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Open File Report 5811

Aggregate Resources Inventory of the Moosonee Area

By

Staff of the Engineering and Terrain Geology Section

1991

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V.G. Milne, Director
Ontario Geological Survey

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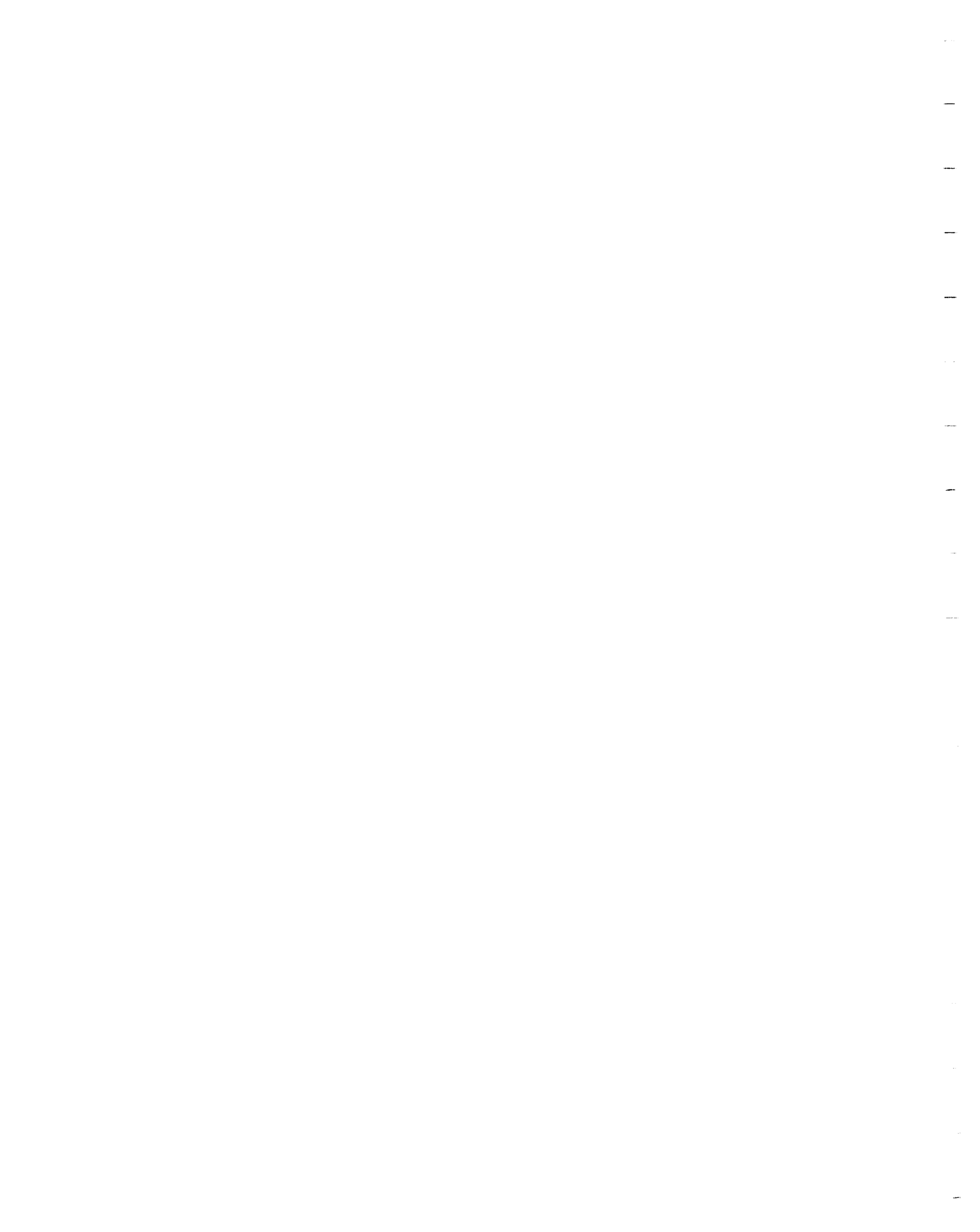
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ABSTRACT

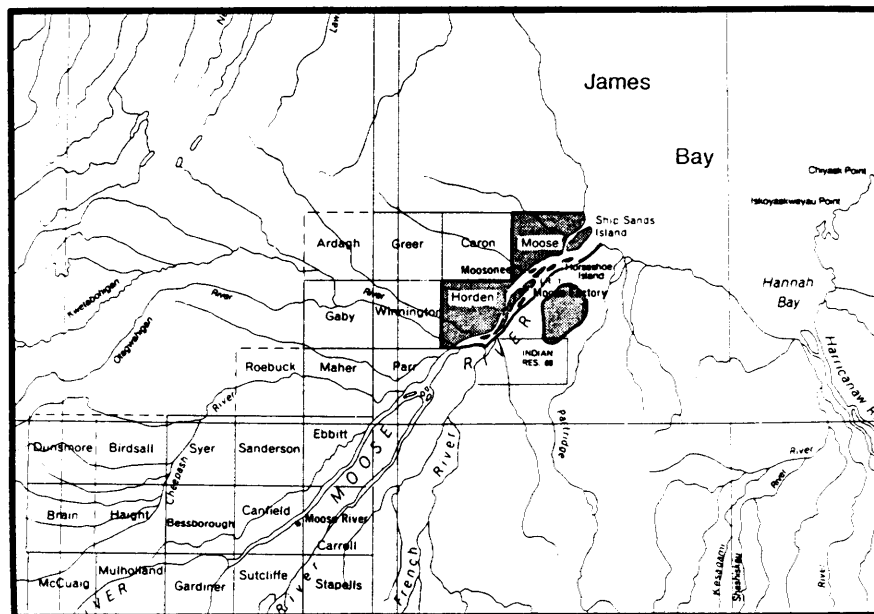


Figure 1. Key map showing the location of the Moosonee area, scale 1:1 584 000.

This report includes an inventory and evaluation of sand and gravel as well as bedrock resources for the Moosonee area, northeastern Ontario. The report is based on detailed field assessment undertaken during the summer of 1990. The investigation was conducted in order to determine the quality and quantity of the sand and gravel and bedrock resources for use in both road-building and general construction applications. This information is required for the evaluation of aggregate resources development potential and for land use planning decisions.

In the project area, two areas containing locally significant amounts of sand and gravel have been selected as resource areas of primary significance. Selected Resource Areas 1 and 2 consist of beach deposits related to the ancient Tyrrell Sea. These Selected Sand and Gravel Resource Areas occupy approximately 2700 ha. Previous extraction reduces the area currently available for extraction to 2650 ha, containing possible sand and gravel

resources of approximately 72.8 million tonnes. In addition, numerous river bar deposits have been selected at the secondary level of significance. These river bar deposits provide alternate sites for extractive development and may add significantly to the resource base of the report area.

The sand and gravel in the study area is generally of good quality and well suited for many road-building and general construction uses. The material varies from sandy aggregate, suitable for road subbase, to coarse gravel, suitable for crushing. The main sources of crushable gravel are the beach deposits located within the Rabbit Ridge area. The abundance of sand in sections of these deposits has necessitated the use of selective extraction and sand control measures during crushing operations. There are also large tracts of land within Moose and Horden geographic townships which contain little or no aggregate resources. Consequently, it may be necessary to transport aggregate lengthy distances

to supply construction requirements in certain areas.

The surficial deposits of this area are underlain by Devonian limestone and dolostone strata of the Stopping River and Kwataboahegan formations. The Kwataboahegan Formation is considered the most acceptable for potential extractive development and the limestone is generally suitable for a wide range of crushed stone products. Two areas have been selected for possible bedrock re-

source protection within the report area. Possible resources in the two Selected Bedrock Resource Areas are 295 million tonnes.

Selected Resource Areas are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection.



**Aggregate Resources Inventory of the
Moosonee Area
Northern Ontario**

By Staff¹ of the Engineering and Terrain Geology Section

1. Field work and report by R.G. Gorman and D.K. Armstrong; compilation and drafting by Staff of the Aggregate Assessment Office. Assistance with field checking and review of this report was provided by the Moosonee District Office of the Ministry of Natural Resources.

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INTRODUCTION

During the summer of 1990, the sand and gravel as well as bedrock resources of the Moosonee area, northeastern Ontario, were investigated by a two-person field party. The field party consisted of a staff member of each of the Aggregate Assessment Office and the Paleozoic/Mesozoic Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey. Although the results of this work would normally be released in an Aggregate Resources Inventory Paper, the Open File Report format is used here in order to make this information available as quickly as possible. The purpose and methodology used to prepare this report are essentially the same as those used for an Aggregate Resources Inventory Paper, and are presented in Appendix A. The format in which the information is presented on the maps is explained on the map legends and in the appendixes.

This project was noteworthy in the degree to which the various components of government, the operators and the communities co-operated and supported this study. The authors would like to acknowledge the following organizations who supported this project: Moose Band Development Corporation, Moosonee Development Area Board, James Bay Travel Ltd., Ontario Northland Railway, M.J. Labelle Co. Ltd., Ontario Ministry of Natural Resources and Ontario Ministry of Transportation.

The ancient raised beach deposits are important potential sources of sand and gravel within the report area. Particularly notable are the raised beach deposits located at Rabbit Ridge. The Selected Sand and Gravel Resource Areas discussed later in the text include the deposits which are considered the best suited for extractive development. A wide range of aggregate products can be produced from these deposits and their continued availability as sources of aggregate is important. It is essential that planning strategies recognize the value of these areas in land-use plans.

Crushed bedrock is an alternative source of aggregate in the study area. The limestone of the Kwatabohegan Formation is hard, resistant to weathering and is being extracted for a variety of aggregate products.

LOCATION AND ACCESS

The report area occupies approximately 47 000 ha in the District of Cochrane. The study area is covered by the Moosonee (42 P/7), Ship Sands Island (42 P/8), Bushy Island (42 P/2) and Thyret Lake (42 P/1) map sheets of the National Topographic System, at a scale of 1:50 000. The report area encompasses Moose and Horden geographic townships and the Rabbit Ridge (Askaskwayau Ridge) area, which is unsurveyed. The islands and bars located in the Moose River between the mouth of the Kwatabohegan River and James Bay were also included in this study.

Population centres in the report area include the communities of Moosonee (population of 1800) and Moose Factory (population of 2000) (Moose Development Area Board 1991). Both communities serve as commercial, industrial and institutional centres on a regional level. Moosonee not only serves as the centre for provincial governmental services, but acts as the resupply point for the surrounding area and the staging point to supply coastal communities further to the north. Moose Factory, located on Moose Factory Island, is the oldest community settlement in Ontario. The Moose Factory General Hospital is located here and serves the health care requirements of the people of the Hudson Bay Lowland in Ontario. Factory Island Indian Reserve 1 and part of Moose Factory Indian Reserve 68 are located within the report area.

Rail access to the report area is provided by a main line of the Ontario Northland Railway that terminates at Moosonee. The Polar Bear Express and Little Bear train use this track during the summer months and all year round, respectively. Summer road access is generally restricted to a grid network on Moose Factory Island and within the community of Moosonee. A gravel-sur-

faced road runs parallel to the Moose River in Horden geographic township and links the Labelle quarry to the community of Moosonee. During the summer months freighter canoes provide passenger services between Moosonee and Moose Factory Island. The Ontario Northland Transportation Commission provides a barge service for bulk freight transportation between Moosonee and Moose Factory. During the winter months, traffic between Moosonee and Moose Factory Island is served by an ice road. A winter road provides a transportation route across frozen muskeg from Moosonee to the more northerly coastal settlements of Fort Albany, Kashechewan and Attawapiskat. This route is passable by tractor train which is effective in moving large quantities of supplies and heavy equipment. The Moosonee Airport, the only commercial airfield in the report area, enables another transport route to the area. Float-equipped aircraft provides additional air access to the area. During fall freeze-up and spring break-up, helicopters are used to transport passengers across the Moose River.

There are several features which help to attract people north to the Moosonee area. Visitor attractions in the area include a variety of museums, churches, Native handicraft and cultural, educational and interpretive centres. The old Hudson's Bay Post and the historic Hudson's Bay Company Staff House are located on Moose Factory Island. Tidewater Provincial Park (approximately 900 ha), which consists of four islands in the Moose River, is a Natural Environment Park. Kwetabohigan River Provincial Park Candidate occupies approximately 94 ha and is located in the southwestern part of the report area. The Ministry of Natural Resources has proposed this park to meet specific targets for recreation, tourism, protection and heritage appreciation. Ship Sands Island, located at the mouth of the Moose River, is a Federal Waterfowl Sanctuary that is a natural attraction to both birdwatchers and naturalists. In the autumn, many sportsmen are attracted to the area for world-famous goose hunting.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The report area is located within the Hudson Bay Lowland physiographic region (Bostock 1969). The Lowland is a flat-lying, featureless, swampy plain that slopes gradually towards James Bay at an average gradient of 1 m/1.5 km (Ontario Ministry of the Environment 1978). The study area generally consists of a mosaic of different wetland types including fens, bogs and marshes. Extensive peatlands overlie much of the area. Stunted black spruce is the dominant tree cover, with the best growth along stream, creek and river levees. Dense stands of white spruce, balsam fir and balsam poplar also exist in well-drained areas. This area is part of one of the largest wetlands in the world.

Glacial deposits in the study area are related to the last major advance and melting of a continental ice sheet during the Wisconsin stage of the Pleistocene Epoch (informally known as the "Great Ice Age"). Reconnaissance level geological studies by Lee (1968), Craig (1969), McDonald (1969), Skinner (1973), Martini et al. (1980), Shilts (1986) and Prest (1990) cover all or parts of the study area. An aggregate resource assessment in the area of Moose Factory Island was prepared by Marshall, Macklin and Monaghan Limited (1986).

Within the project area, a discontinuous cover of till was deposited by ice that advanced in a southwesterly direction during the most recent deglaciation (Prest 1990). Exposures of this stony, silty sand till are generally scarce. Where found, the till exists as a thin veneer over bedrock. Till is usually not well suited for aggregate use because it often contains excess fines and abundant oversize clasts. Till may, however, be a suitable source of fill in some localities.

Once free of the Pleistocene glacial ice, the Hudson Bay Lowland was inundated by marine waters (Skinner 1973; Martini et al. 1980). This sea, known as the Tyrrell Sea, covered the report area approximately 8000 years BP (Lee

1960, 1968; Skinner 1973). In the deeper waters of this sea, horizontally bedded clay and silt were deposited. Thick sections of this glaciomarine clay and silt underlie most of the report area, except for local bedrock highs. During the recession of the Tyrrell Sea, prominent sand and gravel beach ridges were formed. These beach deposits are considered to be important sand and gravel resources. Particularly notable in the study area are the raised beach deposits located at Rabbit Ridge which generally consist of fine to coarse gravel interstratified with medium to coarse sand. These deposits represent the most significant aggregate resources within the study area.

Postglacial depositional and erosional processes have been of some importance in changing the land surface of the project area. Since deglaciation, the land surface of the report area has been subjected to active isostatic rebound. The ground surface is still rising at a rate of 70 to 120 centimetres per century (Barnett 1966; Webber et al. 1970; Martini et al. 1980).

Tides along the James Bay coastline are of the semi-diurnal form and range from 2 to 3 m in height at the mouth of the Moose River (Environment Canada 1977). Tides affect the Moose River as far south as the mouth of the North French River (B. Hunter, Ministry of Natural Resources, personal communication, 1990). Extensive, low-lying, featureless tidal flat deposits, consisting primarily of fine-grained sediments, occur near the mouth of the Moose River. Ship Sands Island is an example of one such tidal flat deposit.

Numerous river bars and islands occur in the Moose River between the mouth of the Kwetabohigan River and James Bay. These river bars have been deposited by the Moose River as it progressively incised the glaciomarine clay and silt plain. Due to rebound of the land surface, the older river bars have been stranded above the present river water elevation and are locally found capping islands or riverbanks. Thin accumulations of ice-rafted coarse gravel commonly occur on many of the

bars and islands. Some of the more recently formed river bars located between Moosonee and Moose Factory Island have been traditional suppliers of silty, sandy aggregate. The shape and size of many of the recent river bars are constantly changing because of the Moose River's ongoing deposition and erosion of materials. The thickness of these recent river bars tends to be greater than that of the older river bars because of this addition of material by the Moose River. The recent river bars located in the Moose River are more attractive as aggregate sources than the older river bars for the following reasons: 1) the accumulation of sand and gravel is greater, 2) there is less overburden, 3) there is less established vegetation, and 4) they are closer to the market, Moosonee.

EXTRACTIVE ACTIVITY

Nine sand and gravel pits and two quarries are present in the Moosonee area. During field investigations, the pits were observed at various stages of development since they are worked on a demand basis. One of the pits had been worked recently but several sites had been inactive for a considerable period of time. The discovery of other aggregate deposits, identified during field investigation, may lead to further pit development within the report area. The location of the sand and gravel pits and quarries are plotted on the maps which accompany this report, and are described in Tables 2 and 4.

In general, the sand and gravel resources in Moose and Horden geographic townships are considered to be limited. The Rabbit Ridge area, however, contains locally significant deposits of sand and gravel. The material extracted from these deposits has been used for a wide range of aggregate products including, with appropriate processing, crushed gravel. The extraction of aggregate from these deposits only occurs during the winter because access to pit sites in the summer is restricted by the surrounding swampy terrain.

Although numerous river bars are located in the Moose River, extractive activity has been concentrated on those that have been recently formed and are located between Moosonee and Moose Factory Island. Fine to coarse sand and fine gravel is dredged from these bars during winter months.

Two quarries have been opened in the report area in response to a lack of crushable gravel in Moose and Horden geographic townships. These quarries operate mainly on a demand basis during the winter months to produce a wide range of crushed stone products.

Currently, stone and sand for high specification concrete are imported by rail from Cochrane, to supply ready-mix operations in Moosonee.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates the deposits which contain granular material within the Moosonee area. These deposits occupy a total of approximately 4700 ha and contain an original resource tonnage of 120.3 million tonnes. Many of the deposits have limited potential for extraction because of the restricted amount of resources available for extraction, predominance of silt, fine sand, and/or poor accessibility. Consequently, only the most significant resources have been suggested for possible resource protection.

The sand and gravel deposits selected for possible resource protection in the study area are shown on Map 2. Nine beach deposits related to the Tyrrell Sea have been selected as sand and gravel resource areas of primary significance. The beach material is generally well suited for extractive activity. The deposits consist predominantly of subangular, fine to coarse gravel interstratified with medium to coarse sand. Varying amounts of fines were noted in some pit sections. These primary resource areas occupy a total area of 2700 ha. Previous extraction reduces the area currently available for extraction to 2650 ha, containing possible sand and gravel resources of approximately 72.8 million tonnes.

Selective extraction measures are recommended to avoid sections containing abundant clay, silt and/or very fine sand lenses.

Many river bar deposits have also been selected at the secondary level of significance. These deposits provide alternate sites for extractive development and may add significantly to the resource base of the report area.

The deposits selected at the primary and secondary levels of significance are generally thinner than selected deposits in many other areas of Ontario. Average thicknesses of the selected deposits in this project area generally range from 1.5 to 2 m. Bedrock and/or the water table are likely to be encountered within 2 m of the surface at many locations in the selected deposits. The presence of bedrock close to the surface limits the depth of sand and gravel extraction in parts of the selected areas.

Information used in order to determine the significance level of a sand and gravel deposit include observations on geological origin, topographic expression and subsurface materials as well as sample analysis. Pits, roadcut exposures, riverbank exposures and river bar exposures constitute the main sources of subsurface information in the report area. Because of the remote location of many of the deposits, subsurface investigation was usually restricted to manual procedures of soil augering and test pitting, to a depth of 1 m, using a mattock and shovel. As detailed information is usually unavailable at greater depths, resource estimates for the selected deposits should not be treated as proven resources but as possible resources (see Glossary, Appendix C). Detailed subsurface investigation using power equipment is recommended prior to extractive development to determine the quality of the aggregate at depth and to delineate specific areas best suited for extractive development within the deposits.

During field investigations, numerous samples were taken from pit faces, test pits and other exposures. All of

the samples were tested in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation (MTO), Downsview. In addition to grain size analysis (Figures 2a to 6b), nine aggregate quality tests were performed on the coarse and fine aggregate samples. The results of these tests are portrayed in Tables 6a and 6b. The tests included petrographic analysis, percent crushed, Magnesium Sulphate Soundness, Los Angeles Abrasion and Impact, Absorption, Mortar Bar Accelerated Expansion and Water Soluble Chloride Ion Content. Micro-Deval Abrasion testing was carried out on many of the fine aggregate samples. The Mortar Bar Accelerated Expansion test results for the coarse and fine aggregate samples are also presented in Figures 7a and 7b. Results from the detailed coarse aggregate petrographic analysis of the full fraction of the samples are portrayed in table format (Table E2) in Appendix E.

In general, the aggregate in the project area is considered hard and durable and is generally of sufficient quality for most local applications, where sufficient quantities of crushable gravel are available. Granular petrographic numbers ranged from 134 to 208, indicating that the gravel quality is generally good and petrographically suitable for use in Granular A and Granular M crushed stone products. The hot-mix and concrete petrographic numbers ranged from 196 to 257, all unacceptable values. These unacceptable values are largely attributed to the presence of undesirable lithologies such as chert and shaly carbonates originating from the underlying shale- and chert-bearing Devonian bedrock formations. Magnesium Sulphate Soundness test results on the coarse fraction of the samples also indicate a wide range of readings. Unacceptable losses may also be attributed to the presence of deleterious lithologies from the underlying bedrock. When aggregate samples were subjected to Micro-Deval Abrasion testing, the fine fraction of the aggregate experienced acceptable to borderline weight loss results.

Aggregate samples were also subjected to alkali-aggregate reactivity testing to identify potentially reactive aggregates. When subjected to the Mortar Bar Accelerated Expansion test, the coarse fraction of the aggregate samples generally exhibited low expansion limits, however, the fine fraction of the aggregate samples showed slightly higher results.

The corrosion of reinforcing steel in concrete is a major cause of the deterioration of concrete bridge decks in Ontario. The concentration of chloride ions in concrete is one of the controlling factors of corrosion (Rogers and Woda 1977). Excellent Water Soluble Chloride Ion Content test results were obtained for the coarse and fine fractions of the aggregate samples. The test data indicates that it is unlikely that the chloride ions contained within the aggregates would contribute significantly to the corrosion of reinforcing steel in Portland cement concrete.

Petrographic analysis of the fine aggregate was carried out on 7 samples and the test results are generally excellent (see Table 6b). Only minor amounts of undesirable lithologies such as chert and shale, were noted in the samples and in the field. Borderline test results were obtained for Organic Impurity testing and further testing of the sand would be recommended before being used in cement mortar or concrete. Only one test result (MO-SS-5) failed, and excessive organic impurities are indicated.

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 consists of three Tyrrell sea beach deposits located at Rabbit Ridge. Resource Area 1 is subdivided into Areas 1a and 1b.

Pit no. 1 has been opened in Resource Area 1a. At the time of field investigation, faces in the pit ranged in height from 1.5 to 3 m. The estimated gravel content in the pit faces ranged from 30 to 50%. A sample of the material taken from the pit contained

42% gravel, 56% sand and 2% fines (Figure 2a). The faces primarily exposed horizontally stratified fine to coarse gravel and medium to coarse sand. The material appears well suited for the production of a variety of aggregate products including crusher-run gravel with appropriate processing. The abundance of sand in sections of the pit necessitates the use of selection and sand control measures during crushing operations. Granular A, 19 mm concrete stone and Granular B Type 1 have been produced from pit no. 1 by the Moose Band Development Corporation. These aggregate products have been used locally on Moose Factory Island for road-building and general construction uses. The 19 mm concrete stone has been used in basement foundations on the Island.

The two beach deposits that constitute Resource Area 1b are also potential gravel sources. Test pitting and soil augering in these features uncovered fine to coarse gravel and fine to coarse sand. The gravel content of this material was estimated to range from 40 to 50%. Coarse granular material is common on the surfaces of these deposits. The deposits appear to have significant potential for extraction of both pit-run and crusher-run products, but detailed subsurface testing is recommended prior to extractive development.

The three beach deposits that constitute Resource Area 1 occupy approximately 260 ha, of which 249 ha are considered available for extraction. Assuming an average deposit thickness of 2 m for Areas 1a and 1b, aggregate resources are estimated to be 8.8 million tonnes. The area is accessible during the winter months by a winter road that traverses the Rabbit Ridge area.

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 includes 6 Tyrrell Sea beach deposits located in the Rabbit Ridge area. Resource Area 2 has been subdivided into Areas 2a to 2f, of which Area 2a is the most extensive.

Pit nos. 2 to 9 have been opened in Resource Area 2a. Faces in these pits were generally less than 1.5 m in height and contained fine to coarse gravel with a fine to coarse sand matrix. Silt seams were noted in some of the pits and should be avoided during extraction. Many of these pits were extensively used in the past and faces were slumped and overgrown. Bedrock was observed in the floor of pit nos. 5 and 9. Estimated gravel contents were as high as 50%. A sample taken from pit no. 3 contained 46% gravel, 47% sand and 7% fines (Figure 2a). Overall, the deposit is considered to be well suited as a local source of road-building and construction aggregate. Limited amounts of crushable gravel may be available from localized pockets in the deposit. The depth to bedrock may be variable in the undeveloped parts of Area 2a. Consequently, subsurface investigation is recommended prior to further extractive development.

Resource Area 2b is also a potential source of gravel. Road cuts, along the winter road which traverses this deposit, exposed sandy fine to coarse gravel. The gravel content of this material ranged from 30 to 50%. Several 1 m deep test pits were also excavated in this deposit. The test pits generally uncovered fine to coarse gravel and fine to medium sand. The deposit appears to be well suited for the extraction of a variety of aggregate products and may also be a potential source of crushable gravel with appropriate processing. The resource potential of Area 2b appears to be similar to that of Area 2a, however, subsurface investigation is strongly recommended to assess the quality of the aggregate at depth.

Areas 2c to 2f are deposits that are also considered as potential sources of gravel. The deposit boundaries have been delineated largely through aerial photograph interpretation. Although no pits have been established in any of the deposits, the areas are expected to contain materials similar to that found in Areas 2a and 2b and thus may have a comparable resource potential. Material exposed at the surface of the deposits and in a series of test pits ranged

from fine to coarse sand to coarse gravel.

Resource Area 2 totals approximately 2430 ha, of which 2410 ha are considered available for extraction. Assuming an average thickness of 1.5 m for both Areas 2a and 2b, aggregate resources are estimated to be 64 million tonnes. A winter road provides access to Resource Area 2.

Resource Areas of Secondary Significance

Several recent and older river bars have been selected at the secondary level of significance. Extractive activity has been concentrated in three recently formed river bars located between Moosonee and Moose Factory Island. Winter dredging operations established in these bars have encountered fine to coarse sand and fine gravel. Samples of the dredged material contained 14 and 8% gravel (Figure 4a, MO-SS-3 and MO-SS-4). Results of the analysis of the samples indicate that the aggregate may be best suited for use as Granular B Type 1 and Select Subgrade Material (SSM). Blending would likely be required to produce asphaltic sand products. Historical MTO data on file indicates that dredged aggregate from these bars has been used for Granular B Type 1 and SSM. Sandy aggregate from these river bars was utilized for the granular subbase during the construction of the Moosonee Airport. Blending sands have also been produced from the dredged aggregate and have been used in conjunction with the quarried limestone for the production of Granular A.

The remaining river bars selected at the secondary level are older bars. The older river bars are generally less attractive as aggregate sources because the sand and gravel found within them is not as thick as that found in the recent bars. Exposures in these river bars were generally less than 3 m high and revealed material ranging from fine sand to fine gravel. Occasional thick lenses of silt were also observed. The materials from three of these bars were sampled and found to contain less than 15% gravel (Figures 3a and 4a, MO-SS-1,

MO-SS-2 and MO-SS-5). In general, the aggregate in these deposits is considered best suited for pit-run uses and SSM.

The future development of these secondary areas will involve mitigative measures with respect to the potential loss of fisheries habitat.

BEDROCK GEOLOGY AND RESOURCE POTENTIAL

Recent and glacial sediments in the project area are underlain by Devonian limestone and dolostone strata of the Stooping River and Kwatabohegan formations. The distribution of, and the contacts between, the formations are portrayed on Map 3. The bedrock surface is relatively flat and the formations have a gentle regional dip to the southwest, towards the centre of the Moose River sedimentary basin. The general Paleozoic geology of the Moose River Basin has been described by Sanford et al. (1968), and the Devonian strata in the basin are described by Telford (1988), Stoakes (1978) and Sanford and Norris (1975a, 1975b).

The Lower Devonian Stooping River Formation underlies surficial sediments in the northern third of the project area. Although not exposed in the project area, this formation was encountered in the Moose Factory Drill Hole No. 1, drilled on Moose Factory Island by the Canadian Department of Public Works in 1949 (Sanford and Norris 1975b). In this drill hole, the Stooping River Formation occurs between 35.1 and 95.5 m below the normal high tide elevation, and consists predominantly of grey, variably argillaceous, fossiliferous and cherty limestone, dolomitic limestone, minor dolostone and calcareous sandstone. The siliciclastic and cherty constituents of this formation could severely restrict the use of the rock for the production of crushed stone products. The formation has not been selected for possible resource protection because it is covered by thick drift and the availability of better quality bedrock resources in the Kwatabohegan Formation.

In the southern two-thirds of the project area, the Stooeping River Formation is conformably overlain by the Middle Devonian Kwataboahagan Formation. This formation is generally covered by more than 3 m of drift, although exposures can be found in and around the Labelle quarry, in the floors of pit nos. 5 and 9 (Maps 1 and 2) located at Rabbit Ridge, and at various locations along the Moose and Kwetabohigan rivers and Maidmans Creek. The Kwataboahagan Formation consists of thin- to thick-bedded, light grey to tan-brown, fine- to coarse-grained, very fossiliferous limestone with subordinate intervals of sparsely to moderately fossiliferous bituminous dolostone. Minor amounts of chert occur in some scattered beds. The thickness of the unit varies from 24 to 77 m (Telford 1988).

During field investigations, 4 bedrock samples from the Kwataboahagan Formation were obtained for aggregate quality testing (Table 6a, MO-SS-6 to MO-SS-9). Limestone samples were taken from: 1) the floor of pit no. 5 at Rabbit Ridge (MO-SS-6), 2) the Labelle quarry (MO-SS-7), and 3) an outcrop along the Kwetabohigan River (MO-SS-8). An interval of dolostone was also sampled near the Ontario Northland Railway crossing at the Kwetabohigan River (MO-SS-9). The reader is referred to Table E3, in Appendix E, for the results of a detailed chemical analysis of the 4 bedrock samples. The Mortar Bar Accelerated Expansion test results are portrayed in Figures 7a and 7b and Table 6a. Results from the detailed petrographic analysis of the full fraction of the bedrock samples are portrayed in Table E2, in Appendix E.

With the exception of the dolostone sample (MO-SS-9), the samples from the Kwataboahagan Formation appear suitable for a wide range of aggregate products. Granular petrographic numbers for the limestone samples ranged from 100 to 118, indicating that the bedrock quality is good and petrographically suitable for use in Granular A and Granular M crushed stone products. Hot-mix and concrete petrographic numbers ranged from 112 to 147. These petrographic numbers indicate that some of the

samples are borderline to unacceptable for asphalt paving and structural concrete use. Unacceptable values may be attributed to the presence of undesirable lithologies such as shaly partings and chert within the Kwataboahagan Formation. The presence of excessively high quantities of chert locally may restrict high specification uses of the limestone.

The average weight loss during the Magnesium Sulphate Soundness test for the limestone samples was 2 to 9, which is within the ranges for most products. Los Angeles Abrasion test data for limestone sample MO-SS-7 also indicates an acceptable percent loss for most products. Absorption test results for the limestone samples exceed the allowable limits for most high specification uses. However, the limestone could potentially be used in concrete if it proves to have a satisfactory field performance, and if it is not deleteriously reactive. Excellent test results were obtained for all bedrock samples when subjected to both the Mortar Bar Accelerated Expansion test and the Water Soluble Chloride Ion Content test.

The bedrock within the report area may exhibit wide variations with respect to aggregate quality over relatively short distances. Consequently, any site that may be proposed for quarry development should be carefully investigated before extraction operations commence. Selective coring and testing would be necessary to ensure successful and economic crushed stone production.

SELECTED BEDROCK RESOURCE AREAS

Two areas have been selected for possible bedrock resource protection within the report area. One is located in the eastern part of Horden geographic township, near Barkers Island, and the other is within the Rabbit Ridge area. The bedrock in these areas consists of the Kwataboahagan Formation which is generally overlain by less than 3 m of drift. The boundaries that form these bedrock areas have been based largely on aerial photographic interpretation supported by a limited number of field

data stations. The Selected Bedrock Resource Areas occupy a total available area of approximately 630 ha and contain resources of approximately 295 million tonnes. Additional bedrock resources may be available from areas of drift-covered Kwataboahagan Formation located along the Kwetabohigan River. These areas have not been selected for resource protection because of the presence of the proposed Kwetabohigan River provincial park. The presence of this candidate provincial park may inhibit extractive development.

Selected Bedrock Resource Area 1

Selected Bedrock Resource Area 1 consists of bedrock of the Kwataboahagan Formation which is generally overlain by less than 3 m of overburden. The drift overlying the formation consists of glaciomarine clay and silt, which could be stripped. Surface outcrops of the Kwataboahagan Formation are common along the bed of Maidmans Creek. Quarries 1a and 1b have been developed in Resource Area 1. Quarry no. 1a, operated by M.J. Labelle Co. Ltd., was opened in 1970 in response to a shortage of surficial deposits containing crushable gravel in Moose and Horden geographic townships (M. Labelle, M.J. Labelle Co. Ltd., personal communication, 1990). The total face height of quarry 1a is approximately 10.7 m, and during field investigation approximately 3.3 to 3.9 m of light grey to tan-brown fossiliferous limestone was exposed above the water table. The strippings from quarry 1b have been dumped onto the floor of quarry 1a. At the time of field investigation, approximately 2 to 2.6 m of Kwataboahagan Formation was exposed in quarry 1b above the water table. The total face height of quarry 1b was approximately 4.25 to 5.4 m. Due to a high water table, all overburden stripping, drilling, blasting and primary crushing operations are performed during the winter months (Derry Michener Booth and Wahl and Ontario Geological Survey 1989). A wide range of crushed stone products suitable for a variety of local road-building and general construction requirements, are produced from both of these quarries. Products

available from these quarries include Granular A, 100 mm crusher-run, armour stone and asphalt stone. The armour stone was recently used to stabilize the slope of a riverbank in Moosonee and the asphalt stone has been produced for use in a cold-mix application for the Moosonee airport runway. Extensive washing of the stone was necessary in order to remove the contaminating fines that originated from the overlying glaciomarine clay and silt. Field performance of this cold-mix application is generally good.

Selected Resource Area 1 occupies approximately 180 ha, of which 162 ha are considered to be presently available for extraction. Assuming a workable thickness of 18 m, total available resources of stone in Area 1 are estimated to be 76 million tonnes. Access to this resource area is provided by a gravel-surfaced road.

Selected Bedrock Resource Area 2

Selected Bedrock Resource Area 2 is located in the Rabbit Ridge area. The Resource Area consists of bedrock of the Kwataboahagan Formation which is overlain by less than 3 m of overburden. The drift overlying the Kwataboahagan limestone consists of beach deposits that have also been selected for resource protection. The bedrock is exposed in the floor of two sand and gravel pits developed in the beach deposits. No quarries have been developed in the resource area, however, a sample of this bedrock, taken from the floor of pit no. 5, produced acceptable aggregate quality test results. Also, rock from the same formation is being extracted from Resource Area 1 for a wide range of aggregate products. For these reasons, this resource area may prove to be suited for bedrock extraction. Detailed testing is strongly recommended before extraction begins.

Resource Area 2 occupies an available area of 470 ha. Assuming a workable thickness of 18 m, available bedrock resources are estimated to be 220 million tonnes. A winter road, which traverses the Rabbit Ridge area, allows access to this resource area.

SAMPLE SITES OUTSIDE OF REPORT AREA

While in the Moosonee area, a reconnaissance flight was organized by the Ministry of Natural Resources to obtain additional information on the aggregate quality of materials used in several northern communities outside the report area. Samples were obtained from the aggregate stockpiles at the airports of Fort Albany, Attawapiskat and Peawanuck. A sample was also taken from a raised beach deposit located near Cape Lookout in Polar Bear Provincial Park.

Aggregate testing included gradation analysis, the results of which are shown in Figures 5a, 5b, 6a and 6b. Test results from the aggregate quality testing are shown in Tables 6a and 6b and indicate that the aggregate is generally hard and durable and suitable for a range of aggregate products. Good granular petrographic numbers indicate that the aggregate appears suitable for a variety of granular products. The hot mix and concrete petrographic numbers ranged from 110 to 172. These petrographic numbers indicate that some of the samples are borderline to unacceptable for asphalt paving and structural concrete use. The high values obtained from the Fort Albany Airport may be attributed to the underlying shale- and chert-bearing Devonian bedrock formations. This bedrock may also be responsible for the high $MgSO_4$ loss and high absorption gain for the aggregate sample from Fort Albany Airport. Test results from the Micro-Deval Abrasion test are acceptable to borderline.

The test results from the Mortar Bar Accelerated Expansion test showed a range of values from acceptable to borderline to unacceptable (Tables 6a and 6b). This information is also presented on Figures 7a and 7b. The fine fraction of the Attawapiskat and Peawanuck Airport samples both exceeded 0.20% and should be considered potentially deleteriously reactive. The high concentration of argillite and greywacke lithologies within these samples may be responsible for these high expansion limits. It is, however, 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.

One sample tested for Chloride Ion Content showed a very low result indicating that the chloride ions present would not contribute significantly to the corrosion of reinforcing steel in Portland cement concrete. Petrographic examination of the fine aggregate showed minor amounts of chert and shale present. Borderline results were obtained for Organic Impurity testing and further testing of the sand would be recommended before using it in cement mortar or concrete.

SUMMARY

The Tyrrell Sea beach deposits represent the most significant surficial aggregate resources within the study area. A number of these beach deposits contain locally significant resources of sand and gravel and have been grouped into two Selected Sand and Gravel Resource Areas. In addition, numerous river bars have been selected at the secondary level of significance. These deposits may add considerably to the project area's resource base.

The sand and gravel in the project area is generally hard, durable and suitable for a variety of local road-building and general construction applications. The deposits contain material which varies from sand, suitable for pit-run uses, to coarse crushable gravel. In general, it is considered that the selected areas contain sufficient sand and gravel resources to meet most anticipated local demands in the area.

The surficial sediments in the project area are underlain by Devonian limestone and dolostone strata of the Stooping River and Kwataboahegan formations. Two areas of the Kwataboahegan Formation have been selected for possible bedrock resource protection within the report area. The Kwataboahegan

Formation is generally capable of supplying a range of aggregate products.

Enquiries regarding the Aggregate Resources Inventory of the Moosonee Area, Northeastern Ontario should be directed to the Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, 7th Floor, 77 Grenville St., Toronto,

Ontario, M7A 1W4, [Tel. (416) 965-1183] or to the Resident Geologist, Porcupine District, Ministry of Northern Development and Mines, 60 Wilson Avenue, Timmins, Ontario, P4N 2S7, [Tel. (705) 267-1401] or to the Moosonee District Office, Ministry of Natural Resources, P.O. Box 190, Ontario Government Building, Revillion Road, Moosonee, Ontario, P0L 1Y0, [Tel. (705) 336-2987].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, MOOSONEE AREA¹.

1 Class No.	2 Deposit Type (see Appendix D)	3 Areal Extent Hectares	4 Original Tonnage ² Millions of Tonnes
Moose Geographic Township			
4	S-LB	11	0.3
Horden Geographic Township			
3	S-RB	17	0.9
4	S-RB	28	0.7
		<u>45</u>	<u>1.6</u>
Moose River Bars³			
2	S-RB	31	2.6
3	S-RB	96	3.4
4	S-RB	1710	35.4
		<u>1840</u>	<u>41.4</u>
Rabbit Ridge Area			
3	G-LB	260	9.2
4	G-LB	2550	67.7
		<u>2800</u>	<u>77.0</u>
		=====	=====
TOTAL FOR STUDY AREA:		4700	120.3

1. Identified deposit areas within Tidewater Provincial Park, the communities of Moosonee and Moose Factory, Factory Island Indian Reserve 1 and Moose Factory Indian Reserve 68, have been omitted on all tables.

2. For practical purposes, the Original Tonnage figures for this project area have been shown to the nearest decimal place, because of the small amounts of material present in some deposits.

3. Geological boundaries for many of the river bars are constantly changing because of the Moose River's ongoing deposition and erosion of materials.

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

TABLE 2. SAND AND GRAVEL PITS, MOOSONEE AREA.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Metres	6 % GRAVEL	7 REMARKS
Rabbit Ridge Area						
1	-	-	-	1.5-3	30-50	water on pit floor, partially overgrown
2	-	-	-	<1.5	30-50 variable	overgrown, largely depleted
3	-	-	-	<1.5	30-50 variable	partially overgrown, largely depleted, lenses of silt
4	-	-	-	<1.5	30-50 variable	partially overgrown
5	-	-	-	<1.5	30-50 variable	partially overgrown, bedrock exposed in pit floor, largely depleted
6	-	-	-	<1.5	30-50 variable	partially overgrown
7	-	-	-	<1.5	30-50 variable	partially overgrown
8	-	-	-	<1.5	30-50 variable	partially overgrown, lenses of silt
9	-	-	-	<1.5	30-50 variable	partially overgrown, bedrock exposed in pit floor, lenses of silt

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, MOOSONEE AREA.

1 DEPOSIT NO.	2 AREA Hectares	3 CULTURAL SETBACKS Hectares	4 EXTRACTED AREA Hectares	5 AVAILABLE AREA Hectares	6 ESTIMATED DEPOSIT THICKNESS Metres	7 AVAILABLE AGGREGATE ¹ Millions of tonnes
1a	248	0	8	240	2	8.5
1b	<u>9</u>	<u>0</u>	<u>0</u>	<u>9</u>	2	<u>0.3</u>
	260	0	8	249		8.8
2a	1600	0	15	1580	1.5	42.0
2b	730	0	0	730	1.5	19.4
2c	15	0	0	15	1.5	0.4
2d	42	0	0	42	1.5	1.1
2e	30	0	0	30	1.5	0.8
2f	<u>11</u>	<u>0</u>	<u>0</u>	<u>11</u>	1.5	<u>0.3</u>
	2430	0	15	2410		64.0
TOTAL FOR STUDY AREA:						
	=====	=====	=====	=====		=====
	2700	0	23	2650		72.8

1. For practical purposes, the Available Aggregate figures for this project area have been shown to the nearest decimal place, because of the small amounts of material present in some deposits.

TABLE 4. QUARRIES, MOOSONEE AREA.

1 NO.	2 MTO NO.	3 LOT	4 CONC.	5 FACE HEIGHT Metres	6 REMARKS
Horden Geographic Township					
1a	B21-1	S1/2 6&7	8	10.7	limestone, partially water filled, winter extraction
1b	B21-1	S1/2 6&7	8	4.25-5.4	limestone, partially water filled, winter extraction

TABLE 5. SELECTED BEDROCK RESOURCE AREAS, MOOSONEE AREA.

1 DEPOSIT NO.	2 AREA Hectares	3 CULTURAL SETBACKS Hectares	4 EXTRACTED AREA Hectares	5 AVAILABLE AREA Hectares	6 ESTIMATED QUARRIABLE THICKNESS Metres	7 AVAILABLE RESOURCES Millions of tonnes
1	180	16	2	162	18	76
2	470	0	0	470	18	220
TOTAL FOR STUDY AREA:						
	=====	=====	=====	=====		=====
	650	16	2	630		295

TABLE 6a. RESULTS OF COARSE AGGREGATE QUALITY TESTS, MOOSONEE AREA AND NORTHERN SAMPLE SITES.

Pit No./ Sample Site Selected	Petrographic Number		Percent Crushed	Magnesium Sulphate Soundness % Loss	Absorption %	Los Angeles Abrasion % Loss	Mortar Bar Accelerated Expansion %	Water Soluble Chloride Ion Content %
	Granular	Hot Mix & Concrete						
Pit no. 1	172	255	-	20	-	-	-	0.005
Pit no. 3	142	201	-	11	-	-	0.072	0.005
MO-SS-1	-	-	-	-	-	-	-	-
MO-SS-2	-	-	-	-	-	-	-	-
MO-SS-3	154	227	-	-	-	-	-	-
MO-SS-4	208	257	-	-	-	-	-	-
MO-SS-5	134	196	-	-	-	-	-	-
MO-SS-6	105	147	-	7	2.8	-	0.015	-
MO-SS-7	118	140	-	9	2.1	29	0.066	0.007
MO-SS-8	100	112	-	2	2.5	-	0.016	-
MO-SS-9	216	312	-	82	-	-	0.031	-
Fort Albany Airport	135	172	58	17	3.0	-	0.069	-
Attawapiskat Airport	122	141	-	2	1.6	-	0.191	0.006
Cape Lookout, Polar Bear Provincial Park	101	110	-	-	-	-	0.032	-
Peawanuck Airport	110	124	-	-	-	-	0.109	-

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

TABLE 6b. RESULTS OF FINE AGGREGATE QUALITY TESTS, MOOSONEE AREA AND NORTHERN SAMPLE SITES.

Pit No./ Selected Sample Site	Petrographic Analysis			Micro-Deval Abrasion % Loss	Absorption %	Mortar Bar Accelerated Expansion %	Water Soluble Chloride Ion Content %	Organic Impurities
	% chert	% shale	% mica					
Pit no. 1	0.3	0.3	0	15	1.73	0.181	-	3
Pit no. 3	0	0.1	0.4	19	2.40	0.143	-	2
MO-SS-1	0.1	1.3	0	7	-	-	-	3
MO-SS-2	0	1.7	0	7	-	-	-	3
MO-SS-3	1.2	2.7	0	10	1.70	0.158	0.005	3
MO-SS-4	0.3	1.2	0	9	1.00	0.177	0.005	3
MO-SS-5	0.9	0.4	0	11	1.30	0.158	0.004	4
MO-SS-6	-	-	-	-	-	-	-	-
MO-SS-7	-	-	-	-	-	-	-	-
MO-SS-8	-	-	-	-	-	-	-	-
MO-SS-9	-	-	-	-	-	-	-	-
Fort Albany Airport	2.1	0.3	0	18	-	0.117	-	3
Attawapiskat Airport	0.3	0.5	0	14	1.2	0.221	-	3
Cape Lookout, Polar Bear Provincial Park	0.3	0.9	0	-	-	0.158	-	-
Peawanuck Airport	0.2	0.5	0	-	-	0.214	-	-

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

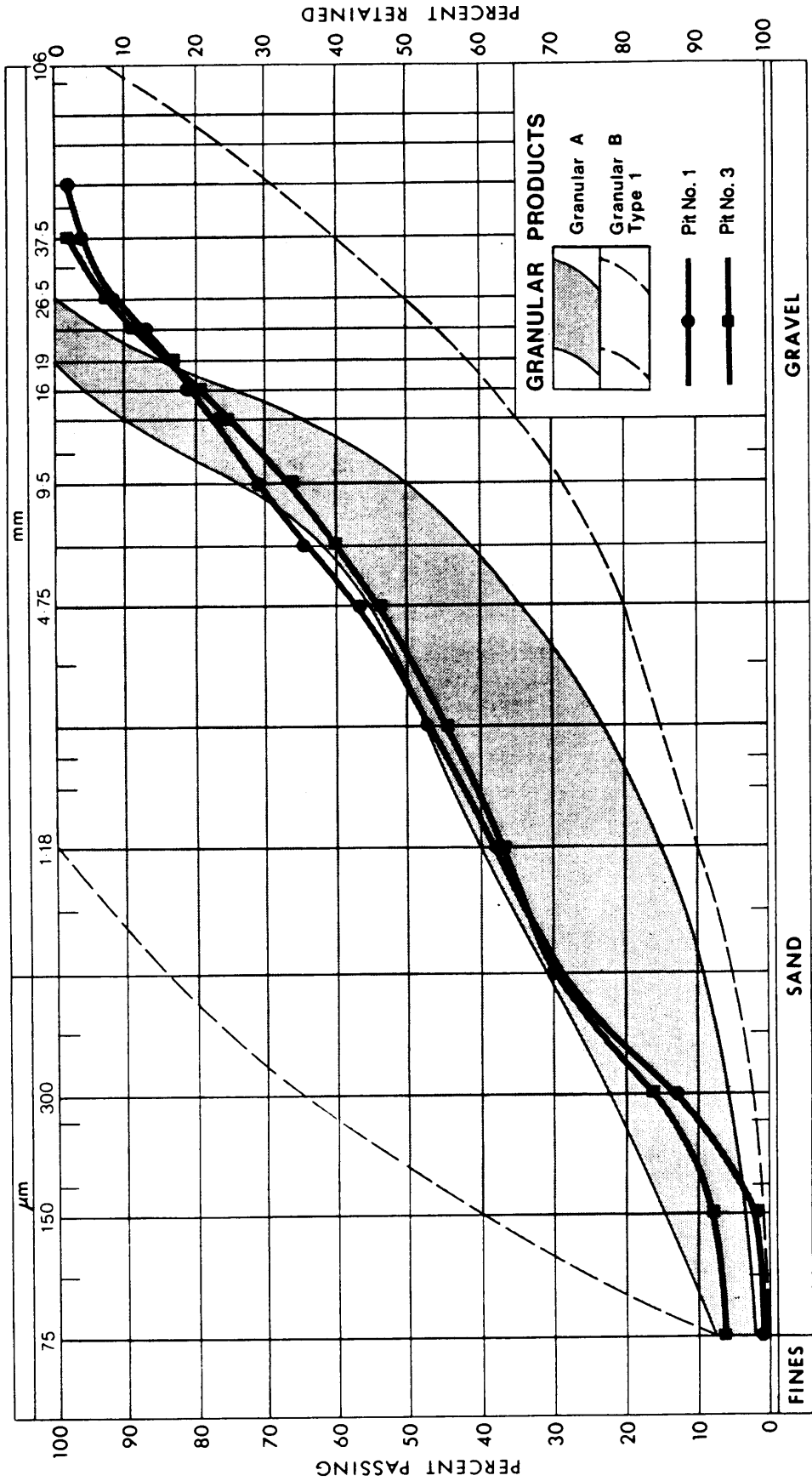


FIGURE 2a. AGGREGATE GRADING CURVES, MOOSONEE AREA.

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

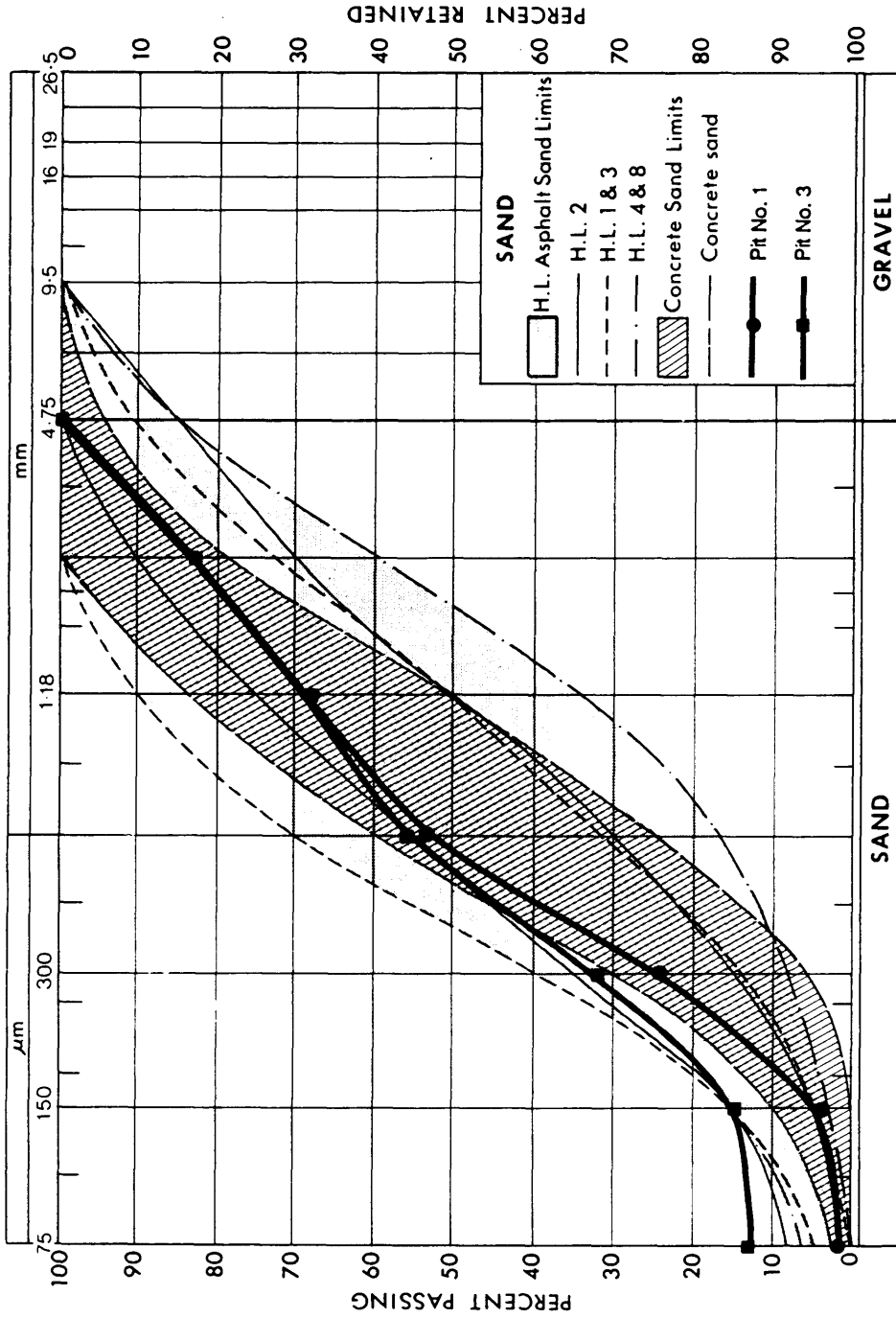


FIGURE 2b. AGGREGATE GRADING CURVES, MOOSONEE AREA.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards 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.

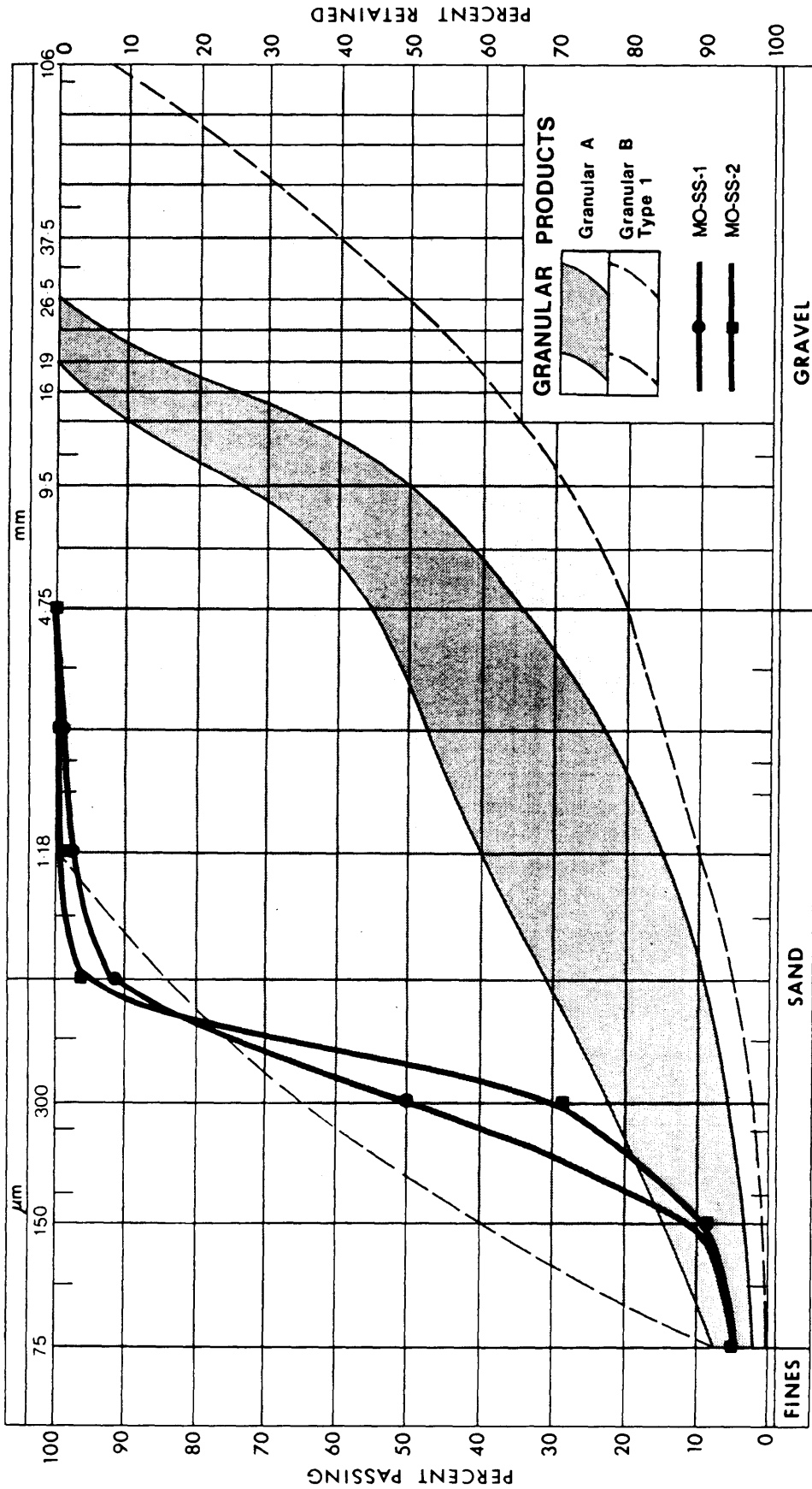


FIGURE 3a. AGGREGATE GRADING CURVES, MOOSONEE AREA.

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

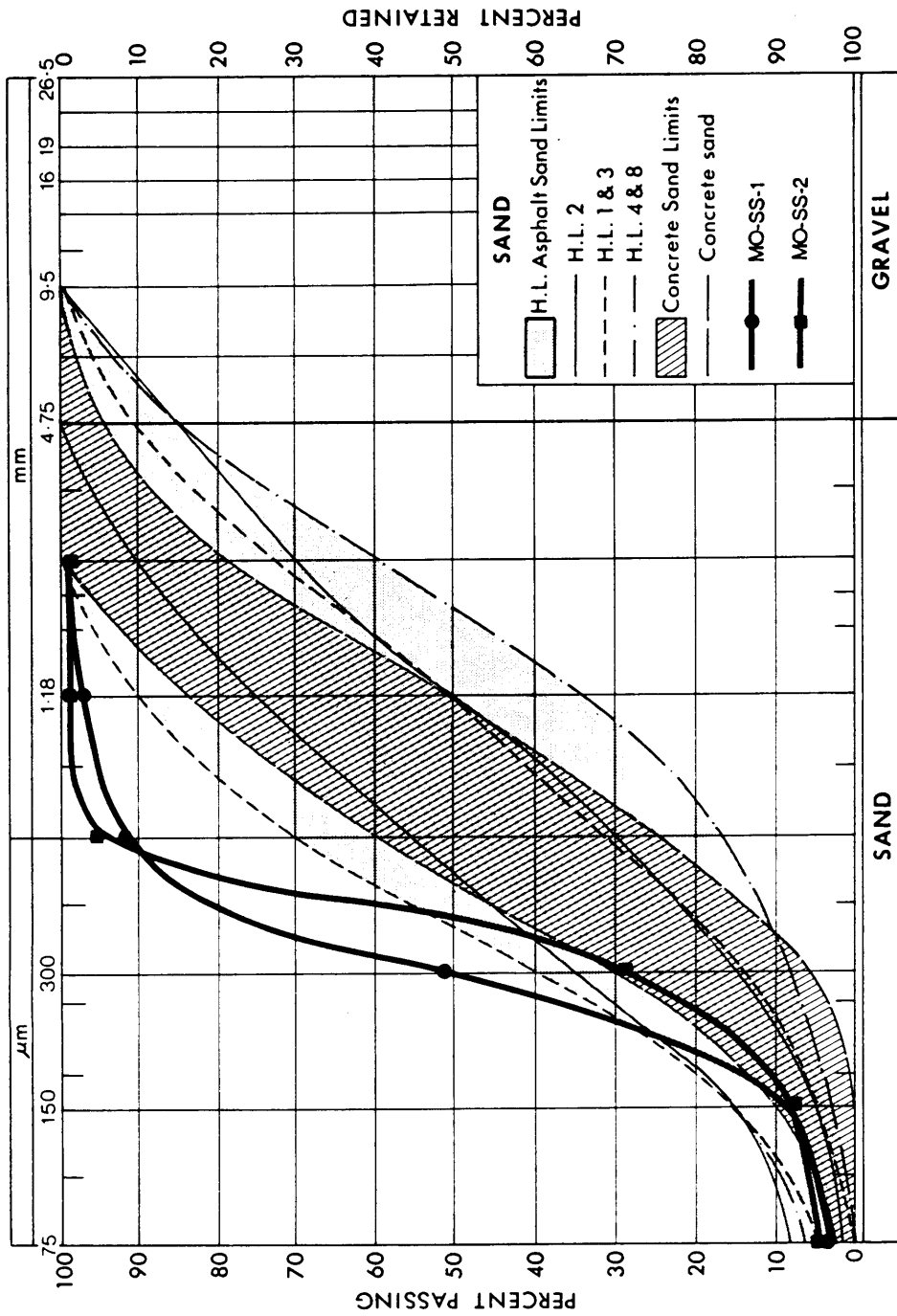


FIGURE 3b. AGGREGATE GRADING CURVES, MOOSONEE AREA.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards 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.

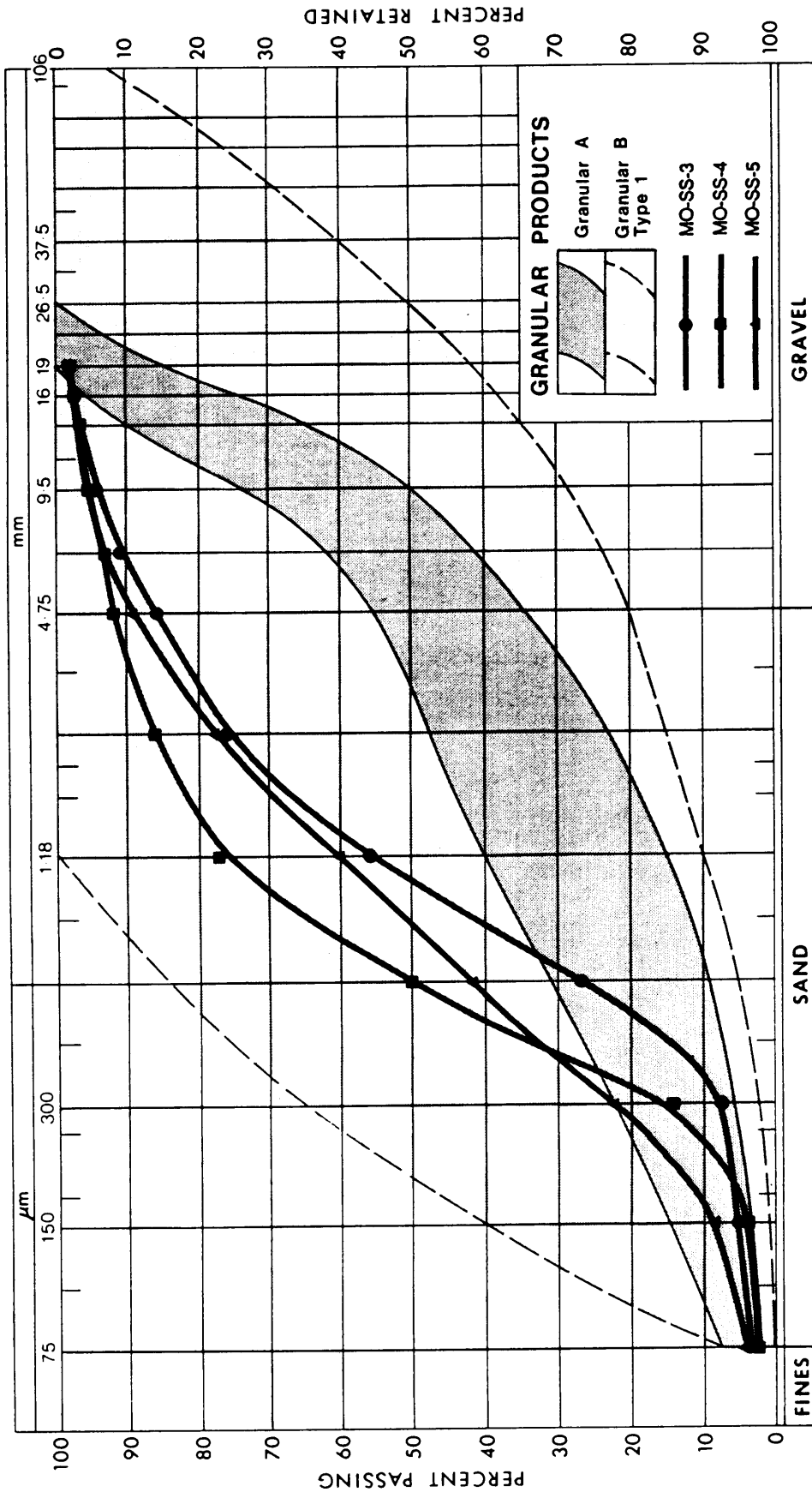


FIGURE 4a. AGGREGATE GRADING CURVES, MOOSONEE AREA.

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

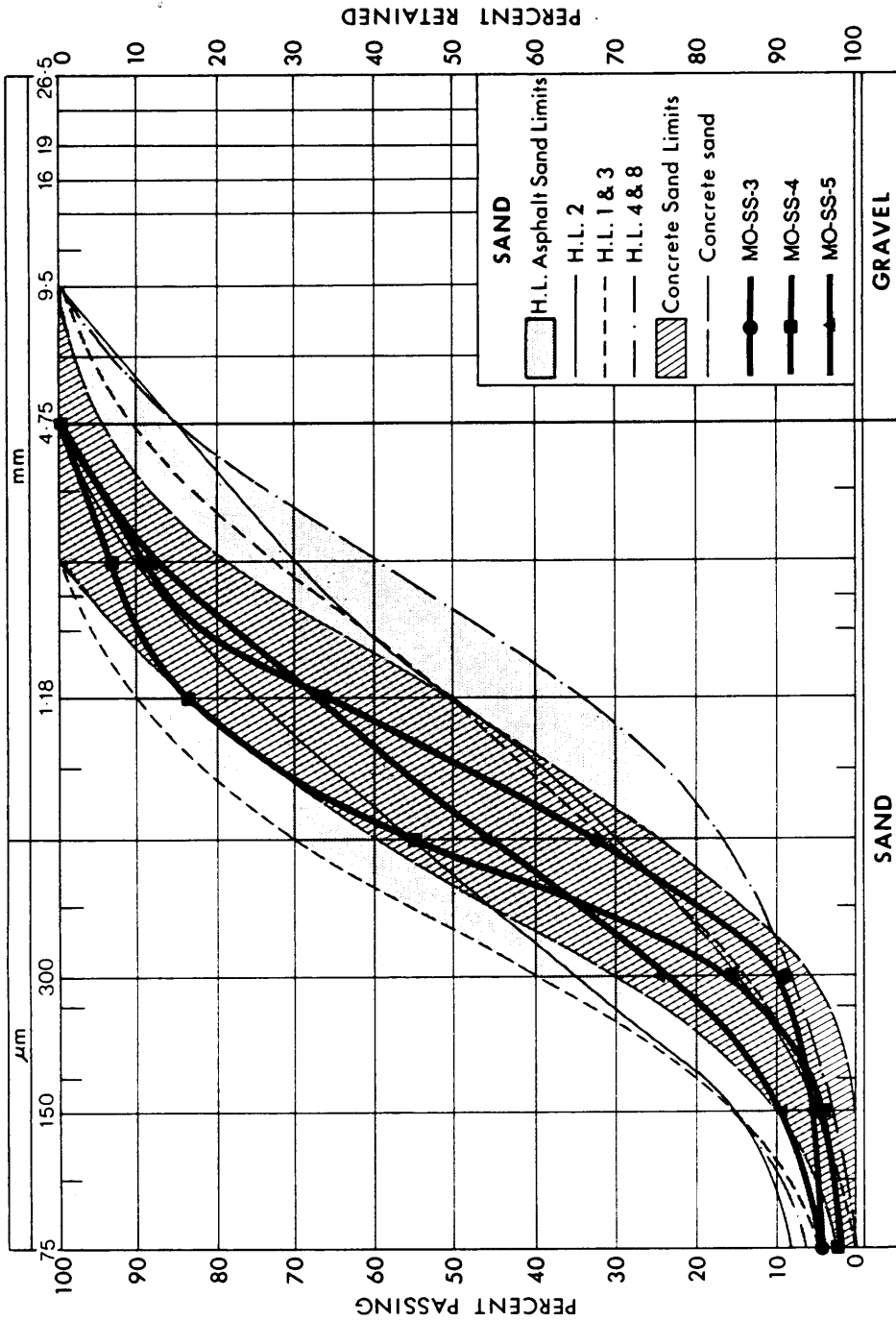


FIGURE 4b. AGGREGATE GRADING CURVES, MOOSONEE AREA.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards 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.

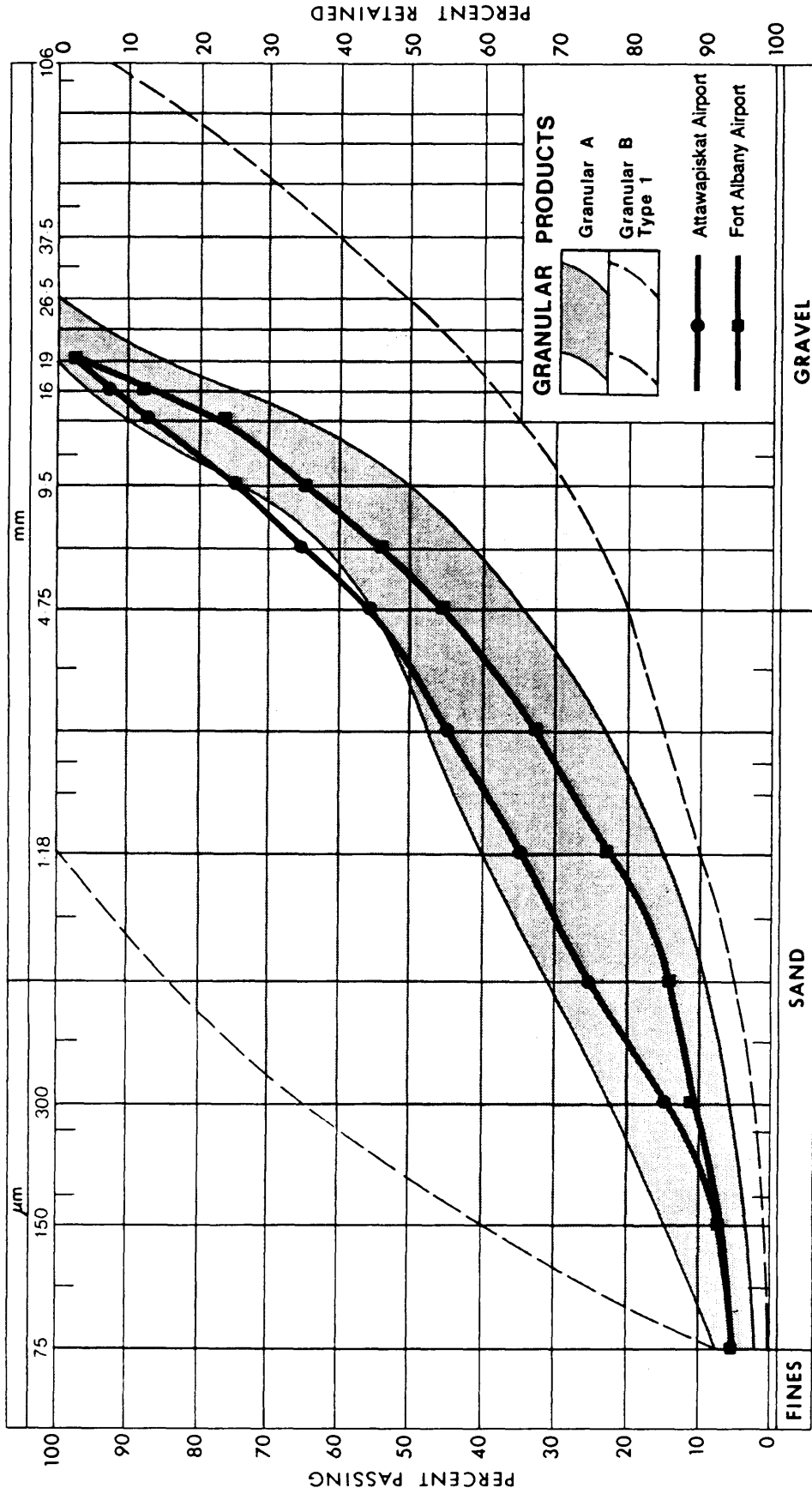


FIGURE 5a. AGGREGATE GRADING CURVES, MOOSONEE AREA.

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

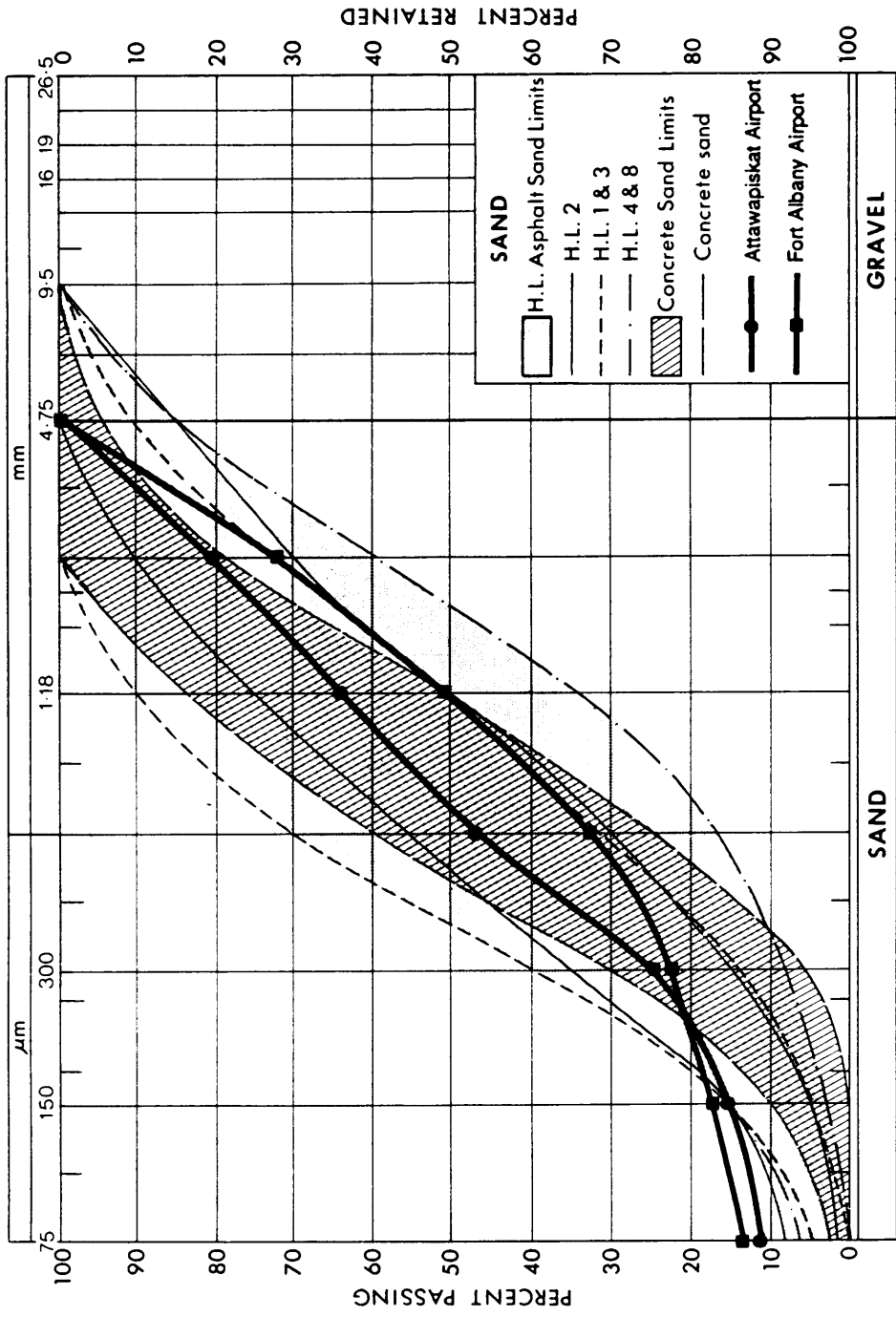


FIGURE 5b. AGGREGATE GRADING CURVES, MOOSONEE AREA.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards 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.

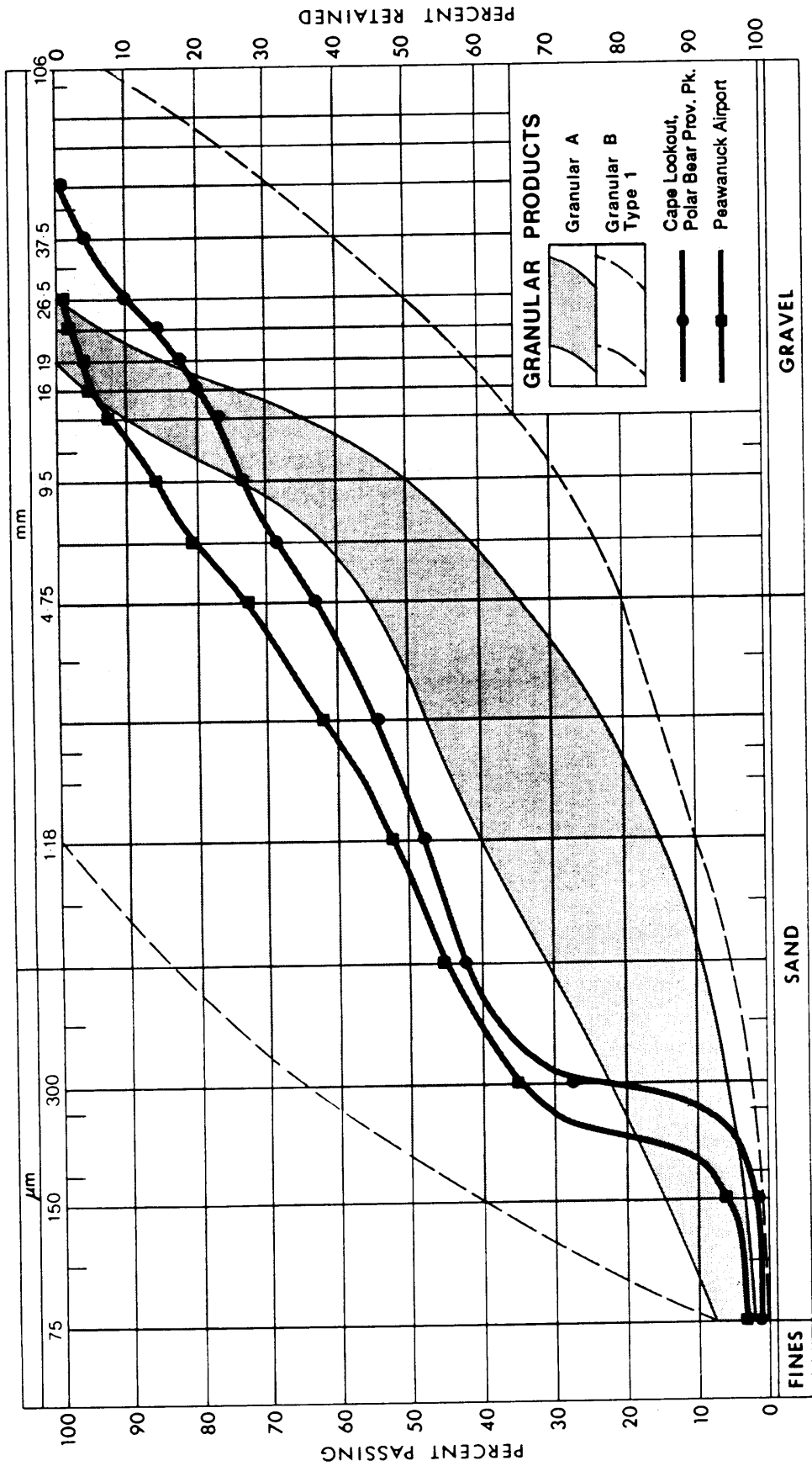


FIGURE 6a. AGGREGATE GRADING CURVES, MOOSONEE AREA.

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

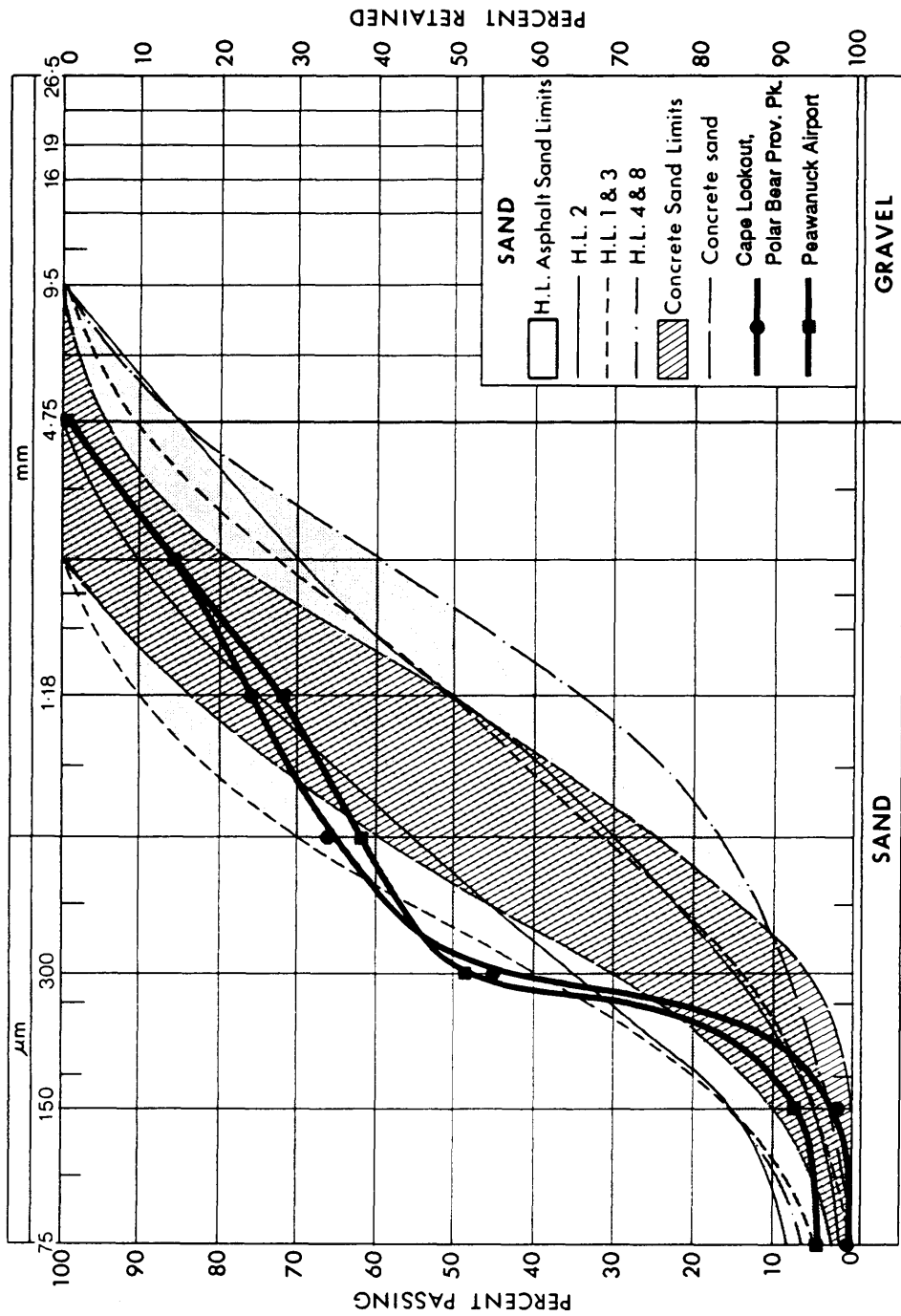


FIGURE 6b. AGGREGATE GRADING CURVES, MOOSONEE AREA.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from Ontario Provincial Standards 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.

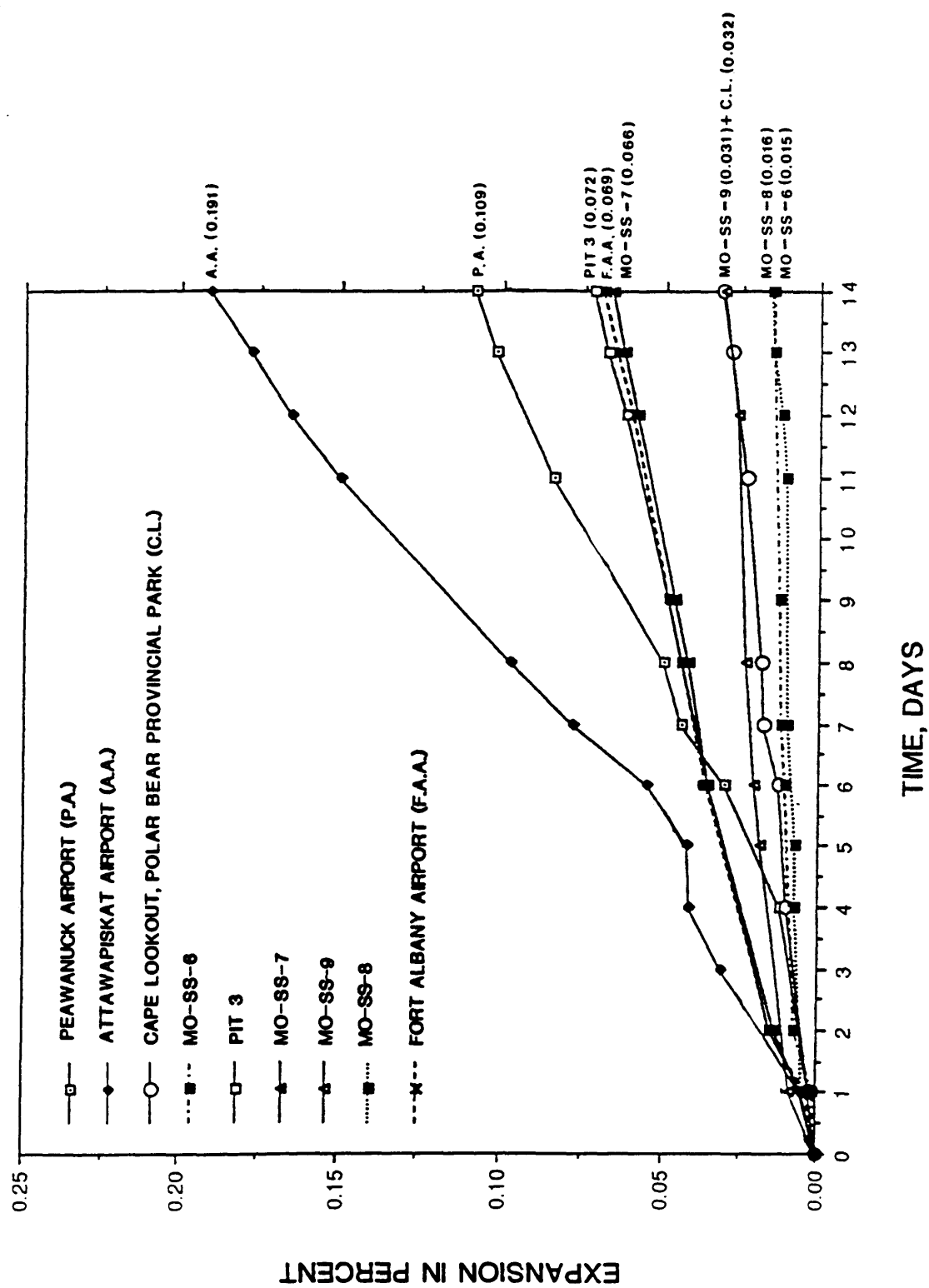


Figure 7a. MORTAR BAR ACCELERATED EXPANSION TEST, COARSE AGGREGATE, MOOSONEE AREA AND NORTHERN SAMPLE SITES.

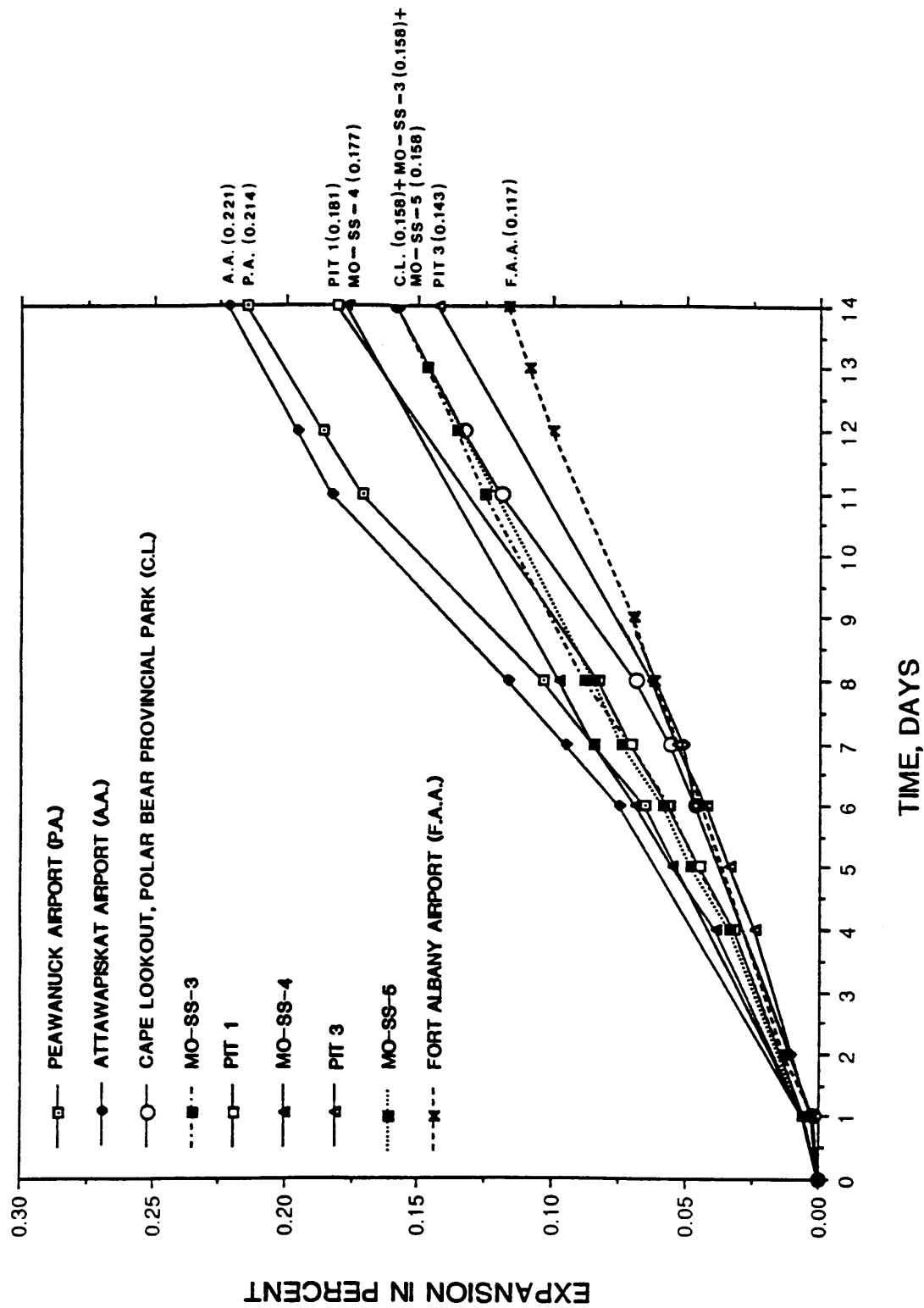


Figure 7b. MORTAR BAR ACCELERATED EXPANSION TEST, FINE AGGREGATE, MOOSONEE AREA AND NORTHERN SAMPLE SITES.

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APPENDIX A - PURPOSE, METHODOLOGY AND DATA PRESENTATION OF THE AGGREGATE RESOURCES INVENTORY

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1987, the total tonnage of mineral aggregates extracted was 142 million tonnes, greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Northern Development and Mines 1989).

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

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on 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.

This report presents 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 1 - INVENTORY METHODS

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as surficial geology maps and reports as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and by Regional and District offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole excavation. The symbols for and locations of sample sites and test hole sites are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied

in greater detail. Representative sections in these deposits are sampled in 11 to 45 kg units from existing pit faces or from test pits. The samples are analyzed for grain size distribution, and in some cases petrographic analyses and the following tests are carried out: Los Angeles Abrasion and Impact, absorption, Mortar Bar Accelerated Expansion, Water Soluble Chloride Ion Content, Micro-Deval Abrasion, Organic Impurities and Magnesium Sulphate Soundness. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation, or in the Geoscience Laboratory, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The locations of additional aggregate sources were obtained from records held by Regional and District offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

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, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000. These base maps are prepared by the

Surveys, Mapping and Remote Sensing Branch, Ontario Ministry of Natural Resources with information taken from maps of the National Topographic System by permission of Energy, Mines and 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. 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 logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 17 700 (the mass 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 1766 kg/m³.

$$\text{Tonnage} = \text{Area} \times \text{Thickness} \times \text{Density Factor}$$

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 and abandoned pits are included in this category).

The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the mass density factor (Column 5 x Column 6 x 17 700) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve 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 measured extent of an area is 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 dolostone are calculated using a density factor of 2649 kg/m³ or 8070 t/ha. Sandstone resources are calculated using a density estimate of 2344 kg/m³ and shale resources are calculated with a factor of 2408 kg/m³.

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 table which accompany the report. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (see Glossary, Appendix C) in accordance with terminology of the Ontario Resource Classification Scheme

(Robertson 1975) and with the Association of Professional Engineers of Ontario (1976).

PART II - DATA PRESENTATION AND INTERPRETATION

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

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Map 1 is derived from existing surficial geology maps of the area and from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

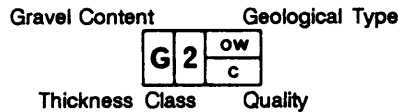
On the map, all sand and gravel deposits are outlined and shaded. The present level of extractive activity is also indicated. Sand and gravel pits are identified by a numbered dot on Map 1 and described in Table 2. Each description notes the location and estimated face height of the pit as well as the estimated percentage gravel it contains.

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 two 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:



This 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 the 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 D) 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:



MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

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

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by an intricate pattern on Map 2.

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.

Deposits of secondary significance are indicated by a dotted pattern on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be con-

sidered part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no pattern. They are not considered to be important resources areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in 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 reserves 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 composing the deposit, and from variations

in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. 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 all concrete aggregate and for road-building aggregate, 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 uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation (MTO) and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 6, 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 C 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 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 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).

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. 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 District Office of the Ministry of Natural Resources.

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.

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 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology and topography maps, as well as on site and test pit investigations. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundary of the bedrock units are shown by a thin dashed line. Isolated outcrops are indicated by an "X". Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Quarries are identified by a numbered dot on Map 3 and are described in Table 4. Each description notes the location and estimated face height. 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 is shown in metres beside the open dot. Sample sites are indicated by a square and test results from these samples are shown in Tables 6a and 6b.

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 primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation.

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. However, in this case limited sampling was done and no generalizations were made due to the remoteness of this area. The areas delineated on Map 3 are covered by less than 3 m of drift. Quarrying is possible in less than 3 m of drift and thus these zones represent potential resource areas. Outside of these delineated areas, the bedrock potential was not explored due to time constraints.

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 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 3 by dark shading and the calculated available tonnages are given in Table 5.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection.

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APPENDIX B - SUGGESTED ADDITIONAL READING

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APPENDIX C - 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 type of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

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

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: 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 500 million years ago. The Cambrian preceded the Ordovician Period.

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

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 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found 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, elongate 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 the 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.

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

Granular base and subbase: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. 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, and 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).

Hot-laid (or asphaltic) 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 and 8) used to bind the surface course to the underlying granular base.

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.

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 500 and 435 million years ago.

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

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.

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.

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

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.

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

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

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

Wisconsinan: Pertaining to the last glacial 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 D - 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 cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated

ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. 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.

River Bar (RB): A river bar is an accumulation of sand or gravel, which is formed in a channel, along a bank or at the mouth of the river. River bars in general, lack silt and clay and are commonly well sorted. A decrease in the velocity of the river causes these ridge-like features to form and when the water is low, bars commonly emerge. In some aggregate poor areas these are used as sandy aggregate sources.

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 and Marine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes or seas that existed at various times during the deglaciation of Ontario. Well developed lacustrine or marine 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, glacial 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 E - AGGREGATE QUALITY TEST SPECIFICATIONS

Numerous 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.

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.

Water Soluble Chloride Ion Content: The corrosion of reinforcing steel in concrete is a major cause of the deterioration of concrete bridge decks in Ontario. The concentration of chloride ions in concrete is one of the controlling factors of this corrosion. There are no specifications in Ontario for maximum water soluble chloride ion content of aggregates, however, corrosion will not occur if the chloride content is below the threshold value of about 0.04% chloride ion by weight of concrete.

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 is a new abrasion loss test that is quick, cheap and more precise than the fine aggregate Magnesium Sulphate Soundness test which suffers from a wide multi-laboratory 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 a new 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.

Organic Impurities: A natural sand may be durable from a freeze-thaw point of view, however, if the sample contains an excessive amount of organic matter, it is then unsuitable for concrete. The organic impurities are usually decayed matter, humus or loam. Though most often found in the overburden, organics can occur in lenses or stringers in the deeper part of the deposit. Organic

impurities tend to interfere with the hydration of the cement, reduce the bond strength and also affect the air entrainment. If organic matter is present throughout the deposit, washing of the sand may remedy the situation. The Sodium Hydroxide Colorimetric test is used to determine the amount of organic material present in concrete sand. Acceptable test numbers are 1 and 2, whereas, 3 indicates a borderline material and a need for further testing such as a mortar strength test. The numbers 4 and 5 are indicative of failure.

Percent Crushed: A crushed particle is a piece of coarse aggregate which has at least one well-defined, mechanically fractured face. This test method covers the visual determination of the percent, by mass, of crushed particles in a processed crushed aggregate. The test procedure gives a measure of the stability characteristics of the coarse aggregate in hot-mix pavement.

Petrographic Analysis: 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.

Petrographic Analysis of Fine Aggregate: Petrographic analysis of fine aggregate appraises the quality of the sand. The test method determines the amounts of silicate and carbonate rock types, and secondly, the quantity of deleterious materials, such as chert, shale and mica, is established. The latter is required in order to assess the potential for problems such as lack of freeze-thaw durability and alkali-aggregate reactivity. The chert content should not exceed 5%, and if it does, an alkali-silica reactivity test should be carried out. The shale and mica contents should not exceed 5% and 1%, respectively.

TABLE E1a. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS, COARSE AGGREGATE.

Type of Material	TYPE OF TEST									
	Petrographic Number Maximum	Magnesium Sulphate Soundness Maximum % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Percent Crushed Minimum	Mortar Bar Accelerated Expansion %	Water Soluble Chloride Ion Content %			
Granular A	200	-	-	60	50					
Granular B Type I	250**	-	-	-	-					
Granular M	200	-	-	60	50					
Selected Subgrade Material	250**	-	-	-	-					
Surface Treatment										
Class 1	135	12	1.75	35	60					
Class 2	160	15	-	35	60					
Class 3	160	12	2.0	35	60					
Class 5	135	12	1.75	35	60					
Hot Mix - HL 1	100	5	1.0	15	100					
Hot Mix - HL 2	-	-	-	-	-					
Hot Mix - HL 3	135	12	1.75	35	60					
Hot Mix - HL 4	160	12	2.0	35	60					
Hot Mix - HL 8	160	15	2.0	35	60					
Structural Concrete,										
Sidewalk, Curb, Gutter and Base	140	12	2.0	50	-	*	*			
Pavement Concrete	125	12	2.0	35	-					

* Test results are analyzed for specific contracts. Please refer to Appendix E for detailed explanation.
 ** requirement waived if the material has more than 80% passing the 4.75 mm sieve.

(Ontario Provincial Standard Specifications OPSS 304, 1002, 1003, 1010 and SP313F10)

TABLE E1b. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS, FINE AGGREGATE.

Type of Material	TYPE OF TEST						
	Magnesium Sulphate Soundness Maximum % Loss	Micro-Deval Abrasion % Loss	Petrographic Analysis Maximum	Organic Impurities Maximum	Material Passing 75 um %	Mortar Bar Accelerated Expansion %	Water Soluble Chloride Ion Content %
Surface Treatment							
Class 4	20						
Hot Mix - HL 1	16	20			0-5		
Hot Mix - HL 2	20	25			3-8		
Hot Mix - HL 3	16	20	*		0-5		
Hot Mix - HL 4	20	25			0-7		
Hot Mix - HL 8	20	25			0-7		
Structural Concrete, Sidewalk, Curb, Gutter and Base	16	20	*	3*	0-3 0-5 ^m	*	*
Pavement Concrete	16	20	*	3*	0-3 0-5 ^m		

* Test results are analyzed for specific contracts. Please refer to Appendix E for detailed explanation.
 ** For manufactured sand

(Ontario Provincial Standard Specifications OPSS 304, 1002 and 1003)

TABLE E2. PETROGRAPHIC ANALYSIS OF FULL FRACTION OF AGGREGATE SAMPLES, MOOSEE AREA AND NORTHERN SAMPLE SITES.

GOOD AGGREGATE (%)	PIT 1	PIT 3	MO-SS-3	MO-SS-4	MO-SS-5	MO-SS-6	MO-SS-7	MO-SS-8	MO-SS-9	P.A.*	F.A.A.*	C.L.*	A.A.*
CARBONATES (HARD)	3.9	8.8	4.7	0.3	4.9	10.2	48.2	62.1		48.7	33.6	46.5	13.2
SANDSTONE-ARKOSE (HARD)		0.6	2.4	2.5	4.2						0.8	0.2	
GNEISS-SCHIST (HARD)	0.2	2.1		1.1	2.1							0.2	0.4
QUARTZITE (COARSE- & FINE-GRAINED)					0.9							0.2	
GREYWACKE-ARGILLITE (HARD)	10.9	11.8	17.0	9.5	22.8					14.9	11.7	22.8	31.4
VOLCANIC (HARD & SLIGHTLY WEATHERED)		0.6	2.3	0.2	1.1					2.9	0.2	0.1	2.0
GRANITE-DIORITE-GABBRO	0.7	1.4	12.8	3.1	12.4					5.1	6.9	1.5	4.3
TRAP										1.4	6.9		
CARBONATES (SLIGHTLY WEATHERED - MEDIUM HARD)	19.6	31.5	14.6	7.7	12.4	65.5	32.7	31.7	3.5	20.1	19.1	16.3	34.0
CARBONATES (SLIGHTLY CHERTY)	1.2			0.2		1.9	2.0					9.6	0.9
IRON FORMATION (HARD; SLIGHTLY WEATHERED)	1.5	0.8											
FAIR AGGREGATE (%)													
CARBONATES CRYSTALLINE (SLIGHTLY WEATHERED)		0.5											
GNEISS (BRITTLE)-SCHIST (MEDIUM HARD)		0.4			8.1					0.5			0.2
CHERT-CHERTY CARBONATES (UNLEACHED)	5.5	0.7	7.1	1.6		2.4	1.6				3.3	0.6	0.6
GREYWACKE-ARGILLITE (MEDIUM HARD)	0.1												1.6
SANDSTONE-ARKOSE (BRITTLE)													0.3
CARBONATES (SOFT; SLIGHTLY SHALY)	37.4	31.2	15.7	3.7	11.2	17.7	8.0	6.2	48.1	2.2	6.3	0.7	5.2
CARBONATES (WEATHERED)	10.6	6.5	10.2	65.3	12.1	2.3	5.7		43.8	1.8	2.8		4.0
FLINT-JASPER-FINE-GRAINED VOLCANICS	0.5												0.7
POOR AGGREGATE (%)													
CARBONATES (SHALY OR CLAYEY)	6.5	2.6	6.1	2.1	1.4		1.2		4.6	0.2	2.6		0.9
CHERT-CHERTY CARBONATES (LEACHED)	1.3	0.7	6.5	2.6	5.5		0.6			1.2	2.3	1.3	
CEMENTATIONS										0.2			
CEMENTATIONS (TOTAL)										0.2			
ARGILLITE-TUFFARGILLITE-SLATE (UNWEATHERED-FISSILE)													0.2
DELETERIOUS AGGREGATE (%)													
CLAY			0.6		0.9					0.5			

* P.A. - Peawanuck Airport, F.A.A. - Fort Albany Airport, C.L. - Cape Lookout, A.A. - Attawapiskat Airport

TABLE E3. CHEMICAL ANALYSIS OF BEDROCK SAMPLES, MOOSONEE AREA.

SAMPLE SITE	HEAT LOSS %	INSOLUBLE RESIDUE %	R ₂ O ₃ %	CaO %	MgO %
MO-SS-6	42.9	3.0	0.4	48.4	4.9
MO-SS-7	40.9	5.4	0.6	51.3	1.8
MO-SS-8	43.0	2.8	0.5	47.6	5.6
MO-SS-9	46.4	1.2	0.5	31.7	19.9

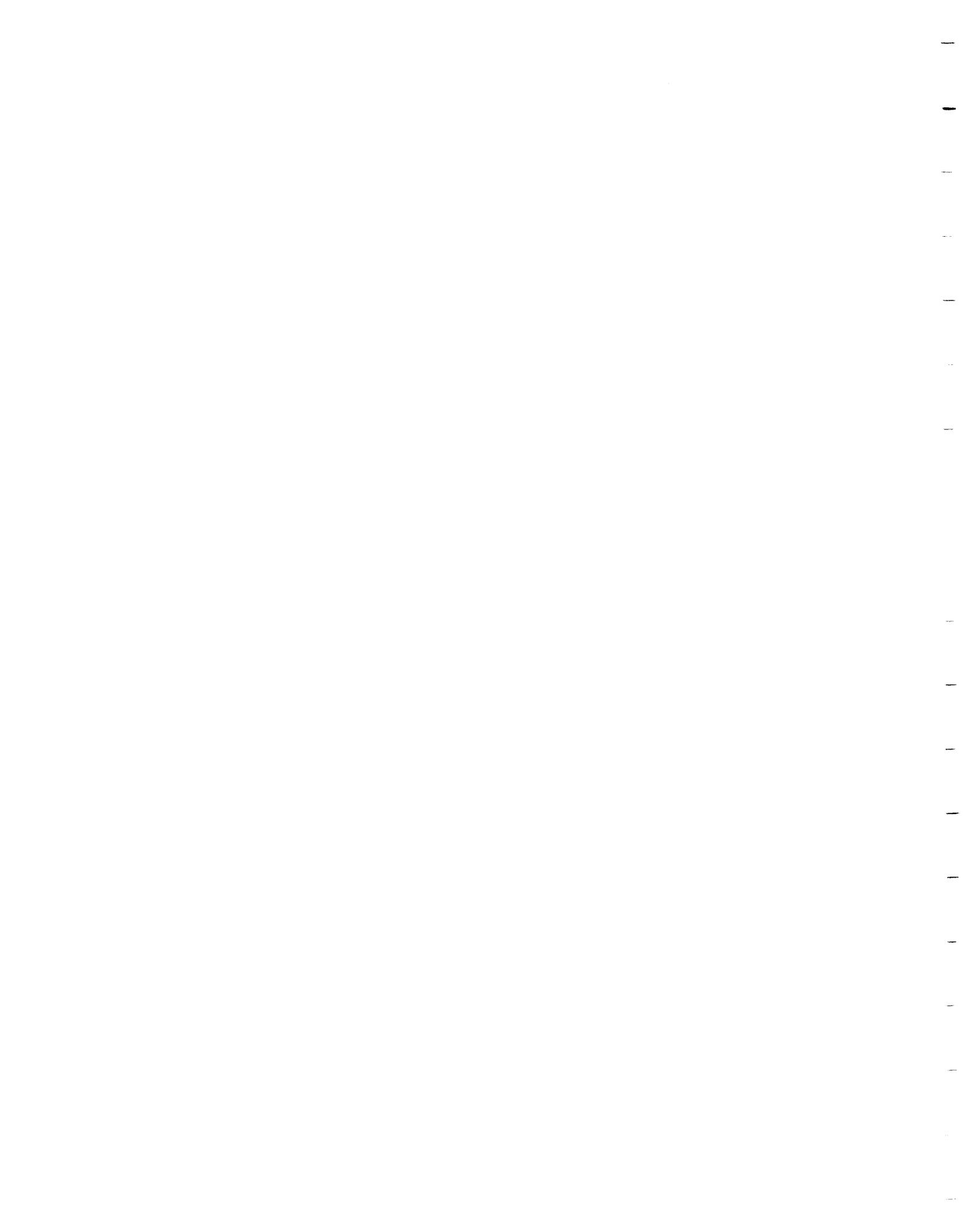
CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

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 7	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 02	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	1.308 0	cubic yards	1 cubic yard	0.764 555	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 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 62	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	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)	1.016 046 908 8	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)	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.



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	K	Kame
E	Esker	LB	Lacustrine Beach - Marine Beach
EM	End Moraine	LD	Lacustrine Delta
IC	Undifferentiated Ice Contact Stratified Drift	LP	Lacustrine Plain
ICT	Ice Contact Terrace	RB	River Bar
		WD	Windblown Forms

(see Appendix D 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

Base map by Surveys, Mapping and Remote Sensing Branch, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation.

Selected drilled water well data from the Ontario Ministry of the Environment.

Field work by Staff of the Aggregate Assessment Office and Paleozoic/Mesozoic Geology Subsection.

Compilation and Drafting by Staff of the Aggregate Assessment Office.

This map is to accompany OGS Open File Report 5811.

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Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.

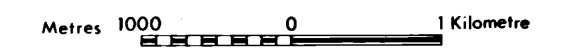


ONTARIO GEOLOGICAL SURVEY
 AGGREGATE RESOURCES INVENTORY

MOOSENEE AREA

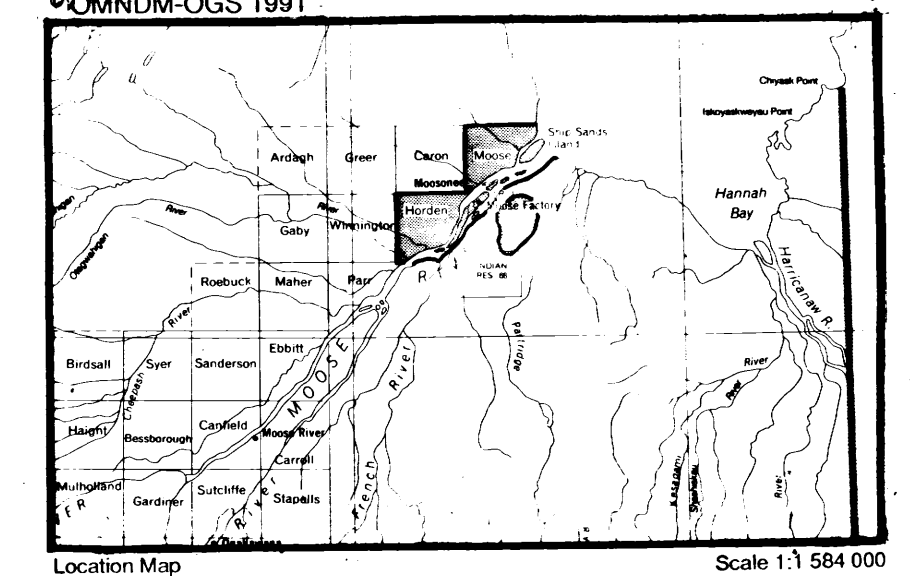
**MAP 1
 DISTRIBUTION OF SAND AND GRAVEL DEPOSITS**

Scale 1:50 000



NTS Reference: 42 P/1, 42 P/2, 42 P/7, 42 P/8

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SYMBOLS

(Some symbols may not apply to this map.)

- Township boundary.
- Project area boundary.
- Geographic township within township boundary.
- County, District, Regional or District Municipal boundary.
- Community 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.
- Extracted area of sand and gravel pits.
- Sand or gravel pit; Identification number; see Table 2.
- Test hole location; Identification number.
- Selected sample site; Identification number; see Figures 3a - 4b.
- Geophysical traverse line; Identification number.
- Selected Water Well location. Layers of material are described by reported thickness of material (in metres); reported type of material (number only - overburden, G - Gravel, S - Sand, C - Clay, T - Till, B - Boulders, BK - Bedrock, Hpan - Hardpan, Sm - Stones, Silt - Silt).
- Texture symbol; see below; see Figures 2a - 6b.
- Deposit symbol; see below.

TEXTURE SYMBOL

(This symbol is used where sample analysis data are available.)

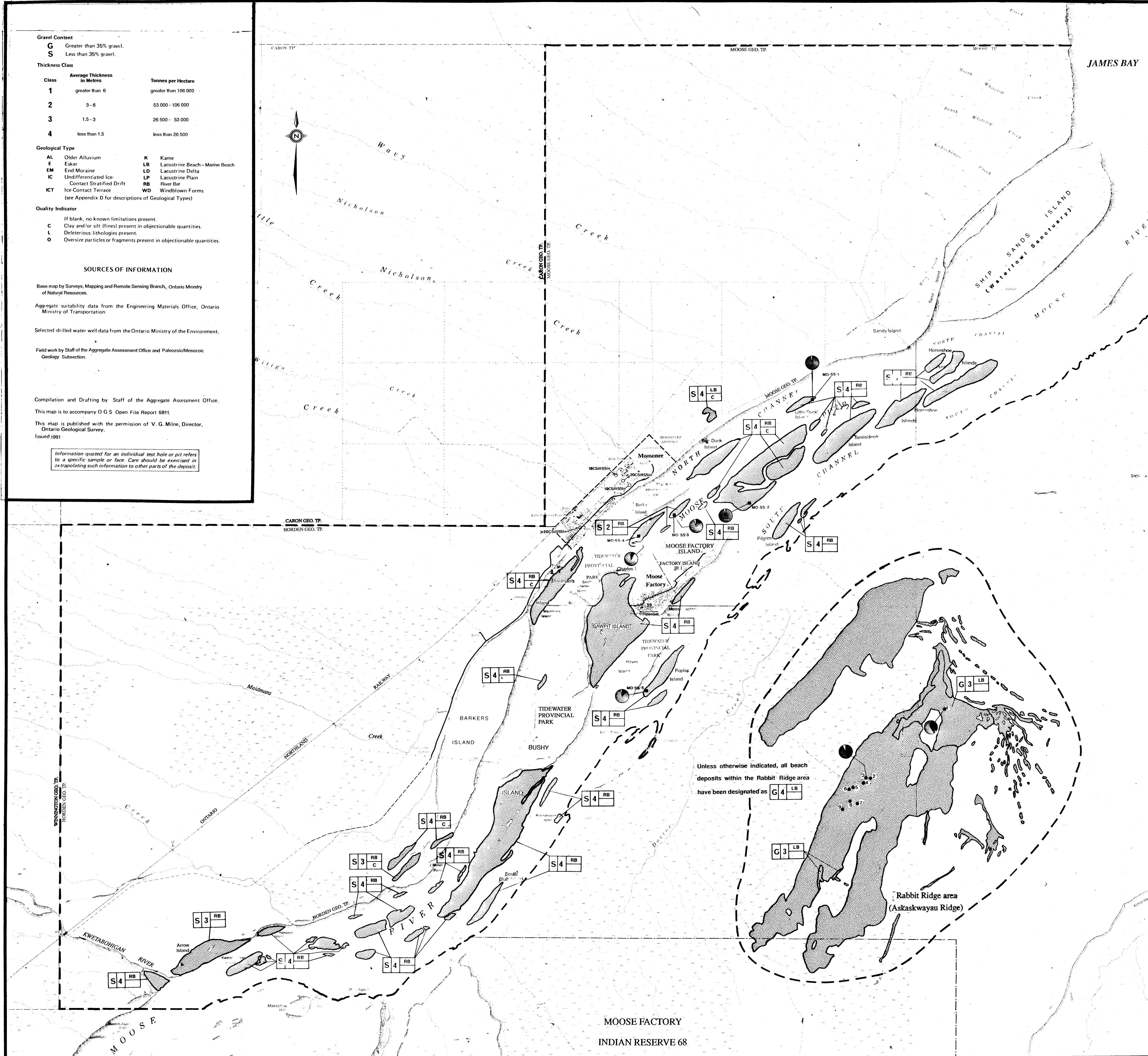
- Fines: silt and clay (< 0.75 mm)
- Sand (0.75 - 4.75 mm)
- Gravel (> 4.75 mm)

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

DEPOSIT SYMBOL

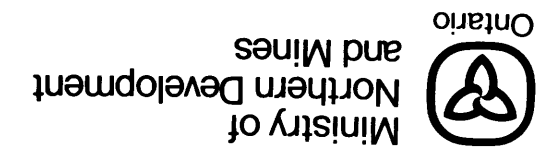
Gravel Content Geological Type
 Thickness Class Quality Indicator

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



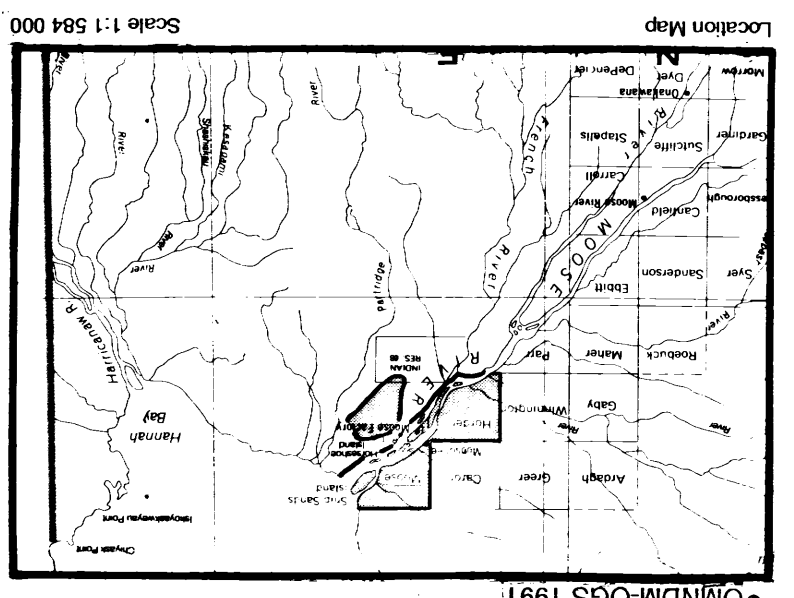
MOOSE FACTORY
 INDIAN RESERVE 68

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY
MOOSEEE AREA
MAP 2
SELECTED SAND AND GRAVEL
RESOURCE AREAS



Scale 1: 50 000
 0 1 2 Kilometres
 0 1 2 Miles

NTS Reference: 42 P/1, 42 P/2, 42 P/7, 42 P/8



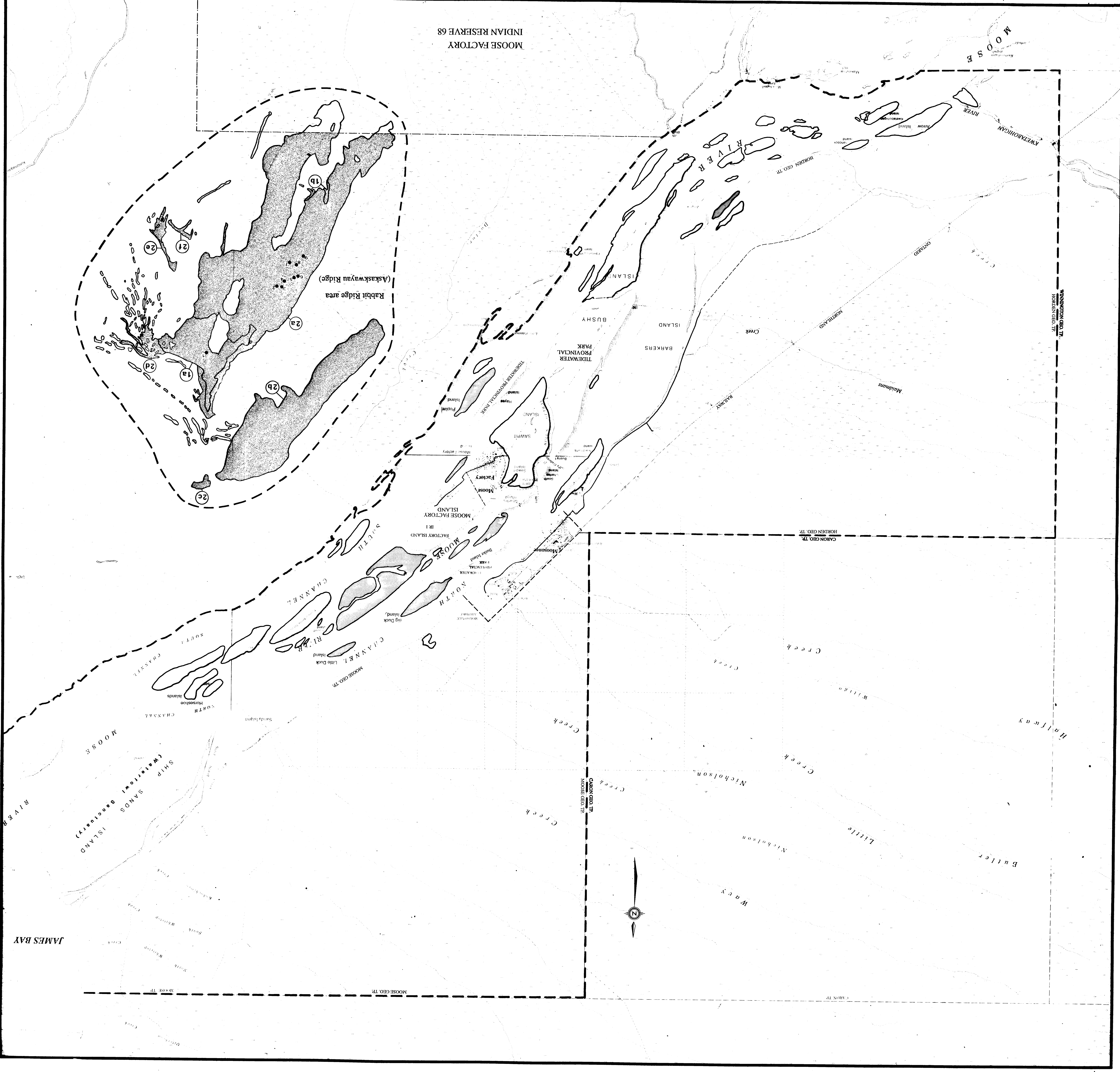
Location Map
 Scale 1: 504 000
 © OMNIM-GSS 1991

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

- MAP UNITS**
- Selected sand and gravel resource area, primary significance; deposit number, see Table 3.
 - Selected sand and gravel resource area, secondary significance.
 - Selected sand and gravel resource area, tertiary significance.
- SYMBOLS**
- Township boundary.
 - Project area boundary.
 - Geographic township within township boundary.
 - County, District, Regional or District Municipal boundary.
 - Community 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.
 - Extracted area of sand and gravel pits.
 - Sand or gravel pit; identification number; see Table 2.

SOURCES OF INFORMATION

Base map by Surveys, Mapping and Remote Sensing Branch, Ontario Ministry of Natural Resources.
 Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation.
 Selected dated water well data from the Ontario Ministry of the Environment, Geology Subsection.
 Field work by Staff of the Aggregate Assessment Office and Paleozoic/Mesozoic Geology Subsection.
 Completion and Drafting by Staff of the Aggregate Assessment Office.
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 This map is to accompany OGS Open File Report 8811.
 Issued 1991.



INDIAN RESERVE 68
 MOOSE FACTORY



MOOSONEE AREA

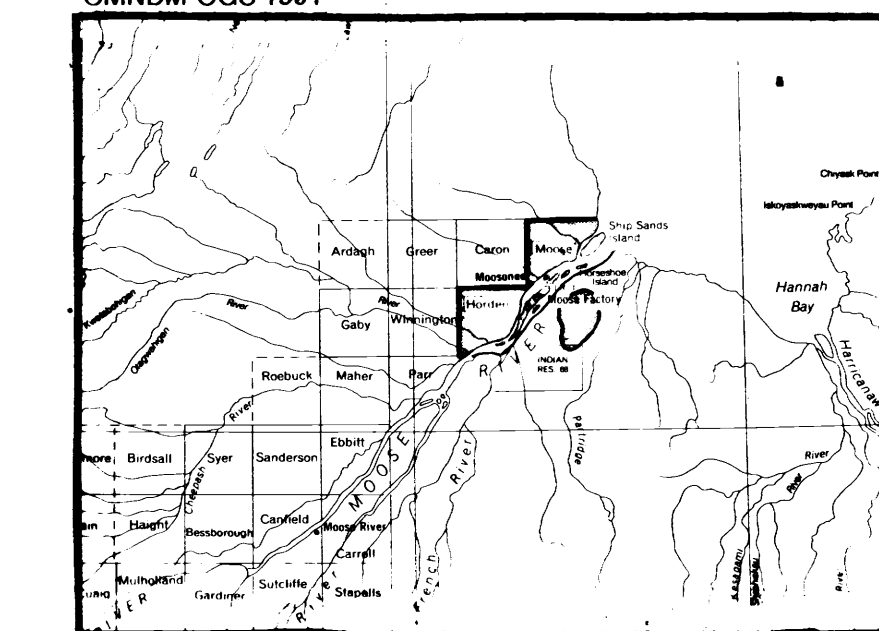
MAP 3
BEDROCK RESOURCES

Scale 1:50 000

Metres 1000 0 1 Kilometre

NTS Reference: 42 P/1, 42 P/2,
42 P/7, 42 P/8

SONMDM-OGS 1991



Location Map (Scale 1:1 584 000)

LEGEND

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

BEDROCK UNITS

PALEOZOIC

DEVONIAN

MIDDLE DEVONIAN

KWATABOHEGAN FORMATION

Limestone, dolomitic limestone and dolomite

LOWER DEVONIAN

STOOPING RIVER FORMATION

Cherty limestone with minor dolomitic limestone and dolomite

SYMBOLS

- Township boundary.
- Project area boundary.
- Geographic township boundary.
- County, District, Regional or District Municipal boundary.
- Community boundary.
- Park, reserve boundary.
- Geological formation boundary.
- Geological formation member boundary.
- Formation thickness boundary (see text).

- Selected bedrock resource area; deposit number; see Table 5.
- Extracted area of sand and gravel pits.
- Quarry; identification number; see Table 4.
- Isolated bedrock outcrop.
- Selected sample site, identification number, see Figures 7a-7b, Tables 6a and 6b.

SOURCES OF INFORMATION

Base map by Surveys, Mapping and Remote Sensing Branch, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation

Geology by: B.V. Sanford and A.W. Norris, 1975.

Additional field work by: Staff of the Aggregate Assessment Office and Paleozoic/Mesozoic Geology Subsection.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

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Issued 1991

