1007, taken from an unlicenced pit (Pit No. 162) yielded a petrographic number of 128.5 for hot-mix and concrete and 109.0 for granular use, an unleached chert-cherty carbonate content of 3.0% and siltstone content of 4.5%.

Resource area 34 covers 638 ha, excluding licenced areas. Considering present and previous extractive activity and constraints due to residential development around the Village of Erin an estimated 436 ha are theoretically available for extraction. Assuming an average deposit thickness of 9 m, possible resources are calculated to be approximately 69.5 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 35

This selected resource area consists of outwash sediments deposited in low lying areas between drumlins in Guelph Township. At present, there are no licenced operations in this selected area, however, Pit No. 119 has been developed in this deposit. The resource area has been given a moderate to high use rating by the MTO, however, the deposit is irregular in extent and composition is variable. Testing by McLellan (1975) for the development of a recreational park showed an unpredictable content of crushable materials. Gravel content as low as 4 to 20% has been

reported (Deike 1981). Although the water table is close to the surface, deposit thicknesses of up to 8 m have been noted. Testing by the MTO has shown that, with selection, material in the deposit is acceptable for a wide range of products including asphaltic hot-mix HL4 and Granular A, B and M. The variability of this deposit may, however, present operational problems for commercial development.

Existing rural-residential uses along major access routes partially limit the availability of this resource area. Assuming an average resource thickness of 5 m and considering cultural constraints and previously extracted areas, the remaining area of approximately 428 ha contains possible resources of 37.9 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 36

Selected Sand and Gravel Resource Area 36, located on the east side of the City of Guelph, forms a part of the Speed River spillway system. The double terraced deposit occupies a total area of 211 ha with estimated thickness of material ranging between 4 to 6 m.

This well-stratified deposit contains one licenced property (Pit No. 114) and one abandoned site (Pit No. 123). A large quantity of crushable gravel (with gravel content of 50% or higher including oversize material) is available above the water table. The MTO has rated sources within this deposit as moderate to high (Deike 1981). Material derived from this deposit is acceptable for a wide range of products including HL4 asphaltic paving hot-mix and Granular A, B and M. Sand grading may vary and require blending for hot-laid aggregate uses.

Existing residential uses, the Guelph airport and industrial land recently serviced by the City of Guelph, severely limit the future availability of material from this resource area. After accounting for these cultural constraints and previously extracted areas, 121 ha remain available for possible resource extraction. Assuming an average thickness of 6 m in the upper terrace and 4 m in the lower terrace, the possible resources are estimated to be a maximum of 10.7 million tonnes (Table 3). As noted, much of this resource may be sterilized by any future encroaching urban development.

Selected Sand and Gravel Resource Area 37

Selected resource area 37 consists of an upper and lower linear terraced outwash deposit situated along the north side of the Speed River in both Guelph and Puslinch townships. Because of varying deposit thicknesses, the resource area has been divided into 2 areas, 37A and 37B.

Resource area 37A consists of the upper terrace of this outwash deposit and is notably thinner (about 5m) and sandier (gravel content 20%) in comparison to the lower terrace which comprises resource area 37B. Presently there are no licenced operations in the area, however unlicenced pits (Pit Nos. 124 and 125) supplied road subbase materials in the past. Detailed test information is not available for this area. Because of industrial development along Highway 24 the availability of material from this resource area is limited.

After accounting for cultural setbacks, only 148 ha from the original 237 ha, are available for extraction. Assuming an average depth of 5 m for resource area 37A, estimated resources are calculated to be 13.1 million tonnes (Table 3).

The lower terrace of this outwash deposit makes up Selected Sand and Gravel Resource Area 37B. This deposit has a thickness of 9 m or more of well stratified sand and gravel with a gravel content of 60%. Although parts of the deposit may contain excess fines for some uses, products such as Granular A and B Type 1 can be produced (Deike 1981). The gravels are also suitable for Granular M, hot-mix asphaltic paving and Portland cement concrete coarse and fine aggregates provided that suitable processing is carried out. A good portion of the deposit is licenced. Pit No. 115 is both a pit and a quarry. It is largely located in resource area 37B, but also crosses over into resource area 37A. This large commercial operation has washing and asphalt facilities to supply a wide range of products for the Guelph and Cambridge markets (Trauffer 1976).

Resource area 37B occupies a total of 136 ha, of which 76 ha are potentially available for extraction after considering constraints. Assuming an average thickness of usable sand and gravel material of 6 m, possible sand and gravel resources in Area 37B total 8.1 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 38

Selected Sand and Gravel Resource Area 38 is part of an extensive outwash deposit that lies immediately north and west of the Paris Moraine. The resource area lies within both Puslinch Township and the south end of the City of Guelph. Extractive activities have not been extensive in the part of the deposit that lies within the City of Guelph. The resource area appears suitable for the production of Granular B Type 1 with some areas suitable for Granular A. With processing, parts of the deposit would be suitable for hot-mix asphalt paving and Portland cement concrete coarse and fine aggregates.

In the northern part of the Puslinch Township portion of the resource area, a materials investigation (Dominion Soils Investigation Inc. 1979) revealed that the deposit is generally coarser near the surface and becomes finer with depth. The average deposit thickness is 5 m, however, beneath the coarse aggregate an additional 7 m (average) of finer material is present. This lower material is marginally suitable for Granular A. With processing, some parts of the deposit would be suitable for hot-mix asphalt paving and Portland cement concrete coarse and fine aggregates.

Resource Area 38 occupies a total of 846 ha, but after allowing for cultural setbacks, such as developed areas within the City of Guelph, a major highway corridor and an industrial subdivision, only 563 ha are potentially avail-

able for extraction. Assuming an average thickness of usable material of 6 m the possible available resources of approximately 59.8 million tonnes (Table 3) are present.

Selected Sand and Gravel Resource Area 39

Selected Sand and Gravel Resource Area 39 is part of an outwash plain and spillway deposit associated with the Paris Moraine. The resource area is located north of Puslinch Lake and southwest of the City of Guelph, and also extends along the south side of the Speed River.

Pits along the Speed River (Pit Nos. 172, 176, 177, 178 and 181) have face heights of approximately 6 m. Portions of the deposit have considerably greater thickness and some operations are also licenced for quarrying operations. Further details regarding quarrying are provided in the bedrock section of the report. The gravel content is approximately 70% in the licenced properties; however, considering the deposit as a whole the average gravel content is approximately 60%. In these pits, products such as Granular A, B Type 1 and M, hot-mix asphaltic paving HL4 and concrete coarse and fine aggregates can be produced (Deike 1976). Blending of different sand grades is also required in some areas to produce acceptable aggregates for hot-mix paving.

In the southern portion of the resource area there are 2 licenced pits (Pit Nos. 181 and 182) as well as several abandoned or rehabilitated pits and sites from wayside permits. The average gravel content of this part of the deposit is 60 to 80% a large quantity of which is crushable and of high quality. The water table is high throughout much of this area, located generally 3 to 5 m below the surface. Laboratory tests performed by the MTO on the materials from the Puslinch Crown Resources Management Area indicate that the gravel is suitable for Granular A and M. The gravel portion is of acceptable quality for hot-mix asphaltic paving HL 3, HL4, and HL8 and for structural concrete coarse aggregates. This source can currently produce Heavy Duty Binder coarse and fine aggregates. Previously, one of the commercial sources in this deposit produced the same materials on a trial basis. The sand fraction meets the specifications for all grades of hot-laid asphalt as well as concrete sand. Since there is a low percentage of sand, blending will also be necessary for all hot-mix paving fine aggregates (Deike 1976). Although the above data pertains to the Puslinch Crown Resource Management Area the material in the remainder of the resource area is expected to be similar in nature.

Resource area 39 comprises of 793 ha, however, after considering cultural constraints, the area potentially available for extraction is 645 ha. Assuming an average depth of material of 6 m, the possible resources are 68.5 million tonnes (Table 3).

Selected Sand and Gravel Resource Area 40

Selected Sand and Gravel Resource Area 40 is an outwash deposit associated with the Galt Moraine. This deposit is situated near the junction of Highways 401 and 6 and occupies a total of 1004 ha. Ten currently licenced operations in this deposit are normally working a 3 to 8 m face above the water table, and on several properties an additional 6 m of material below the water table are removed by dragline. Most of the pits are licenced to allow extraction below the water. In most exposures the material is well stratified and sorted and there is generally less than 5% oversize material (Planning Initiatives Ltd 1989,1994b). The Galt-Aberfoyle Creek drainage system bisects the deposit and results in portions of the deposit being covered by wetland. A major watershed study is currently being completed and will be examining among other matters, the potential impact of extraction on that watershed.

Selected Sand and Gravel Resource Area 40 has a considerable thickness of usable material. Portions of the deposit are up to 18 m in depth with 40 to 80% gravel content. Because the material in the eastern part of the resource area was deposited close to the ice front the aggregate is more poorly sorted, but thicker, than in the western part. The material also becomes finer towards the west. Data from the MTO indicate that the material is acceptable for Granular A, B Type 1 and M, hot-mix asphaltic paving and Portland cement concrete coarse and fine aggregates (Deike 1976). The sand requires blending for hot-mix applications.

Removing licenced and previously extracted areas and cultural setbacks, the available resource area consists of approximately 900 ha. Assuming an average thickness of 9 m throughout the whole deposit above and below the water table, the possible available sand and gravel resources are estimated to total 143.4 million tonnes (Table 3).

RESOURCE AREAS OF SECONDARY SIGNIFICANCE

A total of 59 aggregate deposits have been identified as being of secondary significance. These areas include esker, outwash, ice-contact and kame deposits. These deposits contain materials similar to those selected at the primary level, however, aggregate quality is more varied and the quantity of available material is limited. Also, the possibility of finding fine-grained material within these deposits is greater. Nevertheless, protective measures should be considered for these resource areas since they provide alternate extraction sites.

Cowan (1979) indicates that the aggregate resources contained in the Saugeen Kames, situated in the northern part of Minto Township, are of regional importance. All of the major outwash deposits in that area have been selected as resource areas of primary significance. The kames are composed of ice-contact stratified drift deposits that contain large possible resources of sand and significant, although variable, amounts of crushable gravel. The ice-contact deposits form “islands” of rugged, irregular topography, surrounded by the relatively flat outwash deposits, and are easily delineated on topographic maps. All of the major ice-contact stratified drift deposits in the northern part of the township have been selected as sand and gravel

resource areas of secondary significance. These deposits are generally composed of poorly to well-sorted, stratified sand. In places, oversized boulders are present. The amount and distribution of the crushable material is highly variable in all of the deposits. Cowan (1979) classifies the deposits as, "Area(s) underlain by stratified drift which contain localized masses of usable granular aggregates. Exploration and development cost may be high." Cowan also notes that the probability of locating deposits suitable for local use is moderate, but is low for locating large commercial deposits.

In addition to the ice-contact deposits in the north, several esker segments in the central and southern parts of Minto Township have been selected as sand and gravel resource areas of secondary significance. These deposits have been selected at the secondary level because they contain less usable material than those selected at the primary level or have had most of the usable material removed by prior extraction. The esker deposits at Melgund, and those in the extreme southwest corner of the township for example, have been extensively worked in the past, and little of the esker ridges remain. Additional crushable material may be available below many of the pits and the deposits may contain material useful for local needs. The established extractive land use of these areas makes them attractive sites for continued extraction. Several small esker segments at the Maitland River have also been selected at the secondary level. These deposits are quite thin but may contain small amounts of crushable gravel.

An esker and ice-contact stratified drift deposit located at the eastern boundary of Minto Township has also been selected at the secondary level. The deposit forms the western end of the Riverstown Esker deposit. Two pits (Pit Nos. 10 and 28) in the deposit have been given a moderate to high use rating by MTO (Deike 1978a). Pit faces expose 3 to 6 m of sand and gravel suitable for most uses. Silt seams in the deposit, however, may pose problems for some applications.

The outwash deposit in the extreme northeast corner of Minto Township has been selected as an area of secondary importance. It was formed in the same manner as Selected Sand and Gravel Resource Area 6, but because it is a thinner deposit, the area has been classified at the secondary level of significance.

In the southeast part of the township another outwash deposit has been selected as a resource area of secondary significance. This deposit is part of the network of outwash channels situated in the south-central part of the township. Most of these channel deposits are sand-rich, however, this deposit contains a considerable amount of gravel. Licenced Pit No.15, which is partially included in this area, has 5 to 6 m faces containing 45 to 50% gravel. The local presence of excess fines may limit the uses of the aggregate.

In Arthur Township, several outwash and ice-contact stratified drift deposits located south of Mount Forest and 2 small deposits near the western and southern boundaries of the township have been selected as sand and gravel resource areas of secondary significance. Although very little extraction has taken place in these deposits and subsurface data are scarce, there are indications that significant amounts of both sandy and crushable aggregate exist. Water well data for some of the deposits indicate thicknesses of sandy aggregate in excess of 9 m. Further investigation on a detailed level is necessary to identify those portions of the deposits best suited for extraction.

A small selected resource area of secondary significance is located in north-central Arthur Township. This ice-contact stratified drift deposit presently supports one licenced property (Pit No. 37) containing aggregate with 40 to 75% gravel that, with some selection and sand control, may be used for crushed products. An additional resource area of secondary significance located east of Mount Forest is similar in character to the previously described deposit and is suitable for the production of crushed aggregate.

In West Luther Township, several ice-contact stratified drift deposits situated in the northeast part of the township have been selected as sand and gravel resource areas of secondary significance. The deposits generally contain fine-grained aggregate and may be suitable for some local sand uses.

The largest of the resource areas of secondary significance is the ice-contact stratified drift deposit that forms the eastern flank of Selected Sand and Gravel Resource Area 12. Very little subsurface information is available for this deposit, but limited MTO data indicate that it contains large amounts of fine sand and lesser amounts of crushable gravel. Areas of hummocky topography within the deposit may contain small amounts of gravel. Further investigation of the deposit is required.

Several small ice-contact stratified drift deposits in the central and northern parts of the township have also been selected at the secondary level. No subsurface information is available for these deposits, but it is likely that they contain small amounts of sandy aggregate suitable for local road subbase use.

In Maryborough Township, the sandy deposits that surround the lower flanks of the esker deposit in Selected Sand and Gravel Resource Area 13 have been classified at the secondary level. These deposits contain small amounts of material suitable for low specification uses but, because of the limited quantities of possible resources throughout Maryborough Township, they may be significant for local use. While some licences in the northern part of selected resource area 13 have been cancelled, there has been recent expansion of activity in this area of secondary significance. Two licenced pits (Pit Nos. 64 and 65) with faces up to 12 m have been opened in the deposit. Material from this source is suitable for use as Granular A and B Type 1 (Deike 1978d).

A small outwash deposit located in the northern portion of Maryborough Township near the settlement of Rothsay has been selected as a resource of secondary significance. Pit No. 72 was formerly operated under a wayside permit in the central part of the resource area. Faces in the pit are approximately 3 m in height and expose predominantly sandy aggregate with isolated pockets of

crushable gravel. Crushed aggregate has been produced from the resource area, however, selection and sand control was required. Deike (1978d) indicates the material is suitable for the production of Granular A as well as HL4 asphalt paving coarse and fine aggregates.

A small ice-contact and esker deposit situated in the north-central part of Maryborough Township has also been selected as an area secondary resource. One licenced pit (Pit No. 66) is located within both these deposits. Material from this source is suitable for use as Granular Base Course A and sub-base aggregates (Deike 1978d)

Four esker segments located in the southern portion of Maryborough Township have also been selected as secondary resource areas. Some fines and deleterious lithologies are present within these deposits.

In Peel Township, several small outwash deposits and ice-contact stratified drift deposits in the northern and southern portions of the township have been selected as sand and gravel resource areas of secondary significance.

Several outwash terrace deposits situated in the northwestern part of Peel Township along the banks of the Conestogo River contain small amounts of sandy gravel that, in places, may be suitable for crushing. A few long-abandoned pits may exist in the deposits but no information on the type or quality of material removed is available. Further testing of the deposits would be required to identify areas suitable for extraction.

Several ice-contact deposits along the northern and southern boundaries of Peel Township have been selected at the secondary level of significance. Some extraction in these deposits has taken place in the past. Shallow faces in these pits expose dirty sandy gravel which, in places, may be suitable for crushed products, however, high chert content in the gravel may pose problems for crushed products. The silt content of the fine aggregate is high in places and prohibits use of the material for higher specification products.

Test results for sample No. 95-ZLK-1005 (Table 9) taken from licenced Pit No. 75 provide a petrographic number of 130.6 for hot-mix and concrete and 100.0 for granular uses with an unleached chert-cherty carbonate content of 15.3%. The high chert-cherty carbonate content makes the contained material unacceptable for hot-mix paving and concrete coarse aggregates. The fine aggregate tends to contain a high percent of fines for hot-mix and concrete uses. For further aggregate information of this area see the summary for test hole PE-TH-1 in Table 7.

In the extreme southern corner of Peel Township, 2 areas of sand-rich outwash have been selected as resource areas of secondary significance. Testing done for a licence (Pit No. 78) north of Wallenstein (Black, Shoemaker, Robinson and Donaldson Ltd. 1994) indicated up to 3 to 4 m of sandy gravel and cobbles (55 to 75% gravel). It is apparent that parts of the deposit are overlain by clay. Much of the licenced area lies outside of the boundaries of the selected resource areas. Further investigation may provide data that would allow expansion of the currently outlined resource area.

In the south-central part of Peel Township, an ice-contact/esker deposit has been selected at the secondary level because of minimal remaining aggregate material.

A secondary deposit located along the eastern boundary of Peel Township consists of a low esker segment, with small ice-contact deposits at the northern and southern ends. At one time, 2 pits, now exhausted, were opened in the deposit. Shallow faces in the pits expose sandy aggregate with considerable silt content in places. The aggregate was used to produce Granular B Type 1 (Deike 1978e).

In Pilkington Township several outwash deposits in the central and southern portions of the township have been selected for possible resource protection at the secondary level. The outwash was deposited as part of an extensive meltwater channel system that extends to the south from the Grand River into an east-trending channel, now partially occupied by Cox Creek. The entire system is known as the Cox Creek spillway (Bryant and McLellan 1974).

The Cox Creek spillway deposits are relatively thin and sandy. Little extraction has occurred, although a few abandoned pits and one licenced pit are present. The currently licenced source (Pit No. 93), located in the eastern portion of the deposit, has a face height of 3 to 5 m with a considerable amount of oversized material present. Subsurface information on the texture and quality of the aggregate is scarce. Bryant and McLellan (1974) indicate that the deposit tends to be dirty and/or unsorted and contains significant proportions of clay and silt. MTO surveys indicate that the material has difficulties meeting highway specifications. Despite the generally low quality of the material, its widespread occurrence provides alternatives in locating pits for the provision of locally needed road subbase aggregate.

Portions of the Ariss Esker, located in the southern part of Pilkington Township, have also been selected at the secondary level of significance. The esker is highly segmented and consists of several single, sharply defined ridges with relief of less than 6 m. Minor resources of sand and gravel may be available in these deposits.

In Nichol Township several thin, sandy outwash deposits located in the central and southern portions of the township have been selected as sand and gravel resource areas of secondary significance. Although these sources are probably not suitable for the production of crushed aggregates, they constitute virtually the only alternative sources available for extraction in the township, if Resource Area 21 or sections of Resource Area 22 are, for some reason, unavailable for extraction. These secondary level sources may be able to supply substantial amounts of subbase aggregate, sand cushion and fill for local use. Two unlicenced pits (Pit Nos. 100 and 101), developed in parts of the secondary resource areas, expose 2 to 4 m of sand-rich aggregate.

In West Garafraxa Township, a large portion of the Orangeville Moraine occupies the southeastern corner of the township. Although water well data in the deposit indi-

cate a considerable thickness of granular material, the crushable gravel is variable in occurrence and is usually overlain by an upper silty fine sand unit that may be up to 8 m thick. Cowan (1976) notes that granular materials are best exposed where erosion has taken place. In the portion of the moraine located in Erin and East Garafraxa townships, considerable amounts of crushable gravel are found at depth. The Orangeville Moraine covers a considerable area in West Garafraxa Township and may contain large amounts of gravel suited for a variety of uses. Cowan (1976) includes the area in a class of deposits where prospecting and development costs are high and the probability of locating economic deposits is low. Aggregate suited for local needs may, however, be available.

Two small ice-contact stratified drift deposits are located in the southwestern corner of West Garafraxa Township. These resource areas have rolling topography and relief of up to 15 m. A small pit was previously licenced for operation in the area and faces exposed 3 to 6 m of sandy aggregate with low gravel content. Crushable gravel is available in pockets and lenses within the sandier material.

Additional sand and gravel resource areas of secondary significance include several outwash and ice-contact deposits. Two outwash deposits flanking the Grand River consist of relatively thin narrow terraces. These terraces have been extracted at 2 locations in the past and may contain useful resources of sandy gravel. East of Fergus are 2 areas of ice-contact stratified drift. These deposits are extensively built over but small quantities of possible resources may still be available.

In Guelph Township 3 outwash deposits and one small esker deposit are selected as resource areas of secondary significance. One of the outwash deposits selected as a secondary resource area adjoins Selected Sand and Gravel Resource Area 35. Testing by the MTO and water well log data suggest that this area is less than 3 m thick but the aggregate is of sufficient quality to yield road base subbase aggregates (Granular A, B Type 1 and M) and hot -mix paving coarse and fine aggregates (Pit No. 122).

Also in Guelph Township, a second outwash deposit selected at the secondary level of significance is a continuation of Selected Resource Area 34, however, the deposits thickness is not as great. Granular investigations have not been reported for this area and, therefore, quality information is not available.

A third outwash deposit, located in the City of Guelph, is an eastward extension of selected Resource Area 37. Data from water well records and from licenced sand and gravel pits in adjacent Puslinch Township indicate that the deposit is predominantly gravel with a thickness ranging from 6 to 17 m. The aggregate in this part of the outwash deposit is believed to be of poor quality compared to that of Resource Area 37.

Much of the esker gravel in the Guelph area has been fully exploited, except for a small segment of the Ariss Esker, situated on the northern limits of the City of Guelph. Although not subject to detailed investigation, the deposit could be a useful source of road construction aggregate.

In Eramosa Township, several ice-contact stratified drift and outwash deposits have been selected as sand and gravel resource areas of secondary significance. The first outwash deposits is a thin but extensive outwash plain located in the northern portion of the township. It is developed on the northern edge of the outwash that forms Resource Area 27 and may be a northerly extension of that deposit. Although data is scarce it is thought to consist predominantly of sand and be less than 3 m thick.

Two outwash deposits adjacent to Resource Area 28 in Eramosa Township have also been selected at the secondary level of significance. These deposits are similar in character and use suitability to Selected Sand and Gravel Resource Area 28. However, since the depth of aggregate in the deposits is thinner than in Selected Resource Area 28 they have been selected at the secondary level.

The ice-contact stratified drift deposit in Eramosa Township, that partially surrounds Resource Area 27 has been selected at the secondary level of significance. The deposit has subdued, but irregular topography and has several silt filled depressions that may have formed as a result of the melting of blocks of ice stranded in the ice marginal area. At the eastern edge of the deposit, an abandoned pit exposes variably textured material with isolated pockets of coarse aggregate suitable for crushing. The remaining aggregate is predominantly sand and contains excess silt. The material is suitable for low-specification uses.

Two ice-contact deposits situated in the northwest corner of Eramosa Township have been selected at the secondary level of significance. The deposits are similar in nature to Resource Area 26, but are thinner and sandier. Coarse aggregate may be found in isolated pockets.

A small ice-contact stratified drift deposit in the northern corner of Eramosa Township has also been selected as a resource area of secondary significance. The deposit is a western extension of the Orangeville Moraine. The deposit is predominantly sand, but minor resources of crushable gravel may be found in isolated pockets.

Another small ice-contact feature located at the centre of Eramosa Township has also been selected as a resource area of secondary significance. A licenced pit (Pit No. 132) situated in the deposit exposes 3 to 5 m of irregularly bedded sand and gravel. The presence of silt in the upper layers of the deposit limits the suitability of the deposit for high-specification uses.

In Erin Township, several resource areas of secondary significance have been identified. Further investigation should be undertaken in these areas. Portions of the Hillsburgh meltwater channel, which extends from the eastern boundary of the township to Hillsburgh, may have moderate aggregate resources. Two unlicenced pits (Pit Nos. 160 and 161) have been opened in the deposit and contain faces of 3 to 5 m. Water well data in the area indicates thickness of sandy gravel ranging from 8 to 20 m. Although the resource area is large, much of the southern portion is unavailable for extraction because of development around Hillsburgh.

The Orangeville Moraine which covers much of northern Erin Township, has also been identified as a resource area of secondary significance. Although water well data in the deposit indicates a considerable thickness of granular material, the crushable gravel is variable in its occurrence. The gravel is usually overlain by an upper silty fine sand unit up to 8 m thick. Cowan (1976) notes that the granular materials are best exposed where erosion has taken place; for instance, numerous gravel showings are present in the walls of the entrenched Hillsburgh Meltwater Channel. Two licenced pits (Pit Nos. 151 and 152) in the central portion of the deposit have pit faces ranging between 6 and 20 m with well-stratified, poor to well-sorted sand and gravel consisting of up to 50% gravel, 40% of which exceeds 2.5 cm in diameter. Little quality data is available for this part of the moraine, but Cowan (1976) notes that to the north in Mono Township, siltstone is present in the aggregate and that beneficiation is usually required for high specification uses. Licenced Pit No. 151 is situated in the moraine northwest of Pit No.152. Deike (1976) indicates that this source is developed in the upper sand unit only. Coarse aggregate may be available at greater depths. Licencing reports for a recent expansion of Pit No. 154, located in the south central part of the resource area, indicate an estimated volume of 1.5 million tonnes in a 4.8 ha expansion. The percentage of crushable gravel increases with depth.

The Orangeville Moraine covers a very large area in Erin Township and may contain considerable amounts of aggregate suitable for a variety of uses. Although Cowan (1976) includes the area in a class of deposits where prospecting and development costs are high and the probability of locating economic deposits is low, further detailed investigation, especially in eroded areas on the flanks of the moraine, may identify suitable coarse aggregate resources. Aggregate materials in the moraine contain a considerable amount of siltstone which limits suitability of the aggregate to Granular A, B Type 1 and M uses. Coarser deposits may be beneficiated by special crushing procedures to elevate suitability to hot-mix paving coarse aggregate quality.

In addition, 2 ice-contact stratified drift deposits, located in south-central Erin Township, have been selected as resource areas of secondary significance. Two pits have been opened in the smaller deposit, one of which is presently licenced (Pit No.158). The pits expose approximately 3 to 6 m of variable sand and minor gravel. Similar material may be found in the larger of the 2 resource areas, although subsurface data are lacking. Detailed field checking in this deposit would be required to identify areas suitable for extractive development.

Within Puslinch Township, several aggregate deposits have been selected as sand and gravel resource areas of secondary significance. The first of the outwash deposits is quite thick and extensive and is located south of the Eramosa River, in the northeastern part of the township. Data from water well records and from licenced sand and gravel pits indicate that the deposit is predominantly gravel with a thickness of 6 to 17 m. One licenced sand and gravel pit has been opened in this resource area (Pit No. 175). A 6 to 7 m face exposes poorly sorted, often coarse aggregate consisting of approximately 60 to 70% gravel and 30 to 40% sand. This deposit is currently active and is being expanded. According to Burwasser (1976) the resource area contains large aggregate reserves. The deposit extends through the southern part of the City of Guelph and becomes part of Selected Resource Area 37. Field investigation reveals that the quality of the aggregate in the area selected at the secondary level is much poorer in quality than that in Selected Sand and Gravel Resource Area 37.

Another outwash deposit of secondary significance in Puslinch Township is an outwash plain located along the west side of the Paris Moraine. This deposit is located directly northeast of selected Resource Area 38. Water well information suggests a possible depth of 21 m of gravel, however, quality data are scarce for the deposit.

Within Puslinch Township, a secondary sand and gravel resource area consists of an outwash terrace found in channels that are associated with the Eramosa River complex. This secondary area is located on the northeastern boundary of the township. No subsurface data are available for this deposit and there has been no extractive activity. A property to the north of the township in the same deposit reveals a 5 m face with a gravel content of 50 to 60%. This outwash terrace has been designated as secondary due to the large area lost to cultural setbacks that limit the possible resources required for large-scale commercial production.

A deposit identified at the secondary level of significance in Puslinch Township lies along the northern perimeter of selected Resource Area 39. This selected area is shown on the surficial map (Karrow 1987) as consisting primarily of peat and muck, with some localized surface exposures of ice-contact and outwash gravels. Some licenced pits (Pit Nos. 183, 185 and 187) extend into this area. Examination of water well records indicate up to 21 m of sand and/or gravel below a mixture of peat, muck, clay, and/or stones. While the upper materials may preclude commercial extraction at this time, the rapid depletion of resources in the immediate area may make economic extraction feasible in the future.

A deposit ranked at the secondary level of significance in Puslinch Township consists of 2 glaciolacustrine plain areas situated southwest of Resource Area 39. Water well records indicate possible sand or sand and gravel thicknesses of from 12 to 24 m.

Additional secondary level areas are located west of Puslinch. One area includes a portion of glaciolacustrine sands and outwash gravel. Two unlicenced pits (Pit Nos. 205 and 206) have face heights of 5 to 11 m with 50 to 80% gravel. The second area, situated closer to Puslinch, has been mapped as ice-contact gravel (Karrow 1987). Three unlicenced pits (Pit Nos. 202, 203 and 204) in or immediately adjacent to this area show face heights of 3 to 11 m, with 15 to 80% gravel content.

BEDROCK GEOLOGY

The Paleozoic rocks underlying the glacial drift in the County of Wellington comprise a portion of the eastern rim of the Michigan Basin. In this area the rocks are of Silurian and Devonian age, and consist mainly of limestones and dolostones which contain some shale, gypsum, anhydrite, salt and chert. The rock formations, in general, lie conformably over each other and dip gently toward the southwest. In Puslinch Township, the Silurian Guelph and Amabel Formations dip southwest at 4 to 6 m/km (Morrison Beatty Ltd. 1989). The eastern boundary of the Township of Erin nearly reaches the Niagara Escarpment, however, is far enough away to be outside the Niagara Escarpment Plan Area.

The county is underlain by a series of formations ranging from the youngest Bois Blanc Formation of Middle Devonian age in the west, to subsequently older formations towards the east. These older formations include, in descending stratigraphic order, the Upper Silurian Bass Islands and Salina formations, and the Middle Silurian Guelph and Amabel formations (Chart C). The areal distribution of the bedrock formations are shown on Maps 2A and 2B (Sanford 1969, Ontario Geological Survey 1991).

The bedrock surface is relatively even, but it is interrupted in several places by steep sided valleys which are now filled with glacial drift. Except for local exposures in river valleys and quarries, there are no major outcrops of bedrock within the county. In general, overburden thickness is greater in the northwestern townships. The most bedrock exposures and thinnest overburden occur in the townships of Eramosa, Erin, Guelph and Puslinch and in the City of Guelph.

The Bois Blanc Formation consists of brownish grey, medium-grained, medium- to thin- bedded, cherty limestone. It has been quarried for crushed stone products at several locations in the Niagara Peninsula and is suitable for Granular A, B and M. The high chert content that characterizes the Bois Blanc Formation makes the crushed rock unsuitable for hot-mix asphalt paving and Portland cement concrete coarse and fine aggregates (Hewitt 1960). The formation occurs in the southwestern part of Minto and Maryborough townships (Map 2A). The drift cover over the formation exceeds 15 m except for an area in the central portion of Minto Township. No areas of this formation have been selected for resource protection.

The Bass Islands Formation occurs in a 3 km wide band that trends northwest through the central part of Minto Township and through the western part of Maryborough Township. The formation consists of up to 40 m of brown, microcrystalline dolostone. It is extensively quarried in the Niagara Peninsula and is suitable for the production of crushed aggregate for Granular A, B and M, hot-mix paving and Portland cement concrete coarse and fine aggregates (Hewitt 1960, 1972). Drift cover over the formation is greater than 15 m, except in an area in the central part of Minto Township, southwest of Harriston (Map 2A).

The Salina Formation consists of about 100 m (Telford 1979) of grey to tan, soft shale and dolostone with numerous interbedded evaporitic deposits of salt, anhydrite and gypsum (Liberty and Bolton 1971, Hewitt 1972). In several areas throughout Ontario, salt, anhydrite, and gypsum are mined as an industrial mineral and chemical resource (Hewitt 1960). Gypsum is mined at Hagersville, Caledonia and Drumbo. Salt is mined at Windsor and Goderich. The formation is not suitable for road construction aggregates. This formation occurs in: the northern and eastern part of Minto Township; most of Arthur Township; the central, northern and eastern part of Maryborough Township; most of Peel Township; the western corner of Pilkington; the southwest corner of West Luther and the northwest corner of West Garafraxa townships (Maps 2A and 2B). In all of these areas, the formation is overlain by more than 15 m of overburden. For this reason and because of its lack of suitability for road aggregate uses, no areas underlain by the Salina Formation have been selected for resource protection.

The Guelph Formation underlies parts of West Luther, West Garafraxa, Nichol, Pilkington, Guelph, Puslinch and Eramosa townships, the northeast corner of Arthur Township and the western and central parts of Erin Township (Maps 2A and 2B).

The formation consists mainly of buff coloured, irregular medium- to massive-bedded, fine- to medium-crystalline, sucrosic dolostone (Liberty and Bolton 1971, Telford 1976). Its thickness is about 40 m. Some beds contain abundant fossils which weather irregularly. The dolostone generally has high chemical purity and is a valuable raw material for chemical and metallurgical products (Hewitt 1960). In general, the rock is of reefal origin and therefore, it tends to be soft and weathers easily. In general, it is not well suited for high quality road construction uses, such as hot-mix paving and Portland cement concrete aggregates. In the inter-reefal parts of this formation, however, the rock may be sounder and more resistant to weathering. In such locations, the rock may be acceptable for higher quality aggregate uses.

The Guelph Formation is extracted on a large scale at the Guelph Dolime quarry (Quarry No. 1) for the production of lime (Hewitt 1960, Telford 1976) and also at the Lafarge Canada Inc. quarry (Quarry No. 2) in Puslinch Township. In most areas, the Guelph Formation is overlain by glacial drift greater than 15 m in thickness. Thinner drift cover occurs in: the north central part of West Luther Township; in the southern part of West Garafraxa Township along the Grand River; the valleys of the Grand River, Irvine Creek and Swan Creek in Nichol Township; the central and southern part of Eramosa Township; many parts of Guelph and Puslinch townships; and in the City of Guelph. In the valleys of the Eramosa, Grand and Speed rivers, and the southern part of Puslinch Township, outcrops of this formation occur. In some of these areas, parts of this formation have been selected for resource protection.

Chart C - Bedrock Resources Summary
REGIONAL MUNICIPALITY OF WELLINGTON

FORMATION	ROCK TYPE	APPROXIMATE THICKNESS (m)	SUITABILITY AGGREGATE	OTHER USES	OCCURRENCE	NOTES
Bois Blanc	Limestone, cherty, brownish grey, locally fossiliferous	3-50	Yes (Granular base and subbase only)	-	Southwest part of Minto and west corner of Maryborough townships under more than 8 m of overburden	High chert content makes this formation unacceptable for hot-mix paving and concrete. Chert from this formation is found in gravel in varied amounts
Bass Islands	Dolostone, brown microcrystalline	40	Yes	-	Central part of Minto and west part of Maryborough townships under more than 8 m of overburden	Good quality dolostone, used for high quality aggregates on Niagara Peninsula.
Salina	Shale and dolostone with layers of gypsum, anhydrite and salt	100	No	Gypsum, anhydrite and salt	East part of Minto, most of Arthur, all of Maryborough except west, most of Peel, west corner of Pilkington, southwest corner of West Luther, and northwest corner of West Garafraxa townships under more than 8 m of overburden	Gypsum mined at Hagersville, Caledonia and Drumbo; salt is mined at Windsor and Goderich.
Guelph	Dolostone, fossiliferous, light brown, medium- to massive-bedded	40	No, in most areas; yes in a few areas (best in interreefal areas)	Chemical and metallurgical stone	Most of West Luther, West Garafraxa, Nichol, Pilkington, Guelph, Puslinch and Eramosa townships and northeast corner of Arthur, west and central part of Erin townships	Generally has high chemical purity and locally is very pure. Is used as chemical and metallurgical stone. Generally poor aggregate better in interreefal areas.
Amabel	Dolostone, from very thin to medium bedded brownish grey to greyish black, fine crystalline, bituminous (Eramosa Member) to thick bedded, fossiliferous, white, micro- and fine crystalline	30-35	Yes	Armourstone	East part of Puslinch, east corner of Guelph, south part of Eramosa, south and east part of Erin townships.	High quality, well suited for hot-mix paving and concrete aggregates, a provincially significant resource. Outcroppings and less than 8 m overburden occur at east corner and along Eramosa River in Guelph Township, City of Guelph and Eramosa Township, east corner and east of Town of Erin in Erin Township.

The Amabel Formation underlies the southern part of Eramosa, the eastern part of Puslinch and the eastern part of Erin townships. It forms the hard erosion-resistant cap of the Niagara Escarpment. The formation has been separated into 2 units on the basis of textural differences. The upper level is named the Eramosa Member and consists of very thin- to medium-bedded, brownish grey to greyish black, fine crystalline, bituminous dolostone with some minor sandy layers (Telford 1976, 1979). The thickness of the Eramosa Member in Puslinch Township ranges from 15 to 25 m (Telford 1979). Locally, such as in the southern part of Puslinch Township, this member is suitable for the production of high quality aggregates. The remainder of the Amabel Formation consists of white to blue-grey, fine- to coarse-crystalline, medium- to massive-bedded, fossiliferous dolostone. The formation is approximately 30 to 35 m thick (Telford 1979). The formation is well suited for the production of high quality construction and road aggregates such as hot-mix paving and Portland cement concrete aggregates and is a resource of provincial significance for these uses. Several areas in Puslinch and Erin Townships have been noted for resource protection. In this area 2 quarries, now abandoned, have extracted material from the Amabel Formation. Both quarries expose the lower portion of the Amabel Formation. Additional outcrops of the lower unit of the Amabel Formation are found in the Rockwood Conservation Area west of Rockwood.

In Guelph at the turn of the century, a number of quarries were in operation, producing road construction aggregate, building stone and lime (Parks 1912) but at present, only 2 properties are licenced for quarrying. One of these which has been in operation for many years is Quarry No. Q1. The other quarry (Quarry No. Q2) is licenced both as a gravel pit and as a quarry, but active quarrying of bedrock has not yet occurred. Of the several abandoned quarries in the City of Guelph, only the quarry at the Guelph Correctional Centre remains visible.

SELECTED BEDROCK RESOURCE AREAS

Selected bedrock resource areas in Wellington County consist of those areas in Minto, Nichol, West Luther, Guelph, Puslinch, Eramosa and Erin townships where bedrock of suitable quality for aggregate use is overlain by less than 8 m of glacial sediment.

Selected Bedrock Resource Area 1

In West Luther Township, in the vicinity of the village of Monck, a small portion of the Guelph Formation is covered by less than 8 m of overburden. Recent testing by MTO indicates that the rock is of high quality with potential for hot-mix paving and concrete use. For these reasons, a small area around the village has now been selected for resource protection. This area is located near Highways 9 and 89. The West Luther Marsh Wildlife Management Area and Wildlife Preserve limits its potential.

In mid-1995, a quarry licence application (Henderson, Paddon and Associates Limited. 1993) indicated that the Guelph Formation extends at least 75 m below the overlying soils. MTO test results indicated an 18.4 m section of high quality dolostone overlain by 2 m of overburden.

This newly selected resource area includes approximately 131 ha in total, but at least 31 ha are constrained by cultural setbacks, leaving a maximum total of 100 ha potentially available for extraction. Assuming a depth of 18 m workable thickness, this area could contain up to 49 million tonnes of accessible material (Table 6).

Selected Bedrock Resource Area 2

Selected Bedrock Resource area 2 is located in the central portion of Nichol Township, west of Ennotville. Bedrock resource area 2 consists of the Guelph Formation overlain by less than 8 m of drift. Much of the drift overlying the bedrock consists of Port Stanley Till which should not seriously hinder quarry development in the area. In the remaining portions of the resource area, the bedrock is overlain by the outwash sand and gravel deposits that were selected for possible resource protection. Thus, the potential for the extraction of both sand and gravel for road construction and crushed stone for metallurgical use exists in Selected Bedrock Resource Area 2.

Selected Bedrock Resource Area 2 has a total area of 230 ha. After considering cultural constraints approximately 168 ha are possibly available for extraction. Assuming an average workable thickness of 18 m throughout the available portions, possible bedrock resources are estimated to be 81 million tonnes (Table 6). The resource area is accessible by both Highway 6 and a line of the Canadian National Railway. It is also well situated with respect to local markets.

Selected Bedrock Resource Area 3

Selected Bedrock Resource Area 3 is located near the small community of Marden in Guelph Township. Overburden thickness is less than 8 m and is much less in the eastern part of the resource area. Bedrock resource area 3 is partially overlain by an outwash deposit which has also been selected for resource protection and therefore has a combined natural aggregate and bedrock resource potential.

The Guelph Formation dolostone is generally suitable for lime production because of its high chemical purity although detailed investigation has not been undertaken in this resource area. The area currently available for extraction is estimated to be 354 ha after allowing for cultural setbacks. Assuming a workable thickness of 18 m, possible resources are estimated to be 168 million tonnes (Table 6).

Selected Bedrock Resource Area 4

Selected Bedrock Resource Area 4 is underlain by dolostone of the Guelph Formation. The area is located southwest of the City of Guelph, south of Highways 6 and 24, and extends along the Speed River valley into Puslinch

Township. The resource area forms a part of a larger bedrock resource area that continues to the southwest into the Regional Municipality of Waterloo.

Overburden thickness is less than 8 m and probably less than 5 m in many areas. A few outcrops occur along a small escarpment (Map 2B). Guelph Dolime Limited has operated a quarry at Part Lots 1-5, Concession 5G, Guelph Township and Part Lots 1 and 2, Concession 4G, City of Guelph for a number of years (Hewitt 1960). The quarry face of approximately 13 m represents the total thickness of the Guelph Formation at this location as dolostone of the Eramosa Member (Amabel Formation) is exposed at the base of the section. Part of Selected Bedrock Resource Area 4 is also licenced to Lafarge Canada Inc. for quarry purposes. This resource area lies adjacent to the Glenchristie quarry (Lots 1, 2, and 3, Concession 4, Puslinch Township) which has been operated since the turn of the century. The quarry has produced dolomitic lime, hydrated lime and limestone.

Selected Bedrock Resource Area 4 occupies a total of 740 ha, of which 580 ha are possibly available for extraction. Assuming a total workable thickness of 18 m in this part of the formation, the bedrock resources presently available for extraction are estimated to be 284 million tonnes (Table 6).

Selected Bedrock Resource Area 5

Selected Bedrock Resource Area 5 covers an area of the Amabel Formation that is located at the southern boundary of Eramosa Township and extends into Erin Township. The limit of resource area 6 is defined by the 8 m drift thickness contour. The sediments that overlie the bedrock are ice-contact stratified sand and gravel which have been designated as a selected sand and gravel resource area of primary significance. The combined resource potential of this area makes it attractive for resource protection. Bedrock resource area 5 occupies a total of 1054 ha of which 918 ha are available for extraction. Assuming a workable thickness of 18 m the crushed stone resources possibly available for extraction are 440 million tonnes (Table 6).

Bedrock resource area 5 is well situated with respect to road (Highway 7) and rail transport routes and, for the most part, is sparsely populated. Consequently, it may be well suited for large scale extractive development. Selected Bedrock Resource Area 6 is partially overlain by ice-contact stratified drift deposits, and therefore, has combined natural aggregate and crushed stone resource potential.

Selected Bedrock Resource Area 6

Selected Bedrock Resource Area 6 is situated in the southeast corner of Erin Township and is underlain by the Amabel Formation. The area is extensive and extends into the Town of Caledon to the east and the Town of Halton Hills to the south. Those areas have also been selected for possible resource protection. Bedrock resource area 6 is generally less favourable for development than the areas to the south, but provides a viable alternative if planning or other considerations prevent protection of these latter resources. In Lot 1, Concession 6, test hole drilling indicated 6 to 7 m of sand and gravel which would increase the value of this resource area.

Selected Bedrock Resource Area 6 occupies an area of 1488 ha. No previous extraction has taken place and constraints imposed by land use are minimal. Thus, the area currently available for extraction is estimated to be 1193 ha. Assuming a maximum quarriable thickness of 18 m, total possible resources are approximately 580 million tonnes (Table 6). Access to the area is provided by Highway 7.

Selected Bedrock Resource Area 7

Selected Bedrock Resource Area 7 is underlain by the Guelph Formation. The area is located on the southern boundary of Puslinch Township, near the villages of Crieff and Puslinch and is covered by less than 8 m of overburden (Map 2B). The estimated workable thickness in selected area 7 includes 9 m of the Guelph Formation. Bedrock resource area 7 occupies 620 ha of which 505 ha are available for quarrying. Of this, 120 ha have bedrock outcropping at or near the surface. Assuming a total workable thickness of 9 m, the bedrock reserves potentially available for extraction in the resource area is estimated to be 120 million tonnes (Table 6).

There are no operating quarries in the resource area at the present time, however, there are two abandoned quarries (Q6 and Q7) within the selected area. The area is traversed by a line of the Canadian Pacific Railway and by numerous gravel-surfaced roads.

Selected Bedrock Resource Area 8

Selected Bedrock Resource Area 8 is underlain by the Eramosa Member of the Amabel Formation. The area consists of 2 parts of the Eramosa where drift thickness is less than 8 m. The resource area is located near the hamlet of Puslinch (Map 2B). The resource area consists of 269 ha, of which 210 ha are possibly available for extraction. Assuming a total working thickness of 15 m, the crushed stone resources are estimated to be 84 million tonnes. There are presently no quarries in this resource area, however, the Eramosa dolostone in this part of the township is acceptable for the production of high-quality aggregate. Bedrock resource area 8 is well situated with respect to road and rail transportation. The resource area is located on either side of Highway 6 and is traversed by gravel-surfaced roads and a line of the Canadian Pacific Railway.

Selected Bedrock Resource Area 9

Selected Bedrock Resource Area 9 is underlain by the Amabel Formation and is located on the southeast corner of Puslinch Township in the vicinity of Mountsberg and extends both north and south of Highway 401. The resource area has a cover of less than 8 m of overburden (Map 2B). Selected Bedrock Resource Area 9 consists of 152 ha, of which 129 ha are possibly available for extraction. Assuming a total working thickness of 18 m in this part of the

formation, the crushed stone resources presently available for extraction are estimated to be 62 million tonnes (Table 6). Stone from the Amabel Formation is suitable for a wide range of road-building products as well as high-specification concrete and asphalt aggregate. Bedrock resource area 9 is traversed by Highway 401 and by gravel-surfaced roads.

SUMMARY

Sand and gravel deposits within Wellington County provide a major source of aggregates for the county and for other markets especially the western part of the Greater Toronto Area (GTA). The best quality sand and gravel is generally found in the larger glacial outwash areas associated with the Speed River, the Galt and Paris moraines and related meltwater channels. The better materials, especially those in Puslinch Township, are suitable for high quality uses such as hot-mix asphalt, and coarse and fine aggregates for concrete usage.

In other areas of the county, especially in parts of the northwestern townships of Minto, Maryborough and Peel, high chert content (20%+), limits the range of uses to varying degrees, depending on the location. In those areas, the sand and gravel is used primarily for Granular A, B Type 1 and M for road construction. Siltstone content in the northern and eastern part of Erin Township also limits the range of uses to Granular A, B Type 1 and M unless the gravels are beneficiated by special processing.

The Paleozoic bedrock underlying the glacial drift in Wellington County are of Silurian and Devonian age, and consist mainly of limestones and dolostones. The main bedrock formations of economic importance include the Amabel, and Guelph formations.

Currently quarrying of the Guelph Formation and Eramosa Member of the Amabel Formation occurs within the study area. Quarrying restrictions and depletion of available bedrock in the Niagara Escarpment Plan Area coupled with increased demand for quarried rock for highway construction and high strength concrete is placing increased demand on bedrock resources.

Within Wellington County 10 373 ha containing 1095 million tonnes of possible sand and gravel resources have been selected at the primary level of significance and 5 145 ha of bedrock containing possible resources of 1868 million tonnes have been selected for possible resource protection. Only limited constraints such as residential and industrial development have been taken into consideration. It should be noted that there are many other possible restrictions such as social considerations and transportation difficulties which may also restrict the availability of resources. Nevertheless the inventory provides an overview of possible resources which should be considered in the context of the regional and provincial need for aggregates.

Enquiries regarding the Aggregate Resources Inventory of Wellington County should be directed to the Sedimentary Geoscience Section, Ontario Geological Survey, Mines and Minerals Division, Ontario Ministry of Northern Development and Mines, 7th Floor, 933 Ramsey Lake Road, Sudbury, Ontario P3E 6B5 [Tel: (705) 670-5758], or the Cambridge Area Office, Ontario Ministry of Natural Resources, Cambridge, Ontario [Tel: (519) 658-9355] .

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES WELLINGTON COUNTY			
1 CLASS NO.	**2 DEPOSIT TYPE**	**3 AREAL EXTENT (Hectares)**	**4 ORIGINAL TONNAGE (Million Tonnes)***
MINTO TOWNSHIP			
1	G-OW	74	8
2	G-E	500	39
	G-IC	4100	300
	S-IC	40	4
	G-OW	2060	151
	S-OW	910	76
3	G-E	16	<1
	G-IC	196	9
	S-IC	148	6
	G-OW	520	24
	S-OW	2270	102
4	G-IC	44	1
	G-OW	28	<1
	S-OW	101	2
Subtotal		11007	724
ARTHUR TOWNSHIP			
1	G-E	340	42
2	G-E	32	3
	G-IC	740	54
	G-OW	445	33
	S-OW	510	37
3	G-E	61	2
	G-IC	188	8
	S-IC	600	20
	G-OW	305	10
4	G-E	26	1
	G-IC	69	2
	S-IC	67	2
	G-OW	320	5
	S-OW	740	13
Subtotal		4443	232
WEST LUTHER TOWNSHIP			
1	G-E	28	4
	G-IC	57	6
2	G-E	247	22
	G-IC	123	11
	S-OW	101	5
3	G-E	16	1
	G-IC	400	18
	S-IC	184	8
	G-OW	37	2
	S-OW	760	25
4	S-OW	71	2
Subtotal		2024	104
MARYBOROUGH TOWNSHIP			
1	G-OW	46	6
	S-OW	6	1
2	G-E	91	8

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES WELLINGTON COUNTY			
1 CLASS NO.	**2 DEPOSIT TYPE**	**3 AREAL EXTENT (Hectares)**	**4 ORIGINAL TONNAGE (Million Tonnes)***
	G-IC	101	6
	G-OW	18	1
	S-OW	8	1
3	G-E	73	4
	G-OW	77	3
	S-OW	134	4
4	G-E	73	2
	G-IC	73	2
	S-IC	4	<1
	G-OW	89	2
	S-OW	295	5
Subtotal		1088	46
PEEL TOWNSHIP			
2	G-IC	152	13
	S-IC	12	1
	G-OW	24	2
3	G-E	12	1
	G-IC	107	4
	G-OW	46	2
	S-OW	162	5
4	G-IC	20	<1
	S-IC	61	2
	G-OW	61	1
	S-OW	206	4
Subtotal		863	36
PILKINGTON TOWNSHIP			
1	G-IC	202	23
	S-IC	89	10
2	G-E	49	4
	G-IC	223	16
	G-OW	2270	190
3	G-E	67	3
	G-IC	415	21
	G-OW	89	4
4	G-E	4	<1
	G-IC	243	5
	S-IC	24	1
	G-OW	61	2
	S-OW	1050	24
Subtotal		4786	304
NICHOL TOWNSHIP			
1	G-IC	73	14
	G-OW	34	6
2	G-E	12	1
	G-OW	275	19
3	G-E	16	1
	G-IC	4	<1
	G-OW	310	11
	S-OW	990	29

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES WELLINGTON COUNTY			
1 CLASS NO.	**2 DEPOSIT TYPE**	**3 AREAL EXTENT (Hectares)**	**4 ORIGINAL TONNAGE (Million Tonnes)***
4	G-IC	34	1
	G-OW	44	1
	S-OW	174	3
Subtotal		1966	87
WEST GARAFRAXA TOWNSHIP			
1	G-OW	400	45
	S-IC	1150	130
2	G-OW	660	55
	G-IC	345	33
	G-E	8	1
	G-K	132	11
	S-OW	32	3
3	G-IC	260	10
	S-IC	63	3
	S-OW	2140	96
4	G-OW	22	1
	S-OW	69	2
	S-IC	6	<1
Subtotal		5287	391
CITY OF GUELPH AND GUELPH TOWNSHIP			
1	G-OW	1780	199
	G-E	134	15
	G-K	29	4
2	G-OW	5600	470
	G-E	26	3
	G-K	490	41
3	G-OW	162	6
	G-E	33	1
	G-K	202	8
4	G-OW	267	7
	G-E	44	1
	G-K	101	3
	S-OW	1880	53
Subtotal		10748	811
ERAMOSA TOWNSHIP			
1	G-IC	1000	163
	S-IC	6	1
	G-OW	235	26
2	G-E	69	5
	G-IC	1000	84
	G-OW	1130	102
	S-OW	21	2
3	G-E	75	4
	G-IC	610	27
	G-OW	1270	57
	S-OW	40	1
4	G-IC	375	8
	S-IC	40	1
	G-OW	630	14

TABLE 1 - TOTAL SAND AND GRAVEL RESOURCES
WELLINGTON COUNTY

1 CLASS NO.	2 DEPOSIT TYPE	3 AREAL EXTENT (Hectares)	4 ORIGINAL TONNAGE (Million Tonnes)*
	S-OW	1210	27
Subtotal		7711	522
ERIN TOWNSHIP			
1	G-IC	850	119
	S-IC	5140	721
	G-OW	1295	181
2	G-IC	670	56
	S-IC	630	53
	G-OW	1100	90
3	G-IC	275	14
	G-OW	710	36
4	G-IC	267	6
	S-IC	83	2
	G-OW	445	10
	S-OW	2390	54
Subtotal		13855	1342
PUSLINCH TOWNSHIP			
1	G-E	20	2
	G-IC	1070	163
	G-K	8	1
	G-OW	3950	680
2	G-E	49	4
	G-IC	710	64
	G-OW	510	54
	S-OW	12	1
3	G-IC	490	27
	G-OW	132	7
4	G-E	30	1
	G-IC	355	10
	S-IC	138	4
	G-K	10	<1
	S-K	16	<1
	S-LP	121	4
	G-OW	375	11
	S-OW	550	15
Subtotal		8546	1050
COUNTY TOTAL		72303	4671

Minor variations in 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 WELLINGTON COUNTY					
Pit No.	**Owner/Operator**	**Licenced Area (Hectares)**	**Face Height (Metres)***	**% Gravel**	**Remarks**
MINTO TOWNSHIP					
Licenced Pits					
1	Harry Bouwman	17.90	3-6	45	Below water extraction
2	Dr. Terry Fisk	4.08	5-6	20-50	
3	Township of Minto	9.74	5	50	
4	The Murray Group Limited	18.06	-	-	Not yet opened
5	The Murray Group Limited	40.50	5-8	70	Below water extraction
6	The Murray Group Limited	58.70	8-10	-	
7	The Murray Group Limited	47.00	3-12	35-60	Below water extraction
8	Marsha Elaine Boulton	20.24	5-7	50	
9	Jeff and Susan Small	1.50	3-8	20-30	
10	Matt Seifried	13.20	5-6	60-70	Overlain by sand
11	Donegan's Haulage Limited	80.97	2-3	35	
12	Everett and John Armstrong c/o Carl D'Arcey	39.90	3-5	55-60	
13	Reint Wassink	12.70	3-6	50	
14	Percy Gedcke	14.00	5-6	50	
15	Kenneth James Littlewood	37.40	5-6	45-50	
16	Alex Connell	12.80	2-6	50-60	
17	Township of Wallace	40.49	2-5	50-60	
Unlicenced Pits					
18	-	-	2	0-80	Sand and gravel
19	-	-	TH3.3	60-85	Mainly gravel,unopened, reforested
20	-	-	3	55-75	Mainly gravel
21	-	-	TH3.3	60-85	Mainly gravel, unopened, reforested
22	-	-	TH3.3	40-80	Mainly gravel, unopened
23	-	-	2-4	45-75	Mainly gravel
24	-	-	TH3.3	25-85	Mainly gravel, unopened
25	-	-	5	40	Overgrown
26	-	-	TH3.3	75-80	Mainly gravel, unopened
27	-	-	2-3	5-35	Mainly sand
28	-	-	2-3	35	Mainly sand
29	-	-	3	35-80	Mainly gravel
30	-	-	3-5	10-15	Mainly fine sand
31	-	-	2-3	10-20	Mainly sand, overgrown
32	-	-	3-7	60-70	Mainly gravel
ARTHUR TOWNSHIP					
Licenced Pits					
33	Laverne Martin	1.90	8-10	-	
34	Joe Kerr Limited	6.08	9-15	70-80	
35	Harold J. Whetham	6.32	5-8	70-80	
36	Andrew Tarc	3.00	5-8	-	
37	Raymond & April Halbert	12.96	9-15	50-75	
38	Reeves Construction Ltd.	7.49	3-8	40	Future below water extraction
39	Reeves Construction Ltd.	9.92	5-6	40-55	
40	861467 Ontario Inc.	21.06	6-14	25-65	Below water extraction

TABLE 2 - SAND AND GRAVEL PITS
WELLINGTON COUNTY

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)*	% Gravel	Remarks
41	Township of Arthur	26.16	5-6	40-50	
42	North Wellington Sanitary Landfill	2.02	5-6	40-50	
43	Township of Arthur	6.20	8-10	40-50	
44	Murray Wilson Equipment Inc.	9.92	3	40-50	Below water extraction
45	Cox Construction Limited	8.52	3	70	
Unlicenced Pits					
46	-	-	8-9	25-30	Mainly sand, heavy clay, overburden
47	-	-	3-4	10-20	Sand only
48	-	-	8	40-50	No open pit, thick overburden
49	-	-	3-4	45	Partly overgrown, crushable with sand control
50	-	-	8-9	60	Crushable
51	-	-	2	45	Mainly sand
52	-	-	4	40-50	Depleted above water, dragline required
53	-	-	2-3	45-50	Extraction by dragline.
WEST LUTHER TOWNSHIP					
Licenced Pits					
54	Danny and Donna Clark	14.78	5-6	20-80	
Unlicenced Pits					
55	-	-	3-6	50-60	Mainly gravel
56	-	-	6	55	Rehabilitated, mainly gravel
57	-	-	6	35-50	Sand and gravel
58	-	-	3-12	55-75	Mainly gravel
59	-	-	2	-	Bush covered
60	-	-	-	-	Bush covered, unopened
61	-	-	2	50-80	Mainly gravel
62	-	-	2-11	40-80	Mainly gravel
63	-	-	8	20-80	Overgrown, mainly gravel
MARYBOROUGH TOWNSHIP					
Licenced Pits					
64	Arthur Crushed Stone Inc.	16.61	3-5	35	
65	Kenneth & Bertha Kidnie	26.73	8-12	35	
66	David Wooddisse	19.85	3-4	20	Licence cancelled
67	Gordon Elliott	15.20	3-10	35-40	
68	Willis Sand and Gravel	32.70	5-15	40	
Unlicenced Pits					
69	-	-	3-9	35	
70	-	-	2-6	30	Overgrown, partially rehabilitated
71	-	-	3-5	25-50	
72	-	-	3	60-70	Depleted
73	-	-	8	-	Material below water
74	-	-	3	40	Small, overgrown, mainly sand

TABLE 2 - SAND AND GRAVEL PITS
WELLINGTON COUNTY

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)*	% Gravel	Remarks
PEEL TOWNSHIP					
Licenced Pits					
75	Mildred Lunz	22.47	2-4	50	
76	David Bender	3.24	2-5	-	Primarily sand, partially rehabilitated
77	Edwin Horst	5.06	4	40	
78	Wallenstein Sand & Gravel	45.28	-	-	Recently opened
Unlicenced Pits					
79	-	-	7.5-9	-	Mainly sand
80	-	-	-	35	Unopened, mainly sand
81	-	-	6	40	Depleted
82	-	-	5	25	
83	-	-	5	40	Overgrown
84	-	-	3	50-75	
PILKINGTON TOWNSHIP					
Licenced Pits					
85	Mann Construction Limited	40.10	8-10	50-60	
86	Sand Hill Estates Ltd. (Operated as Ronald Seiling Trucking)	27.14	8-9	50-60	Below water extraction
87	Mann Construction Limited	29.30	8	30-70	Sandy
88	Five Star Swine Ltd. c/o E. Martin	24.95	6-8	40-50	
89	The Murray Group Limited	10.13	5	25-40	Sandy
90	Nancy Watson	27.14	8-9	50	Asphalt plant on site
91	Nancy Watson	10.83	8	50	
92	Dadboys Enterprises Limited (Kurtz)	25.10	4-5	30-50	
93	Mann Construction Limited	40.30	3-5	40-50	
Unlicenced Pits					
94	-	-	6	30-60	Mainly gravel
95	-	-	3	35	Mainly sand, overgrown
96	-	-	3	40-50	Depleted
97	-	-	3-8	60-70	Mainly gravel
98	-	-	5	55-75	Mainly gravel
NICHOL TOWNSHIP					
Licenced Pits					
			NONE		
Unlicenced Pits					
99	-	-	2-3	35	Depleted, gravel content variable
100	-	-	1.5-2.5	65	Gravel under lumber yard
101	-	-	4	50	Reforested
102	-	-	3	35	Sandy gravel

TABLE 2 - SAND AND GRAVEL PITS
WELLINGTON COUNTY

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)*	% Gravel	Remarks
WEST GARAFRAXA TOWNSHIP					
Licenced Pits					
103	Highland Pines Campground (1987) Limited	10.13	3-6	30-70	
104	John Eisen Limited	10.10	2-5	35-55	
Unlicenced Pits					
105	-	-	2-8	75-80	Rehabilitated
106	-	-	3-5	10	Sand only
107	-	-	2	75	Part is trailer park
108	-	-	1-9	45-75	Mainly gravel
109	-	-	2-5	60-65	Depleted, under housing
110	-	-	3-8	25	Some material below water, rehabilitated
111	-	-	3-6	20	Rehabilitated
112	-	-	2	65	Overgrown
GUELPH TOWNSHIP AND THE CITY OF GUELPH					
Licenced Pits					
113	James Thoume Construction Ltd.	16.69	3-5	30-60	
114	Carolyn A. Stradiotto	22.28	6	40-50	
115	Lafarge Canada Inc	140.29			Both a pit and quarry operation
Unlicenced Pits					
116	-	-	4	45	
117	-	-	4	25	
118	-	-	3	45	
119	-	-	5	70	Depleted, processing plant on site
120	-	-	TH4.5	25-60	Mainly sand
121	-	-	-	-	
122	-	-	3	65	Gravel
123	-	-	TH3.5-4	45-80	Mainly Gravel
124	-	-	3	20	Rehabilitated
125	-	-	4	20	
126	-	-	TH4.5-6	55-70	Gravel
127	-	-	3	55-70	Gravel
128	-	-	TH3.5	75-85	Gravel
ERAMOSA TOWNSHIP					
Licenced Pits					
129	Carolina F. Holman	20.25	2-3	30	
130	Henry A. Holman	20.25	2-6	30-35	
131	Cox Farms Ltd.	19.36	-	-	
132	Giuseppe Bernardi	66.02	3-5	35-60	variable
133	William D. McVety	16.20	3-5	30	Primarily sand, below water extraction
134	Sterling Packers Limited	4.94	3-5	-	Partially rehabilitated, gravelly
135	Sterling Packers Limited	11.75	3	-	Partially rehabilitated
136	George W. Leslie and Marion Shirley Leslie	10.50	5-8	30	Expansion application

TABLE 2 - SAND AND GRAVEL PITS
WELLINGTON COUNTY

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)*	% Gravel	Remarks
Unlicenced Pits					
137	-	-	2-3	35	Mainly sand
138	-	-	5-6	30-60	Rehabilitated
139	-	-	3-6	35-70	Some crushable material
140	-	-	3	20-50	Mainly sand
141	-	-	3-5	40-50	Some crushable material
142	-	-	4	35-40	Sandy gravel
143	-	-	4	40	
144	-	-	2-3	50-80	Gravel
145	-	-	3-5	50-60	Gravel
146	-	-	3-5	40-80	Mainly gravel
147	-	-	3	0-50	Variable from sand to crushable material
148	-	-	-	-	
149	-	-	3-5	-	Rehabilitated
150	-	-	5	60-75	Gravel
ERIN TOWNSHIP					
Licenced Pits					
151	J.C. Duff	52.60	6-8	20	Expansion
152	647495 Ontario Limited	44.96	12-15	50	
153	Mann Construction Limited	13.00	3	50	Below water extraction, future fish farm
154	Christian E. Dehn	9.64	2-5	25	Sandy
155	Harry Lockyer	41.51	12	30-50	
156	James Dick Construction Ltd.	136.40	5	-	Below water extraction
157	Mulmur Aggregates Inc. (Cox)	22.28	4-5	65	Below water extraction
158	Mulmur Aggregates Inc.	8.10	3-6	30-75	
159	Dufferin Aggregates	102.06	5	50	Recently opened
Unlicenced Pits					
160	-	-	TH4-5	10-70	Unopened, mainly sand
161	-	-	TH3.5-4.5	10-50	Unopened, mainly sand
162	-	-	8	30	Sandy gravel
163	-	-	TH3.1-4.5	45-85	Unopened, gravel rich
164	-	-	TH2.2-4.6	55-85	Unopened, gravel rich
165	-	-	TH4-4.5	75-80	Unopened, gravel
166	-	-	TH4.5	10-80	Unopened, mainly gravel
167	-	-	TH3-4.5	30-65	Unopened, mainly gravel
168	-	-	4	35-60	Crushable gravel
169	-	-	TH 2.5-5	10-80	Unopened, gravel
170	-	-	3	5	Sand only
171	-	-	-	70	Gravel
PUSLINCH TOWNSHIP					
Licenced Pits					
172	Cox Construction Limited	32.48	5-6	60-70	
173	Lafarge Canada Inc.	140.29	6	35-60	Partially rehabilitated

TABLE 2 - SAND AND GRAVEL PITS
WELLINGTON COUNTY

Pit No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)*	% Gravel	Remarks
174	Fred Prior and Sons Ltd.	6.57	9	50	Licence cancelled, partially rehabilitated.
175	McKenzie Brothers (Guelph) Limited	14.57	6-7	60-70	Good quality stone, adjacent application to expand
176	Preston Sand & Gravel Company Ltd.	35.64	6-7	60-70	
177	Guelph Dolime Limited	78.98	18-25		Pit and quarry, below water extraction
178	Preston Sand & Gravel Company Ltd.				
179	Cox Construction Limited	6.32	6	65-80	Good stone, below water extraction
180	Cox Construction Limited	141.45	6	50	Main site, future below water extraction
181	Preston Sand & Gravel Company Ltd.	17.30	5-7	65-80	
182	Capital Paving Inc.	40.50	5-6	50-60	Below water extraction
183	Capital Paving Inc.	28.85	5-6		Below water extraction
184	TCG Materials Limited	7.03	7-8	65-80	Extension to main pit.
185	TCG Materials Limited	32.40	5-6	10-35	Below water extraction, sandy
186	TCG Materials Limited	8.10	8	60-70	
187	Dufferin Aggregates	73.50	16	40-60	Below water extraction, processing site
188	Dufferin Aggregates	79.30	5-7	60-70	Future below water extraction
189	TCG Materials Limited	56.30	6	70-75	Below water extraction
190	TCG Materials Limited	115.70	8	60-70	Below water extraction
191	TCG Materials Limited	42.40	6-7		Below water extraction
192	University of Guelph	188.60	3		Recently opened, below water extraction.
Unlicenced Pits					
193	-	-	17	50-85	Mainly gravel
194	-	-	TH2.5-4.5	0-75	Unopened, sand and gravel
195	-	-	TH4.4-6	60-70	Unopened gravel
196	-	-	TH4-5	30-75	Unopened, mainly gravel
197	-	-	3-5	60-80	Gravel, rehabilitated, extraction below water
198	-	-	5	75	Gravel
199	-	-	TH3-4.5	45-85	Unopened, gravel
200	-	-	TH2.8-4.5	70-85	Gravel
201	-	-	1-5	10-60	Mainly sand
202	-	-	5-9	15-70	Partially rehabilitated
203	-	-	5	5-80	Partially rehabilitated
204	-	-	3	10-60	Partially rehabilitated
205	-	-	6-11	50-80	Mainly gravel
206	-	-	6	50-70	Gravel

*** TH indicates the thickness of material noted within a test hole**

TABLE 3 - SELECTED SAND AND GRAVEL RESOURCE AREAS, WELLINGTON COUNTY

1 DEPOSIT NO.	2 UNLICENCED AREA (Hectares)*	3 CULTURAL SETBACKS (Hectares)**	4 EXTRACTED AREA (Hectares)***	5 POSSIBLE RESOURCE AREA (Hectares)	6 ESTIMATED DEPOSIT THICKNESS (Metres)	7 POSSIBLE AGGREGATE RESOURCES (Million Tonnes)****
MINTO TOWNSHIP						
1	311	22		289	5	25.6
2	716	173		543	4	38.4
3	89	19		70	5	6.2
4	640	106		534	5	47.3
5	855	198		657	5	58.1
6	43	21		22	7	2.7
7	141	37		104	4	7.4
Subtotal	2795	576		2219		185.7
ARTHUR TOWNSHIP						
8	343	49		294	7	36.4
9	168	39		129	10	22.8
13	54	10		44	5	3.9
Subtotal	565	98		467		63.1
WEST LUTHER TOWNSHIP						
10	150	32		118	5	10.4
11	47	5		42	5	3.7
12	71	22		49	5	4.3
Subtotal	268	59		209		18.4
MARYBOROUGH TOWNSHIP						
14	57	8	1	48	4	3.4
15	28	9		19	9	3.0
Subtotal	85	17	1	67		6.4
PEEL TOWNSHIP						
16	29	7		22	4	1.6
17	39	10		29	3	1.6
Subtotal	68	17		51		3.2
PILKINGTON TOWNSHIP						
18	145	19		126	8	17.8
19	52	8	8	36	7	4.5
20	440	69		371	4	26.3
21	440	104		336	5	29.7
Subtotal	1077	200	8	869		78.3
NICHOL TOWNSHIP						
22	74	11		63	11	12.3
Subtotal	74	11		63		12.3
WEST GARAFRAXA TOWNSHIP						
23	399	91		308	7	38.2
24	179	26		153	4	10.8

TABLE 3 - SELECTED SAND AND GRAVEL RESOURCE AREAS, WELLINGTON COUNTY

1 DEPOSIT NO.	2 UNLICENCED AREA (Hectares)*	3 CULTURAL SETBACKS (Hectares)**	4 EXTRACTED AREA (Hectares)***	5 POSSIBLE RESOURCE AREA (Hectares)	6 ESTIMATED DEPOSIT THICKNESS (Metres)	7 POSSIBLE AGGREGATE RESOURCES (Million Tonnes)****
25	284	51		233	5	20.6
26	321	23		298	5	26.4
Subtotal	1183	191		992		96.0
ERAMOSA TOWNSHIP						
27	152	21		131	4	9.3
28	263	56		207	5	18.3
29	589	122		467	4	33.0
30	56	12		44	4	3.1
31	901	12		889	7	110.1
Subtotal	1961	223		1738		173.8
ERIN TOWNSHIP						
32	195	48	3	144	5	12.7
33	296	59		237	8	33.6
34	638	202		436	9	69.5
Subtotal	1129	309	3	817		115.8
GUELPH TOWNSHIP AND CITY OF GUELPH						
35	598	170		428	5	37.9
36	211	90		121	5	10.7
37A	237	89	2	148	6	13.1
Subtotal	1046	349	2	697		61.7
PUSLINCH TOWNSHIP						
37B	136	58	2	76	6	8.1
38	846	253	30	563	6	59.8
39	793	144	4	645	6	68.5
40	1004	95	9	900	9	143.4
Subtotal	2779	550	43	2184		279.8
TOTAL	13030	2600	57	10373		1094.5

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

* Does not include areas licenced under the Aggregate Resources Act

** Cultural setbacks include heavily populated urban areas, roads (including a 100 m wide strip centered 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 areas.

*** 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 IDENTIFIED BEDROCK RESOURCES, WELLINGTON COUNTY

1 DRIFT THICKNESS (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS (Metres)	4 AREAL EXTENT (Hectares)	5 ORIGINAL TONNAGE (Million Tonnes)*
MINTO TOWNSHIP				
8-15	Bois Blanc	18	1300	630
8-15	Bass Islands	18	1580	760
1-8	Salina	18	71	31
8-15	Salina	18	3850	1650
Subtotal			6801	3071
ARTHUR TOWNSHIP				
8-15	Salina	18	270	132
8-15	Guelph	18	1000	490
Subtotal			1270	622
WEST LUTHER TOWNSHIP				
1-8	Guelph	18	19	9
8-15	Guelph	18	1780	860
Subtotal			1799	869
MARYBOROUGH TOWNSHIP		- NONE -		
PEEL TOWNSHIP		- NONE -		
PILKINGTON TOWNSHIP				
<1	Guelph	18	28	14
1-8	Guelph	18	265	127
8-15	Guelph	18	1170	570
Subtotal			1463	711
NICHOL TOWNSHIP				
<1	Guelph	18	4	2
1-8	Guelph	18	520	255
8-15	Guelph	18	2950	1430
Subtotal			3474	1687
WEST GARAFRAXA TOWNSHIP				
1-8	Guelph	18	121	59
8-15	Guelph	18	202	98
Subtotal			323	157
CITY OF GUELPH AND GUELPH TOWNSHIP				
<1	Guelph	15	93	37
1-8	Guelph	15	2390	960
8-15	Guelph	15	10300	4150
<1	Amabel (Eramosa Member)	15	93	37
1-8	Amabel (Eramosa Member)	15	700	280

TABLE 4 - TOTAL IDENTIFIED BEDROCK RESOURCES, WELLINGTON COUNTY

1 DRIFT THICKNESS (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS (Metres)	4 AREAL EXTENT (Hectares)	5 ORIGINAL TONNAGE (Million Tonnes)*
8-15	Amabel (Eramosa Member)	15	240	98
Subtotal			13816	5562
ERAMOSA TOWNSHIP				
1-8	Guelph	18	1150	560
8-15	Guelph	18	3250	1570
<1	Amabel (Eramosa Member)	15	71	29
1-8	Amabel (Eramosa Member)	15	1170	470
8-15	Amabel (Eramosa Member)	15	620	250
<1	Amabel	18	46	23
1-8	Amabel	18	1150	560
8-15	Amabel	18	1000	480
Subtotal			8457	3942
ERIN TOWNSHIP				
<1	Guelph	18	8	4
1-8	Guelph	18	128	62
8-15	Guelph	18	1295	627
<1	Amabel	18	6	3
1-8	Amabel	18	1960	951
8-15	Amabel	18	2670	1294
Subtotal			6067	2941
PUSLINCH TOWNSHIP				
<1	Guelph	18	240	115
1-8	Guelph	18	1000	480
8-15	Guelph	18	940	455
<1	Amabel (Eramosa Member)	15	16	6
1-8	Amabel (Eramosa Member)	15	700	285
8-15	Amabel (Eramosa Member)	15	1520	620
1-8	Amabel	18	158	76
8-15	Amabel	18	126	61
Subtotal			4700	2098
COUNTY TOTAL			48170	21193

* Minor variations in above table are due to rounding of data.

TABLE 5 - QUARRIES, WELLINGTON COUNTY

Quarry No.	Owner/Operator	Licenced Area (Hectares)	Face Height (Metres)	Remarks
GUELPH TOWNSHIP				
Licenced Quarries				
Q1	Guelph Dolime Limited	52.6	13	
Q2	Lafarge	132.7		
PUSLINCH TOWNSHIP				
Licenced Quarries				
Q3	Guelph Dolime Limited	78.9	18	
Q4	Lafarge	60.0	-	
Unlicenced Quarries				
Q6	Abandoned		3 above groundwater	nearly water filled
Q7	Abandoned		9-14 above groundwater	nearly water filled
CITY OF GUELPH				
Unlicenced Quarries				
Q5	Abandoned		9	
ERAMOSA TOWNSHIP				
Unlicenced Quarries				
Q8	Abandoned			

TABLE 6 - SELECTED BEDROCK RESOURCE AREAS, WELLINGTON COUNTY

1 AREA NO.	2 DEPTH OF OVERBURDEN (Metres)	3 UNLICENCED 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)****
MINTO TOWNSHIP							
				NONE			
ARTHUR TOWNSHIP							
				NONE			
WEST LUTHER TOWNSHIP							
Guelph Formation							
1	1-8	131	31	0	100	18	49
Subtotal		131	31	0	100		49
MARYBOROUGH TOWNSHIP							
				NONE			
PEEL TOWNSHIP							
				NONE			
PILKINGTON TOWNSHIP							
				NONE			
NICHOL TOWNSHIP							
Guelph Formation							
2	1-8	230	62	0	168	18	81
Subtotal		230	62	0	168		81
WEST GARAFRAXA TOWNSHIP							
				NONE			
CITY OF GUELPH AND GUELPH TOWNSHIP							
Guelph Formation							
3	1-8	461	107	0	354	18	168
4	1-8	740	160	0	580	18	284
Subtotal		1201	267	0	934		452
ERAMOSA TOWNSHIP							
5	1-8	1054	136	0	918	18	440
Subtotal		1054	136	0	918		440
ERIN TOWNSHIP							
6	1-8	1488	295	0	1193	18	580
Subtotal		1488	295	0	1193		580
PUSLINCH TOWNSHIP							
7	0-8	620	111	4	505	9	120
8	1-8	269	59	0	210	15	84

TABLE 6 - SELECTED BEDROCK RESOURCE AREAS, WELLINGTON COUNTY

1 AREA NO.	2 DEPTH OF OVERBURDEN (Metres)	3 UNLICENCED 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)****
9	1-8	152	23	0	129	18	62
Subtotal		1041	193	4	844		266
COUNTY TOTAL		5145	984	4	4157		1868

N.B. Minor variations in above table are due to rounding of data.

* Excludes areas licenced under the Aggregate Resources Act.

** Cultural setbacks include heavily populated urban areas, road (including a 100 m wide strip centered on each road), 1 ha for individual houses. NOTE: this provides a preliminary and generalized constraint application only. Additional environmental and social constraints will further reduce the bedrock resource area.

*** Extracted area is a rough estimate of areas that are not licenced but largely depleted such as abandoned quarry sites.

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

TABLE 7 - SUMMARY OF TEST HOLE DATA, WELLINGTON COUNTY

TEST HOLE NUMBER	LOCATION	ELEVATION (masl)	DEPTH (Metres)	DESCRIPTION
PEEL TOWNSHIP				
PE-TH-1	NW of Pit No. 75	373.0	0 - 0.4	Topsoil
			0.4 - 0.8	Brown sandy silt, minor clay
			0.8 - 4.1	Brown cobbly sandy gravel, 30-60% greater than 150 mm in size
			4.1 - 4.9	Brown silt, trace clay and sand, moist
ERAMOSA TOWNSHIP				
ER-TH-1	Lot 1, Conc. 6		0-1.0	Light brown, sandy, gravelly loam
			1.0-6.0	Light brownish grey, coarse to medium silty gravel, coarse and fine sand, some small boulders
			6.0-10.0	Light brown, gravelly, silty sand till, 30-40% coarse and medium sand, 30% fine sand and silt, occasional boulders
			10.0-29.0	Light to medium blue-grey, coarse and medium porosity, very fossiliferous dolostone, prominent coral fragments and shell moulds at 22 m, Amabel Formation
				Initial groundwater level at 12 m.
			29.0 - 45.0	Medium to light grey, coarse reefy porosity leading to fine porosity, fine to medium crystalline dolostone, Amabel Formation
			45.0 - 56.0	Light to medium bluish grey, fine crystalline, fine porosity, thin dark grey shale seams between beds, very fossiliferous dolostone, Amabel Formation
			56.0 - 58.0	Medium grey to medium greenish grey, frequent bundles of dark grey, irregular, shale seams, containing grains and thin seams of pyrite, Reynales Formation
			58.0 - 60.0	Green to medium greenish grey and dark grey interbedded shale and calcareous shale, Cabot Head Formation

TABLE 8 - SUMMARY OF GEOPHYSICAL DATA, WELLINGTON COUNTY

- NONE -

TABLE 9 - AGGREGATE QUALITY TEST DATA, WELLINGTON COUNTY

PIT NO. AND SAMPLE NO.	PETROGRAPHIC NUMBER		SHALE (%)	CHERT/CHERTY CARBONATES CONTENT (%)		SILTSTONE CONTENT (%)
	Granular 16mm crushed	Hot Mix and Concrete		Unleached	Leached	
MARYBOROUGH TOWNSHIP						
Pit No. 68 95-ZLK-1006	101.8	208	0.2	53.1	0	0
PEEL TOWNSHIP						
Pit No. 75 95-ZLK-1005	100.0	130.6	0	15.3	0	0
PILKINGTON TOWNSHIP						
Pit No. 97 95-ZLK-1004	103.6	119.8	0.4	8.1	0	0
ERIN TOWNSHIP						
Pit No. 162 95-ZLK-1007	109.0	128.5	0	3.0	0	4.5

NOTE: The quality test data refers strictly to a specific sample. Because of the inherent variability of sand and gravel deposits, care should be exercised in extrapolating such information to the rest of the deposit.

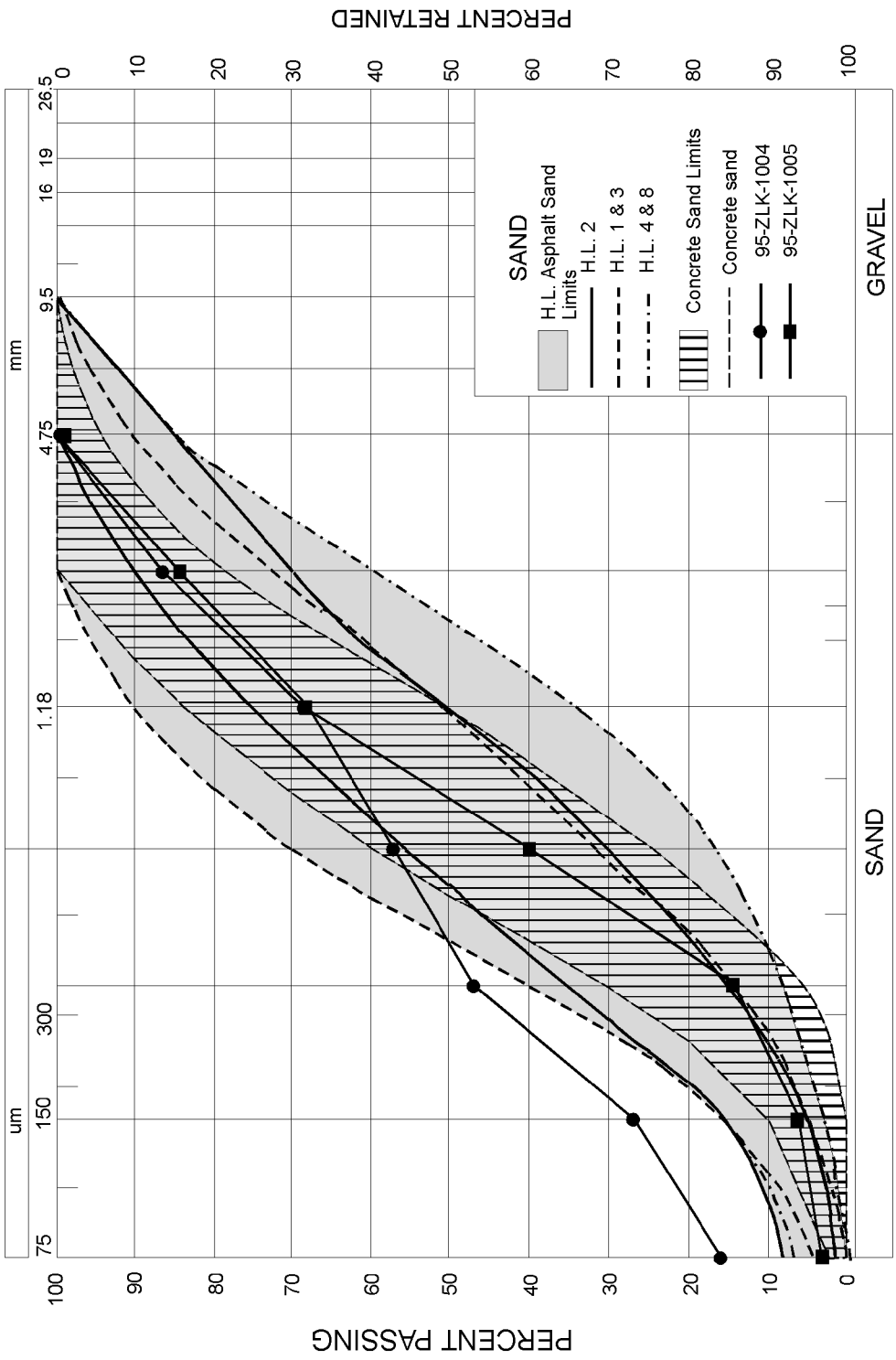


FIGURE 2a AGGREGATE GRADING CURVES, WELLINGTON COUNTY

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.

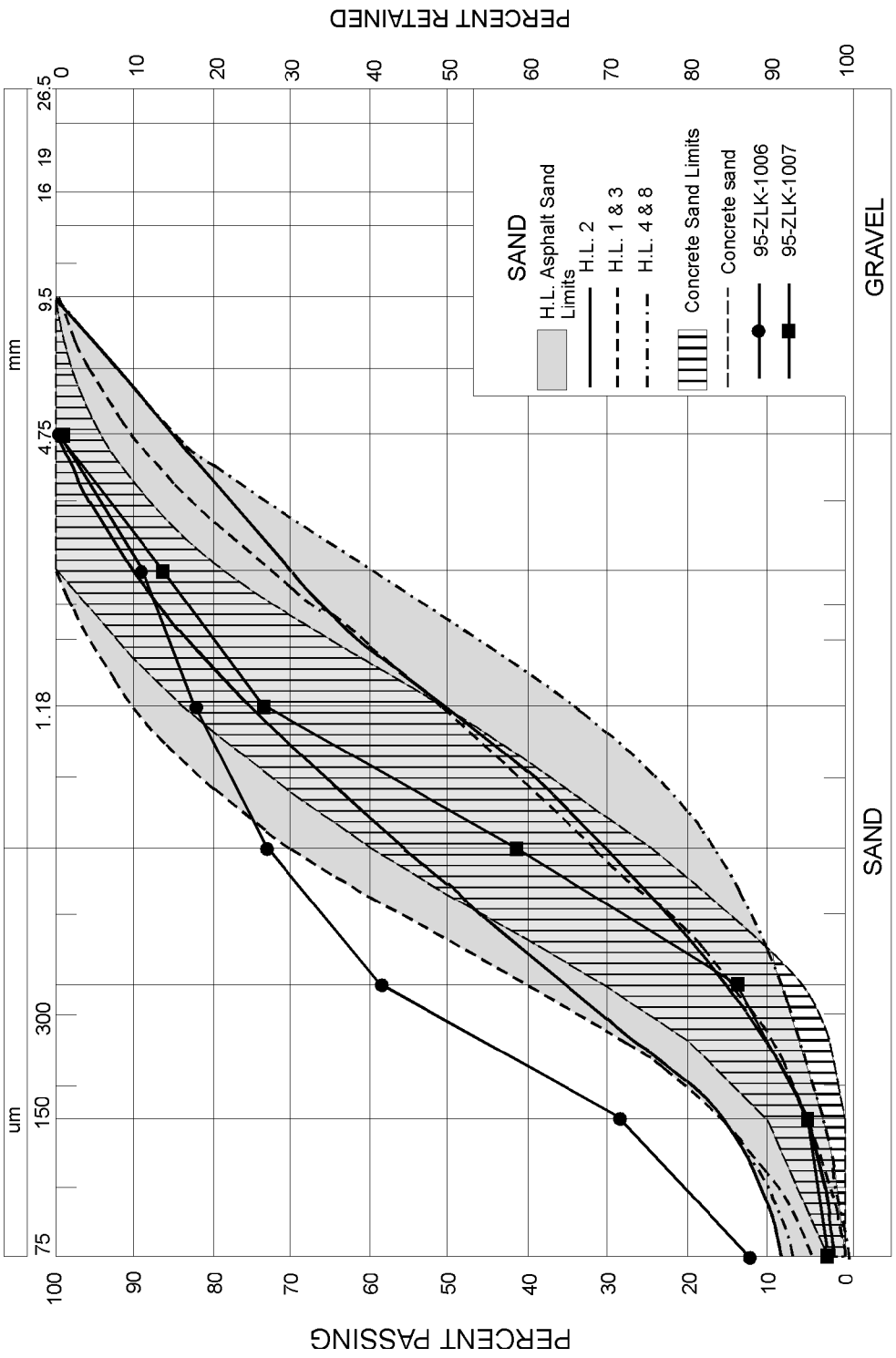


FIGURE 3a AGGREGATE GRADING CURVES, WELLINGTON COUNTY

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 4ºC 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 ag-

gregate. 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 sand-

stone 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.

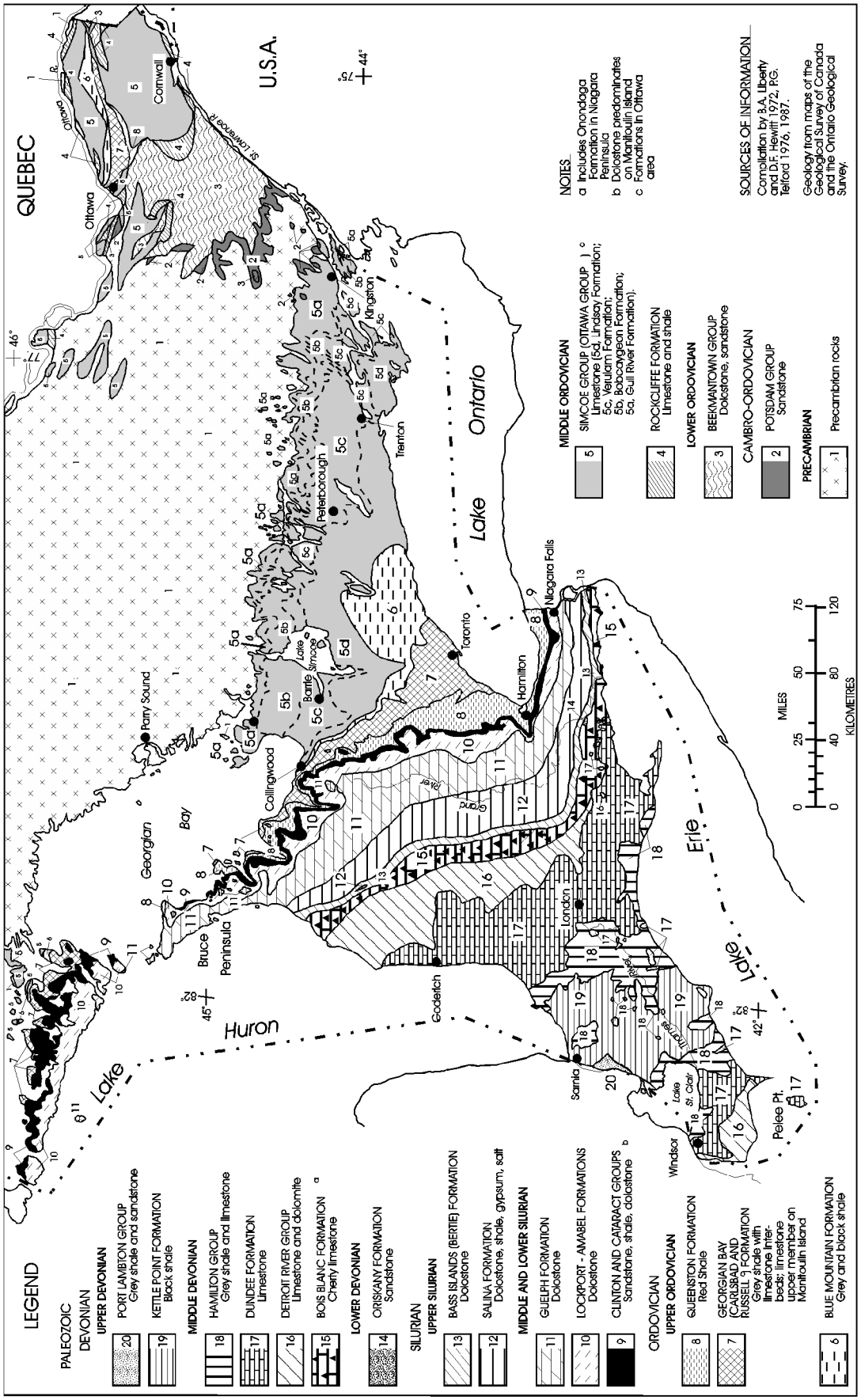

Figure D1. Bedrock geology of southern Ontario.

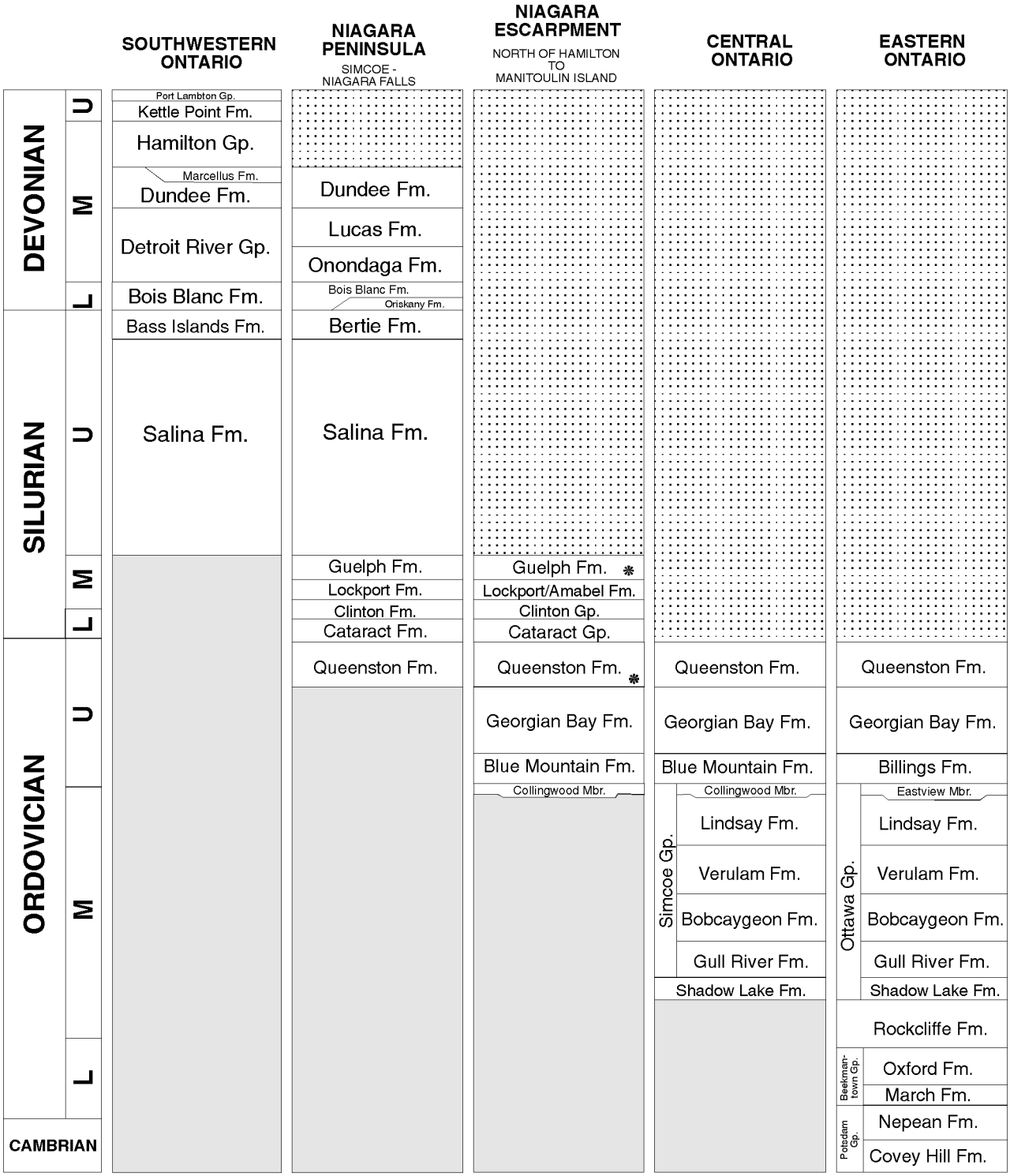

Figure D2. Exposed Paleozoic stratigraphic sequences in southern Ontario (*adapted from*: Bezys, R.K. and Johnson, M.D. 1988. The geology of the Paleozoic formations utilized by the limestone industry of Ontario; The Can. Mining and Metallurgical Bulletin,v.81, no. 912, p.49-58.)

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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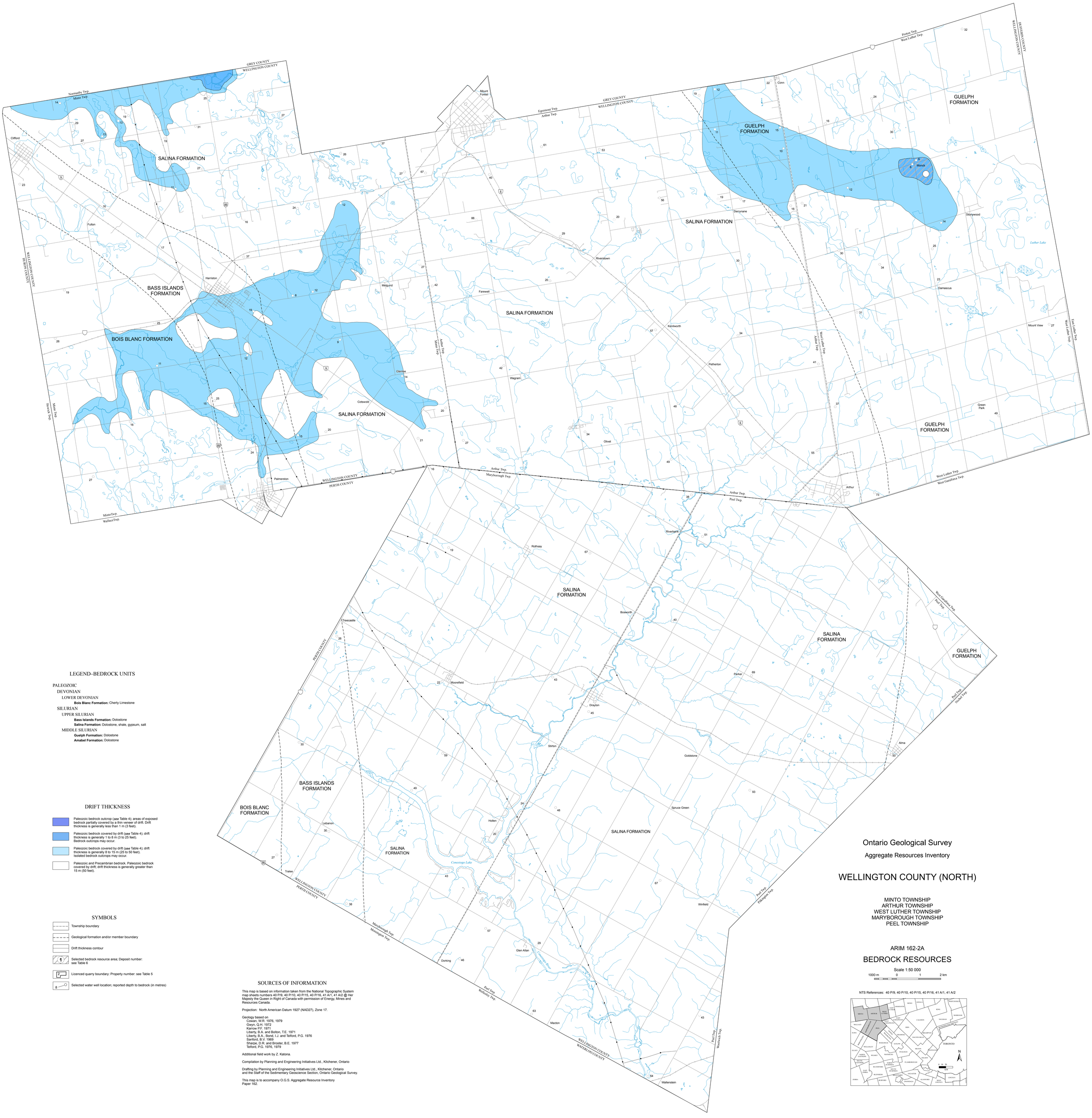


LEGEND–BEDROCK UNITS

PALEOZOIC
- DEVONIAN
  - LOWER DEVONIAN
    - **Bois Blanc Formation:** Cherty Limestone
- SILURIAN
  - UPPER SILURIAN
    - **Bass Islands Formation:** Dolostone
    - **Salina Formation:** Dolostone, shale, gypsum, salt
  - MIDDLE SILURIAN
    - **Guelph Formation:** Dolostone
    - **Amabel Formation:** Dolostone

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 and Precambrian bedrock. Paleozoic bedrock covered by drift; drift thickness is generally greater than 15 m (50 feet).

SYMBOLS

- Township boundary
- Geological formation and/or member boundary
- Drift thickness contour
- 1 — Selected bedrock resource area; Deposit number: see Table 6
- 2 — Licenced quarry boundary: Property number: see Table 5
- 8 — Selected water well location; reported depth to bedrock (in metres)

SOURCES OF INFORMATION

This map is based on information taken from the National Topographic System map sheets numbers 40 P/9, 40 P/10, 40 P/15, 40 P/16, 41 A/1, 41 A/2 @ Her Majesty the Queen in Right of Canada with permission of Energy, Mines and Resources Canada.

Projection: North American Datum 1927 (NAD27), Zone 17.

Geology based on
- Cowan, W.R. 1976, 1979
- Gwyn, Q.H. 1972
- Karrow P.F. 1971
- Liberty, B.A. and Bolton, T.E. 1971
- Liberty, B.A., Bond, I.J. and Telford, P.G. 1976
- Sanford, B.V. 1969
- Sharpe, D.R. and Broster, B.E. 1977
- Telford, P.G. 1976, 1979

Additional field work by Z. Katona.

Compilation by Planning and Engineering Initiatives Ltd., Kitchener, Ontario

Drafting by Planning and Engineering Initiatives Ltd., Kitchener, Ontario and the Staff of the Sedimentary Geoscience Section, Ontario Geological Survey.

This map is to accompany O.G.S. Aggregate Resource Inventory Paper 162.

Ontario Geological Survey

Aggregate Resources Inventory

WELLINGTON COUNTY (NORTH)

MINTO TOWNSHIP
ARTHUR TOWNSHIP
WEST LUTHER TOWNSHIP
MARYBOROUGH TOWNSHIP
PEEL TOWNSHIP

ARIM 162-2A

BEDROCK RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS References: 40 P/9, 40 P/10, 40 P/15, 40 P/16, 41 A/1, 41 A/2

Ontario Geological Survey

Aggregate Resources Inventory

WELLINGTON COUNTY (SOUTH)

PILKINGTON TOWNSHIP
NICHOLS TOWNSHIP
WEST GARAFRAXA TOWNSHIP
GUELPH TOWNSHIP
ERAMOSA TOWNSHIP
ERIN TOWNSHIP
PUSLINCH TOWNSHIP
CITY OF GUELPH

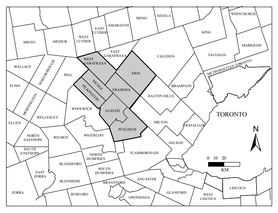
ARIM 162-2B

BEDROCK RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS References: 30 M/12, 40 P/7, 40 P/8, 40 P/9, 40 P/10



SYMBOLS

- Township boundary
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- 1 — Selected bedrock resource area; Deposit number: see Table 6
- 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
- 8 — Selected water well location; reported depth to bedrock (in metres)

LEGEND–BEDROCK UNITS

PALEOZOIC
- DEVONIAN
  - LOWER DEVONIAN
    - **Bois Blanc Formation:** Cherty Limestone
- SILURIAN
  - UPPER SILURIAN
    - **Bass Islands Formation:** Dolostone
    - **Salina Formation:** Dolostone, shale, gypsum, salt
  - MIDDLE SILURIAN
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    - **Amabel Formation:** Dolostone

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- 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 and Precambrian bedrock. Paleozoic bedrock covered by drift; drift thickness is generally greater than 15 m (50 feet).

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Projection: North American Datum 1927 (NAD27), Zone 17.

Geology based on

Cowan, W.R. 1976, 1979
Hewitt, D.F. 1969
Karrow P.F. 1968, 1971
Liberty, B.A., Bond, I.J. and Telford, P.G. 1976
Sanford, B.V. 1969
Telford, P.G. 1976, 1979

Additional field work by Z. Katona.

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This map is to accompany O.G.S. Aggregate Resource Inventory Paper 162.

LEGEND

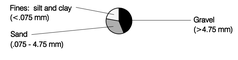
(Some map units and symbols may not apply to this map)

- 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

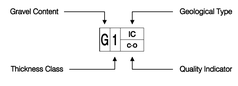
- Township boundary
- Project area boundary
- Park, reserve boundary
- Geological and aggregate thickness boundary of sand and gravel deposits
- Buried geological and aggregate thickness boundary of sand and gravel deposits
- Licenced property boundary: Property number: see Table 2
- Unlicenced sand or gravel pit*. Property number: see Table 2 *Abandoned pit or wayside pit operating on demand under authority of a permit
- Test hole location; Identification number; see Table 7
- Selected sample site: Identification number
- 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, Slt - silt)
- Moraine
- Texture symbol; see below
- Deposit symbol; see below

TEXTURE SYMBOL



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



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

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Geology based on:
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W.R. Cowan, 1976,1979.
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Additional field work by: Z. Katona.

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This map is to accompany O.G.S. Aggregate Resource Inventory Paper 162.

Ontario

Ontario Geological Survey

Aggregate Resources Inventory

WELLINGTON COUNTY (NORTH)

MINTO TOWNSHIP
ARTHUR TOWNSHIP
WEST LUTHER TOWNSHIP
MARYBOROUGH TOWNSHIP
PEEL TOWNSHIP

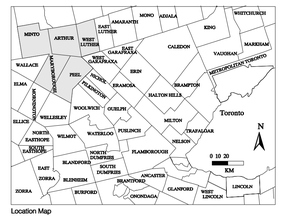
ARIM 162-1A

SAND AND GRAVEL RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 30 M/12, 40 P/B, 40 P/9, 40 P/10 40 P/15, 40 P/16, 41 A/1, 41 A/2



Location Map

Ontario

Ontario Geological Survey

Aggregate Resources Inventory

WELLINGTON COUNTY (SOUTH)

PILKINGTON TOWNSHIP
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WEST GARAFRAXA TOWNSHIP
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ERAMOSA TOWNSHIP
ERIN TOWNSHIP
PUSLINCH TOWNSHIP
CITY OF GUELPH

ARIM 162-1B

SAND AND GRAVEL RESOURCES

Scale 1:50 000

1000 m 0 1 2 km

NTS Reference: 30 M/12, 30 M/13, 40 P/8, 40 P/9, 40 P/10, 40 P/15, 40 P/16, 41 A/2

LEGEND

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- Selected sand and gravel resource area, secondary significance.
- Sand and gravel deposit, tertiary significance.
- Other surficial deposits or exposed bedrock.

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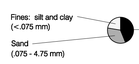
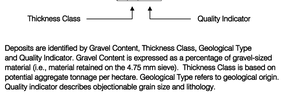
- Project area boundary
- Park, reserve boundary
- Geological and aggregate thickness boundary of sand and gravel deposits
- Buried geological and aggregate thickness boundary of sand and gravel deposits
- 2 — Licenced property boundary: Property number: see Table 2
- 3 — Unlicenced sand or gravel pit*. Property number: see Table 2 *Abandoned pit or wayside pit operating on demand under authority of a permit
- BL-TH-16 — Test hole location; Identification number; see Table 7
- EW-SS-1 — Selected sample site: Identification number
- 8 46S — 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



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



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 30 M/12, 40 P/7, 40 P/8, 40 P/9, 40 P/10 @Her Majesty the Queen in Right of Canada with permission of Energy, Mines and Resources Canada.

Geology based on:
B.V. Sanford, 1969.
W.R. Cowan, 1976,1979.
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T.E. Bolton, 1971.
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P.F. Karrow, 1968,1971.

Additional field work by: Z. Katona, 1995.

Compilation by: Planning & Engineering Initiatives Ltd., Kitchener, Ontario.

Drafting by: Planning & Engineering Initiatives Ltd., Kitchener, Ontario.

This map is to accompany O.G.S. Aggregate Resource Inventory Paper 162.