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ONTARIO MINISTRY OF NATURAL RESOURCES

State of the Aggregate Resource in Ontario Study (SAROS) Paper 5 - Aggregate Reserves in Existing Operations

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This report has been prepared in conjunction with MHBC Planning

REPORT

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Executive Summary

Mineral aggregate, which includes gravel, sand, clay earth, shale, stone, limestone, dolostone, sandstone, granite and other similar deposits, is one of the most vital commodities to the economy of Ontario. It is used to construct homes, schools, hospitals, offices, sewers, bridges and highways, with public infrastructure consuming the largest proportion. It is also used as an additive in the production of a wide variety of everyday materials, such as steel and glass. The consumption rate per capita has remained relatively constant in Ontario at approximately 14 tonnes/person/year. Aggregates are non-renewable and have few viable substitutes.

The aggregate demand and resulting consumption in the Greater Toronto Area (GTA) has remained relatively consistent over the years. However, the licencing of replacement reserves has not kept pace with this consumption, resulting in a 2.5 to 1 consumption to replacement ratio between the years of 1991 to 2009. In addition, more than two thirds of the licenced reserves supplying the GTA are more than 35 years old with reserve bases becoming depleted rapidly.

While the Aggregate Resources Act (ARA) offers some level of protection to licenced reserves, it is important to have an understanding of the relative amounts (volumes and/or tonnages) of those protected reserves in relation to the overall supply/demand relationship within the Province. To answer this question, the Ministry of Natural Resources (MNR) determined that a study on the availability of reserves within existing licenced properties was needed to address the question: what is the status of the licenced reserves in the central portion of southern Ontario? The State of the Aggregate Resource in Ontario Study (SAROS) was initiated and divided into six separate papers. The paper addressing the question related to the existing licenced limestone/dolostone reserve base (amount of reserves) in the central portion of southern Ontario is Paper 5 – Aggregate Reserves in Existing Operations. The scope of work for Paper 5 is comprised of the following tasks:

- determine the current estimated reserves of limestone/dolostone in licenced aggregate operations in selected geographic areas;
- determine areas of relative abundance and scarcity of construction limestone/dolostone aggregate reserves;
- map the current reserves and indicate location relative to potential market demand areas; and
- describe opportunities to maximize resource use within existing licences.

A total of 97 licenced aggregate quarries were evaluated with respect to their remaining reserves as of the end of 2008. These included all quarries within Areas 2, 3, 4 and a portion of Area 5 that have a licenced area of 20 hectares or greater.

The process for estimating the reserves at a particular property included a detailed examination of available imagery, site plans and other available site specific information, which would contribute to a reasonably accurate calculation of remaining reserves on the property. However, it should be noted that the volume and tonnage calculations are based on dimensions, distances and elevations provided on the Site Plan, and these calculations assume that all material is extracted and in turn is viable for aggregate production, and that no reserves are used for construction of internal haul roads, ramps or left in place as benches for rehabilitation.

Utilizing this method of analysis, it was found that the calculated licenced reserves of stone in the 97 limestone and dolostone quarries evaluated within the Study Area, total approximately 3.44 billion tonnes of variable quality. It is important to note that this total includes the full volume of rock found on these properties, both high and lower quality stone, and does not account for unusable by-products (silt sized fines) that are generated through the process, which can be as much as 10% of the total.

High quality stone is required for concrete and asphalt aggregates, and as such, are particularly important. Of the 97 quarries, only 30 quarries evaluated within the Study Area had site-specific geological information, of varying degrees of detail, available for review. The 30 quarries represent approximately 818 million tonnes, or 24**%** of the overall stone reserves evaluated. Of this total (818 million tonnes) approximately 62% or 505 million tonnes was estimated to be of 'high' quality (concrete and/or asphalt). The remainder of those reserves are considered to be of 'acceptable' (road base), 'low' or 'unknown' quality. Subject to a number of limitations with the remaining 67 quarries, for which site-specific geological information is not available, 968 million tonnes, or 37**%** of the overall stone reserves was estimated to be of 'high' quality. The remainder are considered to be of 'acceptable', 'low' or 'unknown' quality. As such, the total estimated amount of 'high' quality reserves is approximately 1.47 billion tonnes. It should be noted that of this total amount of 'high' quality reserves only a maximum of about two thirds, or 987 million tonnes, would be available for inclusion in concrete and asphalt grade products in the form of stone and manufactured sand. The remaining reserves would, through the process of generating concrete and asphalt grade stone, create a by-product such as granular road base.

As part of the evaluation of existing reserves in the Province, a limited assessment of the relative abundance and scarcity of those reserves was also carried out, both in relation to each of the CPCA Areas and with respect to a major market demand area of the GTA, specifically the Vaughan Corporate City Center (VCCC). The VCCC was selected as a reference point for the GTA due to its identification as a growth centre in the Province's Place to Grow Plan. It was found that approximately 2.41 billion tonnes of the 3.44 billion tonne total, is considered to be abundant, located within quarries where the reserve base is greater than 55 million tonnes. These data are summarized as follows:

CPCA Area	Reserve Totals (million tonnes)											
	Abundant				Moderate				Scarce			
	H*	A	L	U	H	A	L	U	H	A	L	U
2	206.9	55.6	0.0	0.0	117.1	108.4	69.1	62.6	55.9	19.9	5.9	4.4
3	191.8	286.3	237.0	77.8	141.4	25.8	25.6	0.0	62.7	14.3	10.8	1.2
4	65.0	0.0	0.0	0.0	37.6	4.9	0.0	0.6	10.1	1.0	0.0	0.0
5	447.1	427.0	348.5	65.7	104.1	34.4	0.0	35.6	33.5	27.2	10.6	6.1
Total	**910.9**	**768.9**	**585.5**	**143.4**	**400.2**	**173.5**	**94.7**	**98.8**	**162.2**	**62.4**	**27.3**	**11.8**

*H – High Quality, A – Acceptable Quality, L – Low Quality, U – Unknown Quality

Interestingly, these 'abundant' reserves are found within only 15 quarries, 12 of which are located more than 75 km from the Vaughan Corporate City Center. This indicates that approximately 70% of the reserve base that is considered to be 'abundant' is found in only 15% of the total number of quarries evaluated. The remaining 85% of the quarries have either a scarce or moderate reserve base. As such, it is clear that the majority of the reserves supplying the GTA market are coming either from moderate or scarce reserves. In addition, when annual tonnage limits and internal customer demand from these quarries are taken into consideration, annual available supply to the general market is further limited.

With the knowledge that the existing reserve base is being depleted at a greater rate than new licences are being granted in the Province, the question then becomes, how can the reserves that are currently licenced be maximized to the greatest extent possible? An evaluation of various options with respect to maximizing the existing reserves was also carried out as part of this paper.

The four options worthy of consideration are:

1) to reduce or eliminate regulatory setbacks;

2) remove road allowances where possible;

3) to extract to a greater depth; and

4) to maximize the importation of material for rehabilitation of the properties rather than using on-site reserves.

While not the answer to the demand/supply question, maximizing the reserves on an existing licenced property is a responsible method for resource management, to the extent that the surrounding natural environment and social receptors are not increasingly affected.

While the total resource base of 3.44 billion tonnes, appears to be a large number, it is important to understand that the majority of these reserves are not high quality stone and are located at greater distances from the market areas that are demanding them, with only approximately 902 million tonnes within 75 km of the Vaughan Corporate City Center. Only approximately 1.47 billion tonnes, of high quality reserves appears to be available to the Greater Toronto Area market, a maximum two thirds (approximately 987 million tonnes) of which would be available for concrete and asphalt grade stone and manufactured sand. Of this total only approximately 476 million tonnes, are located within 75 km of the Vaughan Corporate City Center. Considering that a maximum production of about two thirds of the total high quality reserves is achievable for production of concrete/asphalt grade stone and manufactured sand, this translates into approximately 317 million tonnes, available within a 75 km distance of the Vaughan Corporate City Center. This is provided graphically below:

Reserves that are considered to be 'abundant' are located within relatively few operations located at greater distances from the largest market demand area, the GTA. The supply to the GTA market area is coming from sites that are considered to have scarce to moderate reserves, which are being exhausted at a greater rate than they are being replenished through the granting of new licences by the Province. There will be an increasing reliance on the supply of aggregate from sources at greater distances as reserves close to the market are exhausted.

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1.0 INTRODUCTION

On March 25, 2009 the Ontario Ministry of Natural Resources (MNR) issued a Request for Proposal (RFP) for the purpose of evaluating the current status of the aggregate resources in the Province of Ontario. The study, labelled the *State of the Aggregate Resource in Ontario Study* (SAROS), was divided into six separate papers in order to examine this complex question. On April 30, 2009 the MNR selected Golder Associates Ltd. (Golder) in association with MHBC Planning Ltd. (MHBC) to carry out a portion of this study.

This report is focused on Paper 5 of the SAROS project and addresses the aggregate reserves in existing licenced limestone/dolostone operations in geographic Areas 2, 3, 4 and a portion of 5 as identified by the MNR (see Figure 1). The issue of remaining reserves on an individual property is a confidential topic that requires care when reporting the results of a study such as this. As such, detailed information on reserves for individual licences have been reported in Appendix A, which is to be removed prior to delivery to the general public. The MNR has provided the following explanation with respect to the selection of only limestone/dolostone quarries in Areas 2, 3, 4 and portions of 5 and also the confidential nature of the reserve information contained in this report:

> *Due to the short timeframe available for the completion of the SAROS report, it was necessary to scope down the parameters of the research. With respect to the reserve base examined as part of Paper 5, the approved Terms of Reference state: Reserve estimates will be scoped to Class 'A' licenced quarries and specifically to limestone/dolostone quarries in the Geographic Areas # 2, 3, and 5. Geographic Area # 4 was later included, and these four areas together constitute the predominant production region of the province.*
>
> *and*
>
> *As per Procedure No. A.R. 5.00.22 - Section 7.0 (Aggregate Resources Program: Policies and Procedures Manual): Certain types of an individual licensee's information are withheld under FIPPA (Freedom of Information and Protection of Privacy Act), Section 17 – Third-Party Information, and this includes: Production Data, Annual Licence Fee, etc. A detailed listing for each licenced property in their respective municipality is provided in Appendix A, and this appendix will be kept confidential by the Ministry of Natural Resources.*

Resource information has been summarized per Canadian Portland Cement Association (CPCA) Area and provided within the report. It should be noted that the Canadian Portland Cement Association is now known as the Cement Association of Canada (CAC).

The requirements of the RFP, which have been summarized below, are addressed in the following sections of the report.

1.1 Objectives

The general objectives for the SAROS project, as summarized from the RFP, are to:

- Provide updated base information about current licenced aggregate resources in Ontario;

- Provide information to support provincial, regional and municipal strategic planning for aggregate supply to meet long term demand;
- Provide a more definitive understanding of current supply and future aggregate resource constraints that may affect long term supply; and
- Provide a credible source book of information on aggregate resources available to the general public online.

These objectives were to be met following the scope of work outlined below in Section 1.2 for Paper 5.

1.2 Scope of Work for Paper 5

The detailed scope of work for Paper 5, as stated in the RFP, is comprised of the following tasks:

- Determine the current estimated resource reserves by selected commodity in licenced operations in selected geographic areas:
  - Reserve estimates will be scoped to Class 'A' licenced quarries and specifically to limestone/dolostone quarries in the CPCA Geographic Areas 2, 3, 4 and part of 5.
  - Provide discussion regarding licenced area versus extractable area and reduction in total available reserves due to setbacks, roads, processing area and benches in quarries.
  - Provide discussion on the factors affecting the process of estimating remaining reserves in licenced sites. Explain why sand and gravel deposits are the most difficult to estimate reserves.
- Determine areas of relative abundance and scarcity of construction aggregate reserves by the selected commodity for limestone/dolostone reserves.
- Map the current reserves and indicate location relative to potential market demand areas.
- Determine and describe opportunities to maximize resource use within existing licences (e.g., reduced setbacks, deeper extraction, import of stone/blending).

As part of the scope of work, MNR requested that a literature review be completed to compare the practices of other jurisdictions with those of Ontario. This literature review was to be completed with respect to comparing the level of protection afforded for licenced reserves and those that should be protected from sterilization in order to supply future demand.

1.3 Report Format

The report is divided into seven sections, the first being the introduction. Section 2 provides a background review of information that was available which discussed the protection of aggregate resources and reserves. This section describes examples of aggregate resource protection from Queensland Australia, the United Kingdom and California. Section 3 describes the process used for deriving the estimated reserves of licenced quarries in the central portion of southern Ontario, broadly defined as the 'Greater Golden Horseshoe' (GGH) surrounding the Greater Toronto Area (GTA) and the associated limitations. A summary of the results is provided in Section 4.

Section 5 is a survey of the areas of relative abundance and scarcity of aggregate reserves and resources in southern Ontario, while Section 6 provides a description of the mapping of reserves relative to market demand areas. Section 7 describes a number of opportunities to maximize resource use within Licenced areas, and Section 8 provides conclusions and recommendations.

1.4 Acknowledgements

The assistance of the following members of MNR staff is gratefully acknowledged:

- Brian Hollingsworth
- Stuart Thatcher
- John Friberg
- Josh Annett

and the Aggregate Resource Officers in the District offices.

2.0 LITERATURE REVIEW

This section provides a review of some of the available information related to the protection of aggregate resources and reserves in various jurisdictions outside of Ontario. This review was included in order to provide context with respect to the level of protection offered in the Province of Ontario. Within the broader scope of the SAROS project (see Section 1.1), developing an understanding of a variety of processes used in other jurisdictions to identify and classify resources, and more importantly, permitted reserves, is important in any discussion of determining levels of protection of aggregate resources and reserves in Ontario. At present, the Province of Ontario provides a degree of protection to licenced reserves under provisions of the Aggregate Resources Act (ARA). However, some jurisdictions outside of Ontario have extended a level of protection to identified, but currently non-permitted, resources as well.

While licenced reserves are somewhat protected in Ontario, it is important to determine the amounts (volumes and/or tonnages) of the licenced reserves protected in order to have a sound understanding of the overall supply/demand relationship, and to provide a basis on which to consider a level of protection of non-licenced resources. A primary purpose of Paper 5 is to calculate licenced reserves of limestone and dolostone quarries within defined geographic segments of southern Ontario. However, to gain an understanding of various methods of protecting licenced reserves and non-licenced aggregate resources, it is prudent to review resource and reserve identification and protection strategies in other jurisdictions outside of Ontario, particularly as they relate to defining amounts of resources and reserves.

2.1 Overview

Four components or key policy objectives of aggregate resources planning and regulation are:

- recognition of primary aggregate resources as valuable, and the identification and protection of those resources;
- protection of surrounding environmental and cultural communities;
- rehabilitation of extractive operations; and
- efficient utilization of primary resources and the recycling / re-use of secondary resources.

(British Geological Survey, 2005; Baker & Hendy, B., 2005)

The first component of aggregate resources planning, the recognition, identification and protection of the resource, is the focus of this overview. Furthermore, the importance of a strong geoscience basis, on which this component is developed and implemented, is essential for its success (Stevens & Langer, 2005; Commission of the European Communities, 2008).

There is a considerable amount of literature discussing the safeguarding or protection of aggregate resources from sterilization. For example, Langer (2002) summarized attempts in a number of U.S. States and elsewhere, although they are limited in number and resulted in mixed success. However, Queensland Australia, California and the United Kingdom (U.K.) have been cited as having some success and, as such, are the focus of the following sections.

2.2 Aggregate Resource Planning Examples

The following examples of resource planning in jurisdictions outside of Ontario are provided in the following sections.

2.2.1 Queensland Australia

One response to the resource sterilization issue, brought on in part by a lack of coordination in land-use planning decision-making, is the concept of the identification of "Key Resource Areas" (KRAs), which has been implemented in Queensland Australia for the protection of resources identified as having regional significance (Stevens & Langer, 2005). Applicable primarily in rural areas, KRAs protect not only the reserves of existing operations and identified resources, and transportation corridor or haul routes, but also delineate a separation area or buffer around both. The separation distances are variable and are used as a trigger for evaluating potentially incompatible development. Examples of these separation distances/buffers are:

- 1000 m from the boundary of an existing operation or known resources where blasting or crushing is or would be involved;
- 200 m from the boundary of an existing operation or known resources where no blasting or crushing would be involved; and

- 100 m from each side of a transportation corridor or haul route.

These distances can be modified based on site-specific conditions such as topography or proximity to residential settlements as site specific studies warrant.

A formal policy recognizing KRAs was adopted by the State of Queensland in 2007 as State Planning Policy 2/07 Protection of Extractive Resources, as a statutory instrument under the Integrated Planning Act (Queensland Government, 2007), and states in part:

> "The Policy outcome is to identify those extractive resources of State or regional significance where extractive industry development is appropriate in principle, and protect those resources from developments that might prevent or severely constrain current or future extraction when the need for the resource arises."

The locations of a total of 100 KRAs are identified in the Policy, and large-scale mapping of each of the individual KRAs is included in the document. The Resource Processing Area, the Separation Area and the Transportation Route are delineated for each KRA. Also identified in the State Planning Policy 2/07 document are the KRAs with State biodiversity values (Queensland Government, 2007).

2.2.2 California

As required under provisions of the State's Surface Mining and Reclamation Act (SMARA) of 1975 (California Department of Conservation, 2007), the California Geological Survey and its predecessor organization have published a series of open file reports to classify aggregate and other mineral resources in California Counties (Dupras, 1999; Busch, 2001; etc.). SMARA mandated a two-phase 'classification-designation' process, with the objective of ensuring that aggregates and other construction materials are available when needed, and are not made inaccessible during land-use decision-making actions (Dupras, 1999). The classification phase includes the determination of study boundaries, establishment of Mineral Resource Zones (MRZ), identification of Aggregate Resource Areas (ARAs), calculation of resource tonnages within ARAs, a forecast of 50-year needs and the life-expectancy of current permitted reserves and identification of alternate resources. Upon receipt of the classification information, the open file reports, lead agencies (Counties, Cities, Towns, federal and state departments owning lands, etc) have 12 months to recognize the information (including mapping), and incorporate mineral resource management policies into their planning documents (Busch, 2001). SMARA also requires periodic review, every 10 years following the census, for updating as required (Kohler, 2006b).

Maps included in each open file report typically include (Dupras, 1999):

- Plate 1: Generalized Geologic Map – including both bedrock and surficial features;
- Plate 2: Selected Historic and Active Mining Operations – with a listing of name, current activity, operator, commodities produced and acreage, and areas of portland cement concrete (PCC) and asphaltic concrete (AC), grade of the aggregate operations, base aggregate operations, construction sand operations, fill material operations and clay operations identified;
- Plate 3: Mineral Land Classification of PCC – grade of the Aggregate Resources with a series of 'Mineral Resource Zones (MRZ) identified:

- MRZ-1 – areas where no significant mineral deposits are present and areas of mined-out PCC-grade aggregate resources
- MRZ-2 – areas where significant mineral deposits are present or a high likelihood of presence exists
- MRZ-3 – areas containing mineral deposits (unevaluated)
- MRZ-4 – areas that cannot be assigned to another MRZ

■ Plate 4: Areas Zoned MRZ-2 for PCC-grade Aggregate with:

- MRZ-1 – mined-out PCC-grade aggregate resources
- MRZ-2 – areas where significant mineral deposits are present or a high likelihood of presence exists (urbanized areas and other constraints have not been excluded from the MRZ-2 zoning)

■ Plate 5: Areas Zoned MRZ-2 for PCC-grade Aggregate with:

- MRZ-1 – mined-out PCC-grade aggregate resources
- MRZ-2a – areas where PCC-grade aggregate is currently being mined
- MRZ-2b – areas where significant mineral deposits are present or a high likelihood of presence exists (urbanized areas and other constraints have not been excluded from the MRZ-2b zoning)

■ Plate 6: Aggregate Resource Area (ARA) Map and Active PCC-grade Aggregate Operators with a series of individual 'Aggregate Resource Areas' (ARA) identified:

- ARA (red) - MRZ-2b areas with land-use and other constraints applied
- ARA (blue) – MRZ-2a areas with an active PCC-grade aggregate operator

with a listing of operator and operation names, acreage and estimated tonnage of resources for (ARA (blue) areas, acreage is listed but permitted reserves are identified as "proprietary data"

■ Plate 7: ARA Resources Within 100-year FEMA Floodplain Areas, with:

- ARA (red) identified
- ARA (blue) identified
- FEMA Areas identified as being within a 100-year Floodplain

with a listing of operator and operation names, acreage and estimated tonnage of resources within the 100-year floodplain; for ARA (blue) areas, acreage is listed but permitted reserves within 100-year floodplain are identified as "proprietary data"

■ Plate 8: Mineral Land Classification for Kaolin Clays, with:

- MRZ-2a – areas where kaolin clays resources are measured or indicated as being present and are of prime importance

- MRZ-2b – areas where kaolin clays resources are inferred as being present, and may be upgraded to MRZ-2a through further exploration or changes in technology or economics
- MRZ-3 – areas where kaolin clays resources are inferred as being present, but of undetermined significance, and may be upgraded to MRZ-2a or 2b

While PCC-grade aggregate resources are identified specifically, AC-grade aggregates are also included in this category. Where other mineral resources are present, mapping of those resources is included, as in Plate 8 above. For example, gold is a significant resource in some Counties, and such resources are identified (Busch, 2001). To be considered 'significant' (i.e., MRZ-2), a mineral deposit must meet established marketability and threshold value criteria adjusted for inflation. For construction aggregates, the threshold value in 1999 dollars (US) was $12,776,000 (Dupras, 1999; Busch, 2001).

Each ARA identified on the mapping (some under 40 ha) is described in some detail in the supporting open file report, including estimated overburden depth, estimated minable thickness, and estimated waste material (silt, clay, etc.) proportion. Estimated tonnages are then calculated using an appropriate density factor. ARA tonnages are then reduced where the ARAs fall within the 100-year flood plain.

In one particular County (Dupras, 1999), and based on 50-year demand forecasting that is beyond the scope of this report (Paper 5), it was estimated that permitted reserves of PCC-grade aggregate would be depleted by 2004. Further, assuming that all aggregate resources identified in the ARAs was mined, there would be enough aggregate to meet demand until 2017.

The regional open file reports have provided the basis for development of the map of *Aggregate Availability In California: Fifty-Year Demand Compared to Permitted Aggregate Resources* – "Map 52" (Kohler, 2006a) and the accompanying report, Map Sheet 52 (Updated 2006) *Aggregate Availability In California* (Kohler, 2006b). Each study area for which an open file report has been completed is categorized on the basis of the proportion of permitted reserves compared to the estimated 50-year demand. Study areas with less than 10 years of potential resources and less than five years of permitted reserves remaining are flagged (Kohler, 2006a), but it is noted that such estimates can quickly change. For example, if a 'depleted' County starts to import aggregate from another region (Kohler, 2006b) the California supply - demand structure is designed such that if a nearby County becomes depleted, it will change the scenario of the first County, because it must now provide materials to the second County as well as meet its own needs. Therefore the supply is used up more quickly than would be forecasted by the in-County demand.

A total of 31 study areas are included covering about 25% of the State, however this area accounts for about 90% of the population (Kohler, 2006b). Within the context of Map Sheet 52, 'aggregate' refers to reserves of the higher quality PCC-grade and AC-grade materials. A total of about 3.9 billion tonnes (approximately 4.3 billion tons) of permitted reserves is identified within the 31 study areas, but 25 of these areas have less than one-half of the permitted reserves they are projected to need to meet the 50-year demand (Kohler, 2006b). In addition, a total of about 67 billion tonnes (approximately 74 billion tons) of non-permitted resources has been identified within the 31 study areas, but it is noted that it is unlikely that these resources would be utilized due to social, environmental or economic factors (Kohler, 2006b).

Between the release of the first Map Sheet 52 in 2002 and the 2006 update, permitted reserves declined by 2.3 billion tonnes (approximately 2.5 billion tons), about one-half of which was consumption with the remainder due to revised rehabilitation plans, mine closures, new regulations, haulage restrictions and natural changes in deposit quality. The proportion of permitted reserves relative to overall demand did increase over the 2002 to 2006 period; however only one of the 31 study areas has enough permitted reserves to meet or exceed its projected 50-year demand as of 2006, down from six areas in 2002 (Kohler, 2006b).

2.2.3 United Kingdom

Unlike other jurisdictions, the government of the United Kingdom (U.K.) has national objectives and national policies for minerals planning, including the definition and protection of Mineral Safeguarding Areas (MSAs) and associated storage, handling and processing facilities for bulk transport of minerals (McEvoy, et al, 2007). MSAs are defined as areas of known mineral resources that are of sufficient economic or conservation value to warrant protection for generations to come, so that they are not needlessly sterilized (McEvoy, et al, 2007). While applicable to all minerals, aggregates are most frequently identified as MSAs. National and Regional Guidelines for Aggregates Provision in England have been published and updated since 1994 (Office of the Deputy Prime Minister, 2006; Dept. of Communities and Local Government, 2008), and provide information to planning authorities in order to effectively address geographical imbalances between the supply of, and demand for, aggregates at the national level.

McEvoy, et al (2007) suggests the following approach, to be undertaken by Mineral Planning Authorities, in order to safeguard mineral resources in the U.K.:

1) evaluate the best geological and resource information available;
2) decide which minerals are, or may become, of economic importance in the foreseeable future;
3) decide on how the physical extent of resource areas to be safeguarded should be determined (based on robust and credible scientific evidence);
4) incorporate the results of steps 1 to 3 into a planning policy in which MSAs are identified and designated in a planning document;
5) decide how MSAs will be effectively used to safeguard mineral resources, including identifying potential scenarios for exemption; and
6) decide whether Mineral Consultation Area (MCAs) will be established to protect storage, handling and processing facilities for bulk transport of minerals.

In evaluating development proposals, MSAs are considered with other environmental and cultural designations. The provision for buffers around MSAs, to protect nearby residents and protect the resource from sterilization, is encouraged by the policy. For example, one jurisdiction agreed upon minimum buffer limits and incorporated them into its plan (McEvoy, et al, 2007):

- 500 m for quarries (blasting required);
- 250 m for quarries (no blasting required) and sand & gravel pits;
- 50 m for brick clay pits; and

- 0 m for underground gypsum mines.

The concept of 'landbanks' is an integral component of mineral resources planning in the U.K. Landbanks are areas of mineral resources for which approvals have been gained, and are available for extraction (Dept. of Communities and Local Government, 2006). U.K. Landbanks are analogous to Mineral Resource Zones (MRZ-2a) in California, Key Resource Areas (KRAs) of existing operations in Queensland Australia and licenced reserves in Ontario.

2.3 The Ontario Comparison

A comparison of California's Mineral Resource Zones (MRZs) and Aggregate Resource Areas (ARAs), Queensland's Key Resource Areas (KRAs) and the U.K.'s 'landbanks' and Mineral Safeguarding Areas (MSAs) to Ontario's Aggregate Resource Inventory Papers (ARIPs) is an informative one. The ARIPs provide a basis for including aggregate resource mapping in Official Plans, and the Provincial Policy Statement (PPS) of 2005 states that aggregate resource planning and management policies in Official Plans 'shall be consistent with' the PPS. Distribution of the California Mineral Land Classification (MLC) reports, for example, triggers a time limit within which to recognize the classification information (including mapping), and incorporate mineral resource management policies into planning documents prepared by the lead agencies. This includes both permitted reserves and non-permitted resources.

As previously noted, the Province of Ontario provides a degree of protection to known deposits under the provisions of the ARA and PPS.

Existing licenced reserves can be affected by incompatible surrounding land uses. The encroachment of incompatible land uses to areas surrounding existing licenced reserves can limit the operation and potential expansion of existing operations. The PPS contains policy intended to limit incompatible land uses in areas surrounding existing licenced reserves:

> *Mineral aggregate operations shall be protected from development and activities that would preclude or hinder their expansion or continued use or which would be incompatible for reasons of public health, public safety or environmental impact. Existing mineral aggregate operations shall be permitted to continue without the need for official plan amendment, rezoning or development permit under the Planning Act. When a licence for extraction or operation ceases to exist, policy 2.5.2.5 continues to apply. (Policy 2.5.2.4)*

The establishment of new operations can also be affected by incompatible development. Incompatible land uses located within areas of known deposits or adjacent to these deposits can preclude or hinder the development of the aggregate resource. The PPS contains policy intended to limit the development of incompatible land uses in areas of known deposits:

> *In areas adjacent to or in known deposits of mineral aggregate resources, development and activities which would preclude or hinder the establishment of new operations or access to the resources shall only be permitted if:*
>
> A) resource use would not be feasible; or

B) the proposed land use or development serves a greater long-term public interest; and

C) issues of public health, public safety and environmental impact are addressed. (Policy 2.5.2.5)

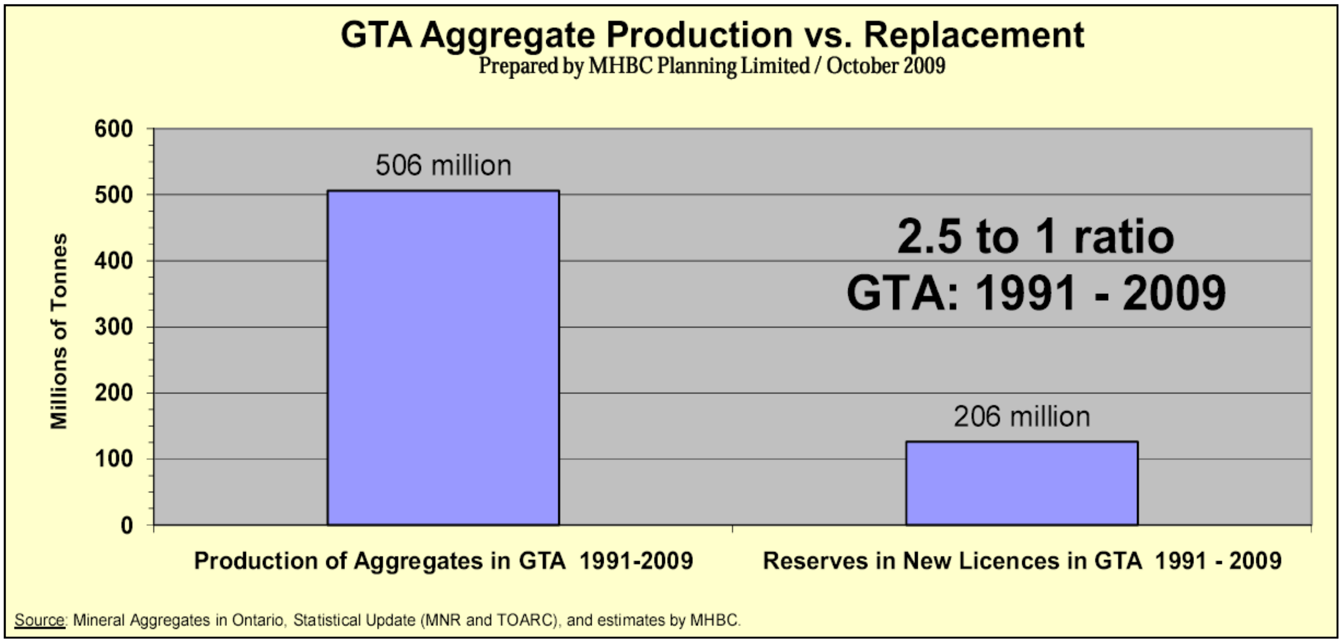
As described in Section 2.2, other jurisdictions have recognized the strategic value of aggregate resources, and have provided a degree of protection to non-permitted resources. The protection of resources in Ontario would be enhanced by the following:

- formal recognition of identified 'high priority' aggregate resource areas of known quantity and quality (based on sound geoscientific investigation); and
- formal acceptance of high priority aggregate resource areas within which licence applications would be encouraged (or at least not unduly hindered), and the linkage of such high priority areas to market demand areas.

It is important to determine the amounts (volumes and/or tonnages) of the licenced reserves protected in order to define the overall supply/demand relationship. Section 3.0 provides a detailed process for the estimation of licenced reserves and the calculations undertaken for limestone and dolostone quarries within specific geographic areas of southern Ontario based on sound geoscientific principles. In the section below (Section 2.4) a discussion on the seriousness of the depletion of reserves in comparison to new licences being granted in the GTA is outlined in order to provide context with respect to the literature review provided above.

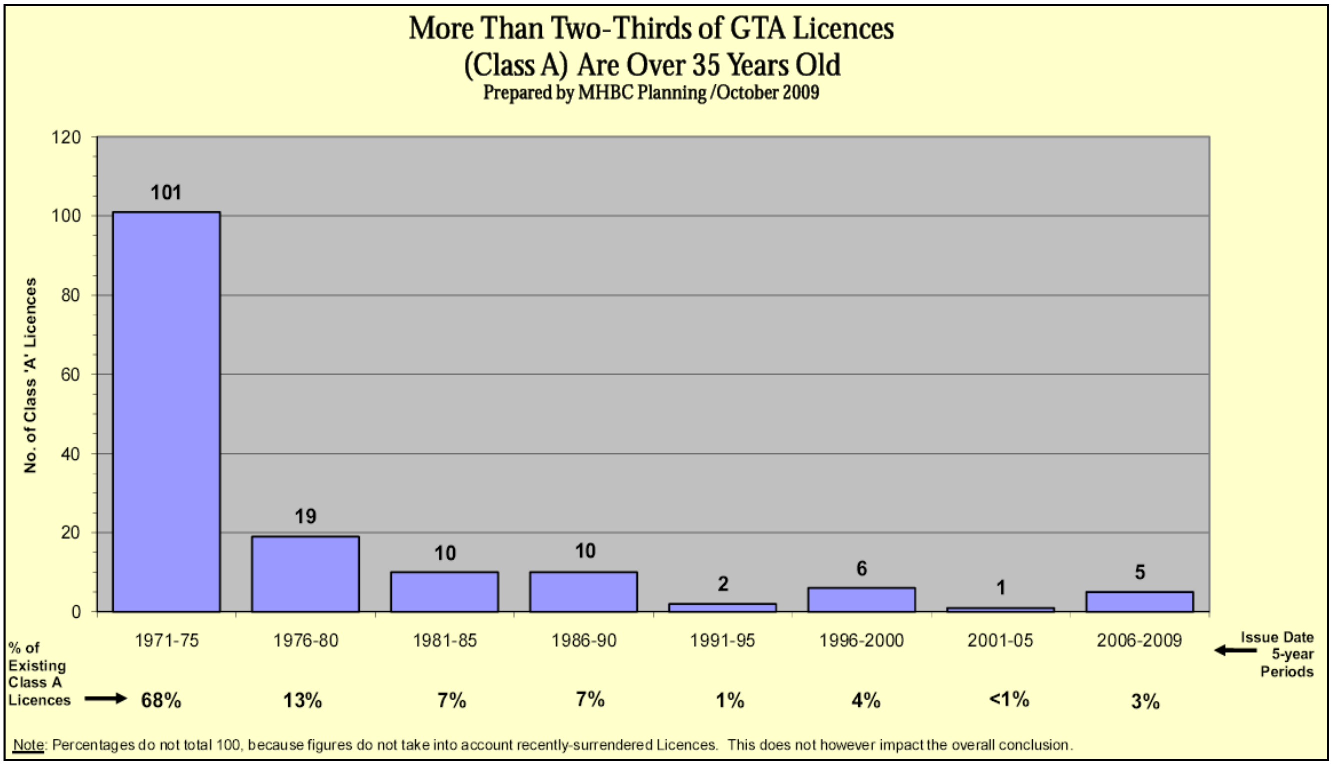
2.4 Aggregate Production versus Replacement in the GTA

The aggregate demand and resulting consumption in the GTA has remained relatively consistent over the years, averaging approximately 14 tonnes per person per year; however, the licencing of replacement reserves has not matched pace with this consumption, resulting in a 2.5 to 1 consumption to replacement ratio between the years of 1991 to 2009. The following graphic depicts the issue clearly (source - MNR/TOARC, 1991-2008: Statistical Updates; MHBC, 2009: historical/ongoing review of file information at MNR Aurora office and personal communications with MNR Aurora staff):



This issue has been ongoing for almost 20 years and is only increasing in seriousness as the regulatory environment in Ontario becomes increasingly difficult with respect to licencing new resources.

To emphasize this point, more than two thirds of the licenced reserves supplying the GTA are more than 35 years old, with reserves having become depleted rapidly in comparison to licences that have recently been granted. This is displayed graphically below (source - MHBC, 2009: historical/ongoing review of file information at MNR Aurora office and personal communications with MNR Aurora staff):



This information provides the context for the following sections on remaining reserves in the majority of the quarries that were assessed as part of this study.

3.0 METHODOLOGY FOR ESTIMATING RESOURCE RESERVES

A main component of the study for Paper 5 included the estimation of remaining reserves in licenced limestone/dolostone quarries in the central portion of southern Ontario, broadly defined as the 'Greater Golden Horseshoe' (GGH) surrounding the Greater Toronto Area (GTA). All quarries located within Areas 2 and 3 were included in the study in addition to those located in Area 4 at the request of the MNR. A portion of Area 5 was also included and together these areas comprised the Study Area for the purpose of this report (see Figure 1). It should be noted that a total of 97 licenced sites were evaluated with areas greater than 20 ha. Individual quarries of less than 20 ha were not evaluated.

3.1 Overview

A total of 97 licenced aggregate quarries were subject to evaluation of licenced reserves (see Figure 2). These included all quarries within Areas 2, 3 and a portion of Area 5 with a licenced area of 20 hectares or greater. In addition, five licenced quarries in Area 4 (one quarry has two Licences combined on one Site Plan, and is considered a single operation) were also included in the evaluation due to their proximity to the GGH market area. With regard to Area 5, only the quarries in the southern portion were included in the Study Area (see Figure 2). A large portion of Area 5 was designated under provisions of the Aggregate Resources Act (ARA) on January 1, 2007. As such, the generation of Site Plans for each of the licences is incomplete at this time. The evaluations were undertaken using the approved Site Plans for each of the quarries (as supplied by MNR), recent ortho-photo imagery of each of the quarries from 2006 to 2008 and annual production data from 2006 to 2008. Production data were used to reduce licenced reserves to a common time period for all of the quarries to the end of the 2008 operating season. The process and the results are described in greater detail in the following sections.

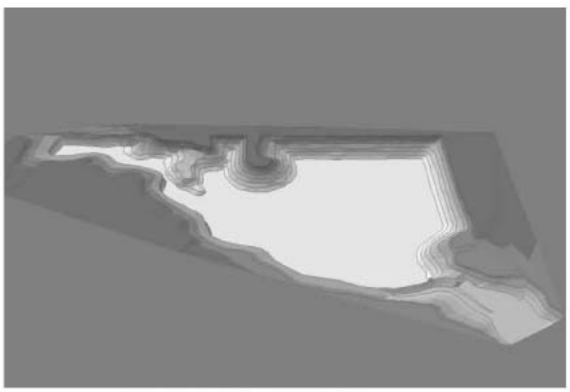
It should be noted that the volume and tonnage calculations are based on dimensions, distances and elevations provided on the Site Plan. The calculations assume that all material is extracted and, in turn, is viable for aggregate production. No allowance for structural geological disruptions such as faults, undulating top of bedrock surface or contact between beds of different quality has been accounted for. This information is very site specific and would require a detailed geological evaluation of the reserves on a site by site basis. In addition, waste factors that are inherent with processing of aggregate have not been accounted for in this process. Also, the requirement for retention of aggregate material on a property for the purpose of rehabilitation has not been addressed and has not been removed from the total reserve estimate.

3.2 Process of Reserve Estimation

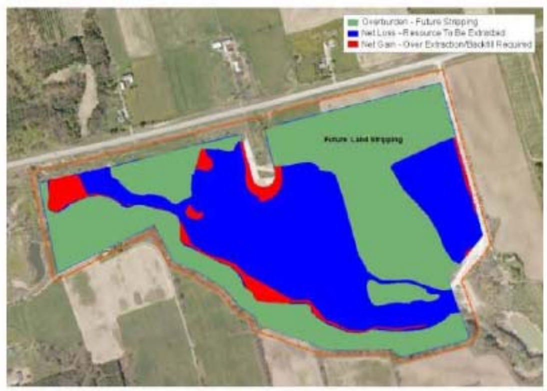
The process for estimating the reserves at a particular property included a detailed examination of available imagery, site plans and other information which would contribute to a relatively accurate calculation of remaining reserves on the property. The steps taken during the evaluation of the quarries is summarized on the following series of diagrams:

A) Site Plan - post-extractive topography

B) Imagery with features



C) Digital terrain model



D) Digital model - licensed reserves

This process is described in detail in Section 3.2.4.

3.2.1 Imagery

Recent orthophoto imagery, the dates of which ranged from 2006 to 2008, for each of the quarries in the Study Area was supplied by MNR in digital format. The imagery was used to capture identifiable features such as roads, boundary lines and quarry faces and was compared to the Site Plans for the property, which, in general, predated the date of the image supplied for the property.

3.2.2 Site Plans

The 'current' Site Plans, as required for each licenced aggregate property in Ontario under provisions of the ARA, are on file at MNR District offices, and were provided by MNR for use in the study. It should be noted that the Site Plans ranged in age from 1992 to 2009, thus resulting in a wide range of 'current' conditions as well as a range in the evolution of site planning development practices.

The pages of each Site Plan were digitized for use in the study using a large format scanner. The digital Site Plan images were then georeferenced to exact locations and overlaid on the imagery in order to delineate the Licence boundaries, setback limits, and other features, usually from the Existing Features sheet. Georeferencing was based on roads, lots/concession, property boundaries, and identified features from MNR's Natural Resources and Values Information System (NRVIS) data sets using Universal Transverse Mercator (UTM) grid coordinates.

Where overburden depths were identified on a particular Site Plan, the average of such depths was used to calculate volumes. If such information was not available, other sources (i.e., drift thickness mapping, water well records, OGS mapping etc.) were used.

3.2.3 Other Information

For sites where overburden depths were not available, the Ontario Geological Survey's (OGS) 'drift thickness' data (OGS, 2007) was used as an approximation. This data set was created from NRVIS Digital Elevation Model (DEM) and OGS interpolated bedrock surfaces, and overburden thicknesses for sites within the Study Area were found to range from 0.5 m to 22 m.

For a limited number of the Licenced properties, notably newer operations, hydrogeological, planning and development and/or resource inventory reports were provided. Information from these sources was used to identify water table elevations and specific rock formations being extracted.

3.2.4 Information Processing

An example of the process of incorporating the spatial information described in the above sections (see Section 3.2) is summarized below:

A) a portion of the Site Plan was digitized, including the Existing Features and Final Rehabilitation sheets with topography;

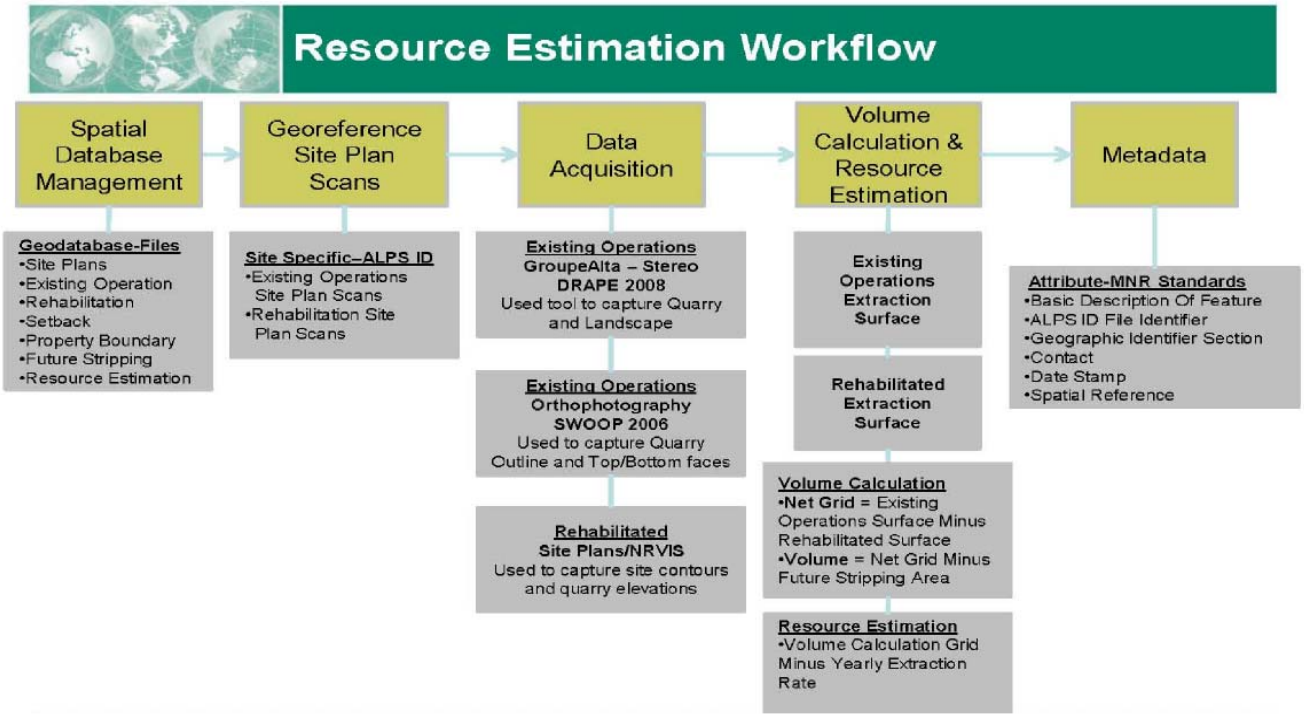
B) imagery with georeferenced Site Plan features – Licence boundaries (brown), setback boundaries (blue) and post-extractive contours (red);

C) creation of the Digital Terrain Model (DTM) based on Site Plan's post-extractive contours exclusive of backfilling representing the maximum extent of extraction; and

D) creation of the Digital Model of Licenced Reserves with Green representing land to be extracted after stripping (less volume of overburden); Blue representing land extracted; and Red representing land to be backfilled as part of rehabilitation.

Reference can also be made to the series of diagrams in Section 3.2 above as an example of a particular site.

This process is also provided graphically as follows:



Calculations were then carried out for the volume of overburden to be stripped, and the volume of stone to be extracted to the depths specified on the Site Plan.

3.2.5 Calculations of Remaining Reserves

The net volume of licenced reserves (gross volume of the solid stone less overburden volume) for each of the sites in the Study Area was calculated using the process described in Section 3.2.4 above. However, since these volumes were derived from imagery spanning several years (2006, 2007 and 2008), it was necessary to update the volumes to a common time period and, as such, the end of the 2008 operating season was chosen and termed the '2008 Remaining Reserves'. Tonnages extracted in 2006, 2007 and 2008 for each aggregate quarry in the Study Area were supplied by MNR and used to reduce the calculated net volumes to the 2008 Remaining Reserve volumes. Since the imagery was acquired in the spring of each year, either before or soon after the start of the operating season, the production for that year, plus any succeeding year(s), was deducted.

The production tonnages were converted to volumes using a constant density factor value of 2.75 tonnes per cubic metre of solid stone. This constant value is an approximate average of the densities of dolostone and limestone, and is a generally accepted value for solid limestone/dolostone density in the absence of site specific values. For example, to derive the 2008 Remaining Reserve volumes using 2006 imagery, the 2006, 2007 and 2008 production tonnages were converted to cubic metres of solid stone and subtracted from the net volume of unextracted solid stone calculated from the imagery.

Thus, the total 2008 Remaining Reserve volumes represent estimates of licenced stone resources remaining in the aggregate quarries within the Study Area at the end of the 2008 operating season, essentially as of January 01, 2009.

3.3 Field Verification and DTM Test Sites

To verify the validity of the reserve estimation process used, a sample of 11 quarries, generally of 60 hectares or more in licenced area, was subjected to field verification visits. These properties were labelled internally as 'field verification sites' to distinguish the extra work that was carried out on them. The intent of the visits was to verify that features, such as the active quarry face(s), captured using the process, based on Site Plans and imagery as augmented by the GroupeAlta DTM tool, were correct. The quarries were selected on the basis of geographic area, production activity and size in order to provide as broad a cross-section of licenced quarries as possible. The sites were located in the Niagara, Hamilton, Halton, Simcoe-Kawartha and Peterborough areas. Those quarries visited are identified in Table A.1 by a symbol after the Licence Number and the general locations are provided on Figure A.2 in Appendix A.

The field verification teams, consisting of two experienced professionals, used Trimble TDS Recon hand-held GPS units to delineate the active face(s) of the quarries. This field work was carried out over a period in early September of 2009. The GPS units were loaded with the imagery and Site Plan for each individual quarry for reference purposes. After the field verification visits, the GPS units were downloaded by those who were carrying out the volume calculations. The active quarry face(s) were then compared to those identified on the imagery.

Based on the results gathered at the field verification sites, it is clear that the data obtained using hand-held GPS units significantly improved the timeliness of reserves calculations over use of the Site Plans and imagery alone, particularly with regard to delineation of active faces. The major limitation of GPS verification is that, while the level of horizontal (x,y) accuracy is relatively high, vertical (z) accuracy is not. Thus, determination of elevations of unstripped and stripped areas (for overburden calculations) and quarry floors (for reserve calculations) is not substantially improved.

A sample of 15 quarries in the Study Area, primarily in Area 5, was also used to test a recently developed process of determining pre-and post-extractive topography by remote means. To complete this exercise, Golder contacted GroupeAlta to gain access to their digital terrain modelling (DTM) tool using recent imagery for the fifteen sites. These properties were then labelled internally as the 'DTM test sites'. It is important to note that two licenced quarries were subject to both field verification and DTM processing which allowed for a comparison of all three methods of evaluation.

The DTM test sites, primarily in the eastern portion of the Study Area, are identified in Figure A.2. The imagery used for the test was originally flown for MNR in 2008 (DRAPE 2008) and has stereo capabilities. Measurement accuracy is dependent on the imagery specifications, but ranges from 50 cm to 65 cm vertically, and ± 20 cm horizontally.

For each DTM test site, the following data were acquired:

- Location of 'current' (2008), but not necessarily active, faces;

- Spot elevations on unextracted portions of the quarry; and
- Spot elevations on the quarry floor.

Based on the results at the DTM test sites, use of the DTM tool was found to significantly improve the accuracy of reserves calculations over just the use of the Site Plans and imagery alone. It was also determined that the DTM tool identified errors in the topographic information depicted on some of the Site Plans. The major limitation of the DTM tool is that it is based on imagery that may be out of date, particularly with regard to a high level of extractive activity.

3.4 General Limitations of Reserve Calculations

There are a number of limitations that have to be considered when calculating reserves based on a desktop review process, as was conducted for this study. The varied age, formats and content of the Site Plans for the licenced properties that were used in the study, created a number of issues requiring resolution on an individual site basis. As well, variable imagery dates were also considered to be limiting factors, although these were able to be rectified to a large degree through the use of production data to update the volumes to a common time period at the end of the 2008 production season.

A number of Site Plans for quarries in the Study Area used only elevation data (spot elevations, contour lines) relative to a given benchmark, and not to an established geodetic datum (i.e., metres above sea level). This created difficulties in determining overburden depths and quarry floor or post-extractive elevations, and thus volumes of reserves, particularly if the given benchmark was not at ground level. In such examples, an assumption had to be made regarding the height of the benchmark above ground level. This only occurred when the benchmark was referenced to be the fencepost on the property and, as such, the height of the fence post was assumed to be 1.5 m.

In the absence of other, more reliable, elevation data (i.e., a DTM test site), an approximate geodetic elevation was derived by comparing a relative spot elevation or contour line on the Site Plan to a NRVIS geodetic elevation, and relating the remaining relative elevations to that NRVIS elevation.

Both relative elevations and assumed benchmark elevations on the Site Plans used for reserve calculations will reduce the accuracy of those calculations, particularly in comparison to other Site Plan elevation data that is based on more accurate geodetic data.

In several instances, the quarry boundaries, as indicated on the Site Plans, did not conform to the NRVIS data provided by MNR. In these cases, a professional judgment decision was made on the basis of the source of the boundary data. In the case of one quarry, the boundaries on the Site Plan were determined by an Ontario Land Surveyor using bearings and distances, and planted iron bars. In this instance, the Site Plan boundaries were used instead of the NRVIS boundaries. In some other instances, the NRVIS boundaries were used instead of the Site Plan boundaries. A list of the assumptions per site is included in the Metadata provided in the digital files accompanying this report as part of Appendix A.

A lack of consistency in the age, format and content of the Site Plans may have lead to some inaccuracies in reserve calculations. Any such inconsistencies could be rectified by field verification, use of a DTM tool or a combination of both in any future reserve verification process. For maximum accuracy and reliable comparison to actual production data, field verification site visits should be undertaken either after the end of annual production (mid- to late December) or prior to commencement of the next production season (late March to mid-April). Due to the time constraints of this study, the field verification site visits were limited to late August, with about one-half of the 2009 production season having been completed.

3.5 Issues Related to Aggregate Quality

The necessity for aggregate reserves to meet a number of standardized specifications for use in such products as concrete and asphalt provides a context to discuss issues related to aggregate quality. These issues can be reconciled with detailed site-specific geological information, but in many cases, such information is not generally available. An exception would be in cases of more recently developed quarries where detailed resource inventories and/or hydrogeological investigations can provide the information as part of the licence application package.

A detailed differentiation of reserve quality was not made due to a lack of site-specific geological information for the limestone and dolostone quarries. However, a limited evaluation of reserve quality was completed for a sample of 30 quarries (out of the total of 97) for which some site-specific geological information was available from a number of sources. Quality estimates for the remaining 67 quarries was based on their location within known geological formations and the accompanying descriptions of those formations and their expected quality within the Aggregate Resource Inventory Paper (ARIP) mapping.

For all of the quarries, the overall calculated reserves of stone were divided into four categories including ‘high’ (concrete and asphalt stone), ‘acceptable’ (for road base), ‘low’ (backfill only), and ‘unknown’ based on stone quality. For example, high quality stone was based on the proportions (or depths) of generally recognized high quality geologic strata, such as the Amabel, Guelph, Upper Bobcaygeon, units of the Gull River, units of the Lockport, units of the Bertie, etc. formations. Lower quality stone (e.g., Verulam, Bois Blanc, etc. Formations) were categorized as acceptable or low quality. However, it should be noted that blending (where local regulations allow), selective extraction and/or beneficiation by further processing can enable lower quality stone to meet higher specifications in some cases. A general description of these formations and the quality issues associated with them is provided on the following table. More detailed descriptions can be found in Appendix D of the various Aggregate Resource Inventory (ARIP) reports published by OGS.

Summary of Geological Formations in Relation to Aggregate Production

Formation Name	Brief Description	Quality Issues	Expected End Products
Bertie	Medium to massive bedded brown dolostone with shale partings up to 18 m thick.	Shaly intervals are unsuitable for use as high specification aggregate because of low freeze-thaw durability. Certain units can make higher end-products.	Granular road base products and certain units can make concrete and asphalt grade aggregate
Bois Blanc	Brownish grey, medium-crystaline, medium to thin-bedded cherty limestone, commonly fossiliferous with shaley, partings and minor interbedded dolostones. Typically ranges between 3 and 40 m in thickness.	Unsuitable for concrete aggregate due to high chert content.	Road base granular aggregates.
Lockport (Eramosa)	Bituminous dolostone with shale partings and variable chert bands and lenses.	Some areas are soft and unsuitable for use in the production of load-bearing aggregate, requiring additional testing. Certain units will make higher end products.	Certain units suitable for concrete and asphalt grade stone while others just suitable for granular road base and lime.
Gull River	Upper Member is thin to thickly bedded, interbedded, grey argillaceous limestone and buff to green dolostone up to 136 m thick. Lower Member is dense limestone with microcrystalline, interbedded dolostone	Certain layers are considered alkali-reactive	Concrete and asphalt grade aggregate.
Amabel	Massive, fine crystalline dolostone with reef facies and occasional shale partings and variable chert bands and lenses. Up to 40 m thick.	None	Lime, concrete and asphalt aggregate, building dimension stone.
Guelph	Medium crystalline, thickly bedded to massive, porous, vuggy, fossiliferous dolostone up to 122 m thick.	None	Lime, chemical uses
Manitoulin	Thin-bedded dolomitic limestones and dolostones.	None	Concrete and asphalt grade aggregate, building dimension stone.

Summary of Geological Formations in Relation to Aggregate Production (continued)

Formation Name	Brief Description	Quality Issues	Expected End Products
Bobcaygeon	Thin to medium bedded, fine-grained crystalline limestone with the middle member containing numerous argillaceous and shaly partings. Up to 87 m thick.	Certain layers are considered alkali-reactive.	Granular road base aggregate, with some units being suitable for concrete and asphalt grade aggregate.
Verulam	Interbedded fossiliferous varying fine to coarse limestone and shale. Up to 10 cm thick for limestone and 5 cm for shale. Rarely utilized.	Unsuitable for use as concrete and asphalt quality aggregate in some areas due to high shale content.	Lime, cement grade in some areas. Granular road base.
Lindsay	Coarse to fine bedded, nodular, crystalline limestone, overlain by 10m of petroliferous, calcareous, fossiliferous shale. Up to 100 m thick.	Some quality issues in some areas but generally suitable for use as concrete and asphalt aggregate	Lime, granular road base, concrete and asphalt grade aggregate, cement production in some areas.
Onondaga	Medium bedded, biostromal and biohermal, argillaceous and fossiliferous limestone with occasional chert nodules. Up to 25 m thick.	High chert content makes much of the material unsuitable for concrete aggregate, asphalt	Granular road base, building dimension stone.

Sources: Appendix D (OGS, 2004); Figure 2-2 (Planning Initiatives, State of the Resource Study 1992)

3.6 Issues Related to Estimation of Sand and Gravel Reserves

Since approximately one-half of aggregates production in Ontario (The Ontario Aggregate Resources Corporation, TOARC, annual statistical updates) is sand and gravel, it is important to consider licenced reserves of sand and gravel in the overall context of aggregate resources supply in the province. However, there is considerable difficulty in defining reserves in sand and gravel deposits with the same degree of certainty as reserves of limestone and dolostone.

The highly variable nature of sand and gravel deposits is a significant impediment to calculating reserves. Even within a spatially well-defined deposit, such as a well-sorted and relatively homogeneous outwash, the mode of deposition, being a glacial and/or periglacial process can result in highly varied strata. Depending on the velocity of the water currents depositing the materials, the contents of an outwash deposit may vary from fine sands to cobbles, and any combination thereof. Ice contact deposits, such as kames and moraines, are even more variable in composition, possibly including silt and/or clay fractions.

By their nature, sand and gravel pits may have fewer operational, environmental and social barriers to overcome than quarries. For example, only limited processing (e.g., screening) may be necessary to produce basic road base materials. Indeed, an end-product known as ‘pit run’ requires no processing at all; it is excavated and loaded for transport to a job site. Therefore, capital costs for processing equipment are usually lower, and may not be necessary at all if portable custom processing equipment is hired on a temporary basis. Operating costs can be lower as well; only a loader operator is required in some cases. Sand and gravel pits also tend to serve a more localized market, and sophisticated procedures for loading, weighing and billing may not be necessary. Ultimately, this means that the typical sand and gravel pit tends to be a smaller and more informal operation than a typical quarry, however they still require a licence under the ARA and must meet some minimum standards prior to licencing and during operation.

To include valid estimates of reserve volumes from sand and gravel pits in a combined estimate of reserve volumes, it would be necessary to incorporate a high level of field verification into such a project, or some broad based assumptions that would render the conclusions suspect. In this context, field verification would need to include analyses of all open faces within any particular pit, as well as a review of all available geological information. However, given the high variability of sand and gravel deposits, even field verification would have its limits, particularly if the area of remaining reserves was aerially extensive. Further, a number of sand and gravel pits, due to a high water table, are ‘wet’ extractive operations, using a clamshell or dragline as part of their practice for removing the below water reserves. As a result, the difficulty in evaluating licenced sand and gravel reserves is compounded, since the operating face is located below the water table, unless site-specific resources inventory documents were available.

4.0 RESULTS OF ESTIMATED REMAINING RESERVE CALCULATIONS

The following summarizes the results of the reserve calculations that were completed as part of this study using the methodology described above in Section 3.

4.1 Reserve Estimate Calculations

Using the methodology described above in Section 3, estimated reserves were calculated for each of the quarries in the study area. A summary of the results is provided below.

CPCA Area	Licenced Area (Hectares)	Extractable Area (Hectares)	Extractable Area as a Percentage of Licenced Area	Net Volume Estimate (million m^3)	Tonnage Estimate (million tonnes)	Average Tonnes (million) per Extractable Hectare
2	2,478.4	1,986.4	80.1%	256.7	705.9	0.4
3	3,032.7	2,578.2	85.0%	390.9	1,074.7	0.4
4	908.7	575.6	63.3%	43.4	119.2	0.2
5	2,578.1	2,037.0	79.0%	559.9	1,539.9	0.8
Total	**8,997.9**	**7,177.2**	**79.8%**	**1,250.9**	**3,439.7**	**0.5**

As noted above, a total estimated reserve volume of approximately 1.25 billion m^3, or 3.44 billion tonnes was determined through the mapping exercise. It should be noted that a total volume of approximately 1.28 billion m^3, or 3.52 billion tonnes, was initially calculated, but once the numbers from TOARC were used to adjust the production, which occurred subsequent to the date of the air photos, this total, as of the end of 2008, was found to decrease by approximately 24 million m^3, or 66 million tonnes. A density factor of 2.75 tonne/m^3 was used to calculate the total potential tonnage remaining in the 97 quarries.

It is important to note that this total includes the full volume of rock found on these properties, both high and lower quality stone, and does not account for unusable by-products (silt sized fines) that are generated through the process, which can be as much as 10% of the total. Also, the volume and tonnage calculations are based on dimensions, distances and elevations provided on the Site Plan, and these calculations assume that all material is extracted and, in turn, is viable for aggregate production, and that no reserves are used for construction of internal haul roads, ramps or left in place as benches for rehabilitation.

A confidential breakdown per licence is provided in Table A.1 of Appendix A. This Table is a summary of the 2008 Remaining Reserves for each of the evaluated quarries in the Study Area, and is provided in ascending order according to the licence (or ALPS) number of the individual quarries. The spreadsheet includes all quarries within the Study Area with a licenced area of 20 hectares or more that were subject to evaluation. Individual quarries of less than 20 hectares were not evaluated, and are not included in the spreadsheet. However, in cases where extensions to existing quarries were found to be less than 20 hectares, evaluations were completed. These are identified on the spreadsheet as 'Combined Licences – Single Operation'. A total of 11 licenced properties were in this category.

There is one quarry with a municipality listed as the Licensee. Since this operation would provide aggregate materials for the needs of the municipality only, and not to other customers, no entry in the 'Estimated Stone' and the 'Volume of Overburden' was provided. A limited number of revisions to the calculations were based on the use of the DTM tool described above in Section 3.

A comparison of the licenced area (i.e., lands within the licence boundaries) with the extractable area (i.e., lands within the setback boundaries), for the 97 quarries evaluated within the Study Area determined that an average total of about 80% of the licenced area was available for extraction (i.e., all lands within the boundaries of the licenced property, but exclusive of setback and other constraints applied), as indicated from data supplied by MNR.

4.2 Quality of Estimated Reserves

As outlined in Section 4.1 above, the reserve calculations that were carried out for the 97 quarries evaluated in this study are total volume/tonnage of stone remaining on site that is licenced within the current extraction envelope of each of the properties. This volume/tonnage calculation includes all ranges of quality, which requires some clarification with respect to the availability of higher quality reserves versus lower quality reserves. As outlined in Section 3.6, there were only 30 quarries of the 97 evaluated that had varying degrees of information discussing the quality of reserves on the specific property. It should be noted that the remaining 67 sites had no available site specific quality information available for review. As such, the quality estimates for their reserves is based solely on their location with respect to available geological mapping from ARIPs, OGS mapping and the generalized description of quality with respect to aggregate production provided in those documents. Considering this, a greater level of confidence in reserve quality is afforded to the 30 properties, while the quality of reserves at the remaining 67 sites is considered to be more uncertain. A summary of the estimated breakdown of quality proportions per site is provided in Table A.2, of Appendix A.

The summary provided on this table indicates that, for the sample of 30 quarries for which site-specific geological information is available, approximately 62**%** of the overall stone reserves were determined to be of 'high' quality. Of the remaining 67 quarries where the site-specific geological information is not available and more generalized information from available mapping was used, an estimate of about 37% of the overall stone reserves in these sites was calculated to be of 'high' quality. The remainder of the reserves in all quarries are considered to be of 'acceptable', 'low' or 'unknown' quality.

It should be noted that this total also includes volume and tonnage estimates for dimension stone quarries. It is important to note this in the context of available supply to the various markets, particularly the GTA where construction aggregates would be in greater demand than dimension stone.

The 30 quarries with additional quality information represent approximately 298 million m^3/818 million tonnes, or 24**%** of the overall stone reserves evaluated. Of this total (298 million m^3/818 million tonnes) approximately 62% or 184 million m^3/505 million tonnes was estimated to be of 'high' quality (concrete and/or asphalt). The remainder of those reserves are considered to be of 'acceptable' (road base), 'low' or 'unknown' quality. Subject to a number of limitations with the remaining 67 quarries, for which site-specific geological information is not available, 352 million m^3/968 million tonnes, or 37**%** of the overall stone reserves was estimated to be of 'high' quality. The remainder are considered to be of 'acceptable', 'low' or 'unknown' quality. As such, the total estimated amount of 'high' quality reserves is approximately 536 million m^3/1.47 billion tonnes. It should be noted that of this total amount of 'high' quality reserves only a maximum of about two thirds, or 359 million m^3/987 million tonnes, would be available for inclusion in concrete and asphalt grade products in the form of stone and manufactured sand. The remaining reserves would, through the process of generating concrete and asphalt grade stone, create a by-product such as granular road base.

It is important to consider the actual available volume and tonnage of material for higher end products, such as concrete/asphalt grade stone and manufactured sand, and the process that is involved to generate those products. While there is very little to no 'waste' generated in most sites that produce higher end products, such as concrete and asphalt grade stone, there is a high percentage of lower value/end use by-products that result. One of the by-products resulting from this process is a 'screening' product that has been used by many producers to generate a manufactured sand that can also be included in the production of concrete and asphalt, giving it a 'high' quality value with respect to this study. Between the actual production of concrete/asphalt grade stone and manufactured sand, a maximum two-thirds (67%) of a single tonne of 'high' quality stone can be considered for use in higher end applications. The remaining third (33%) will create a lower end by-product such as granular road base.

Considering the total resource base of 1.25 billion m^3, or 3.44 billion tonnes that was calculated, it is important to understand that the majority of these reserves are not comprised of high quality stone. Only approximately 536 million m^3, or 1.47 billion tonnes, of high quality reserves appears to be available to the Greater Toronto Area market (discussed further in Section 6), a maximum two thirds (approximately 359 million m^3/987 million tonnes) of which would be available for concrete and asphalt grade stone and manufactured sand due to the by-product generation resulting from those end products.

5.0 DETERMINATION OF AREAS OF RELATIVE ABUNDANCE AND SCARCITY

It is important to understand when reviewing remaining reserves in licenced properties that consideration should be given as to where the sites are located with respect to market demand. This is discussed further in Section 6, but is also important to note with respect to describing the reserves on a property, or grouped in an area, as being considered either abundant or scarce.

5.1 Background/Overview

In order to determine areas within the Study Area as having a relative abundance or scarcity of licenced reserves, individual licenced properties with 20 million m³/55 million tonnes or more of reserves were defined as having 'abundant' reserves. Those licenced properties with less than 5 million m³/14 million tonnes of reserves were defined as having 'scarce' reserves. Those with reserves between 14 million tonnes and 55 million tonnes are considered to have 'moderate' reserves remaining. The choice of 55 million tonnes and 14 million tonnes as the dividing lines was arbitrary, but is considered to be reasonable considering the wide range of licenced areas and annual tonnage limits for the sites examined. Further, it provides an indication of the number of quarries contributing to the relative levels of abundance and scarcity, and those which are approaching the point of scarcity (i.e., those identified as having moderate reserve estimates).

5.2 Results

The licenced reserves of the 'abundant', 'moderate' and 'scarce' quarries were each grouped according to the CPCA Area in which they were located, a summary of which is provided below. It should be noted that a confidential breakdown per upper tier municipality is provided in Table A.3 of Appendix A.

The following summarizes the relative 'abundance' and 'scarcity' of reserves for each of the market areas.

CPCA Area	Reserve Totals			Number of Sites	Total (million tonnes)
	Abundant (>55 million tonnes)	Moderate (14 to 55 million tonnes)	Scarce (<14 million tonnes)		
2	262.6	357.2	86.1	**35**	**705.9**
3	792.8	192.8	89.1	**32**	**1,074.7**
4	64.9	43.2	11.1	**4**	**119.2**
5	1,288.4	174.1	77.4	**26**	**1,539.9**
Total	**2,408.7**	**767.3**	**263.7**	**97**	**3,439.7**

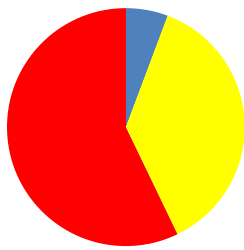
As summarized above, there are an estimated 876 million m^3/2.41 billion tonnes of reserves located in quarries within the study area that would be considered to have abundant reserves using the classification described above. In addition, there are approximately 279 million m^3/767 million tonnes of reserves located within quarries that would be considered to be in a moderate reserve situation and an additional approximate 96 million m^3/ 264 million tonnes of reserves located within quarries where the resource situation would be considered scarce. Interestingly this table would appear to suggest that each of the market areas benefit from an abundant reserve base. However, when this is examined in greater detail, by number of sites for instance, some further conclusions can be drawn and are summarized on the table provided below.

CPCA Area	Total # of Sites	Reserve Total		Abundant		Moderate		Scarce	
		Volume	Tonnage	# of Sites	Total Tonnage	# of Sites	Total Tonnage	# of Sites	Total Tonnage
2	35	256.7	705.9	2	262.6	13	357.2	20	86.1
3	32	390.9	1,074.7	5	792.8	6	192.8	21	89.1
4	4	43.4	119.2	1	64.9	2	43.2	1	11.1
5	26	559.9	1,539.9	7	1,288.4	6	174.1	13	77.4
Total	**97**	**1,250.8**	**3,439.7**	**15**	**2,408.7**	**27**	**767.3**	**55**	**263.7**

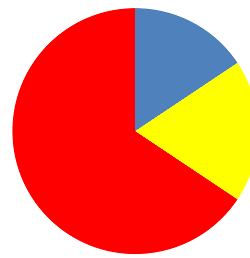
From this summary table it is clear that approximately 70% of the reserve base that is considered to be 'abundant' is found in only 15 quarries, or 15% of the total number of quarries evaluated. The remaining 82 quarries, or 85% of the number evaluated, have either scarce or moderate reserves. It should be noted that the abundance and scarcity of reserves is a relative matter. This classification is not meant to reflect annual production capabilities within the various sites assessed as part of the study. For instance, if a quarry is producing millions of tonnes of product per year and has reserves of 55 million tonnes (classified as the 'abundant' cut-off), it would be considered a relatively scarce situation since the remaining reserves would not last as long as if the annual production was less than a million tonnes per year. Similarly, if an operation currently operates at a smaller scale and produces less than a million tonnes per year, a resource that has been classified as scarce may, in fact, last many years.

The relative abundance and scarcity of licenced reserves, within the context of the number of sites evaluated in each CPCA Area, has been summarized graphically in Figure 4 and provided below.

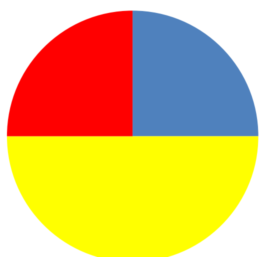
Area 2 - PENINSULA



Area 3 – WEST CENTRAL



Area 4 - GTA



Area 5 – EAST CENTRAL

Number of Sites

Abundant
Moderate
Scarce

It is clear from reviewing Figure 4 and the charts above that each of the market areas are relying on sites with moderate to scarce reserve bases. For example, the chart for Area 2 indicates that the majority of the sites located in this area have reserves that are considered to be scarce (i.e., quarries with less than 5 million m^3/ 14 million tonnes of reserves). Areas 3 and 5 also have more than 50% of the sites considered to have 'scarce' reserves, while the reserves in Area 4, which are reliant on only 4 licences, is nearly depleted in comparison to the other areas. It could be concluded that, without new licenced reserves being added, a large number of the quarries in each of these areas will reach depletion within the next couple of decades, depending on the annual rate of extraction at each of the sites.

5.3 Quality Context

It is important to note the context of quality with respect to abundance and scarcity of the overall reserves. As such, the reserves for each of the 30 sites that had additional information were broken down with respect to the categories described in Section 3.6 (‘high’, ‘acceptable’, ‘low’ and ‘unknown’) and as outlined in Section 4.2 above. The 30 sites that had more detailed quality information available for review accounted for approximately 24%, or 298 million m^3 (818 million tonnes) of the total of 1.25 billion m^3 (3.44 billion tonnes). Of this total (298 million m^3/818 million tonnes), it is estimated that approximately 62% or 184 million m^3 (505 million tonnes) are remaining of higher quality aggregate. It should be noted that the quality of the reserves in the remaining 67 quarries was estimated using ARIP mapping and professional judgement for the split between quality classifications. Of the total reserves remaining that had limited information to review (totalling 953 million m^3/2.62 billion tonnes) approximately 352 million m^3, or 968 million tonnes, was considered to be of high quality. In the context of relative abundance or scarcity, for the various categories of quality, a summary is provided below combining both the more detailed examination of reserve quality and that which is more general:

CPCA Area	Reserve Totals (million tonnes)											
	Abundant				Moderate				Scarce			
	H*	A	L	U	H	A	L	U	H	A	L	U
2	206.9	55.6	0.0	0.0	117.1	108.4	69.1	62.6	55.9	19.9	5.9	4.4
3	191.8	286.3	237.0	77.8	141.4	25.8	25.6	0.0	62.7	14.3	10.8	1.2
4	65.0	0.0	0.0	0.0	37.6	4.9	0.0	0.6	10.1	1.0	0.0	0.0
5	447.1	427.0	348.5	65.7	104.1	34.4	0.0	35.6	33.5	27.2	10.6	6.1
Total	**910.9**	**768.9**	**585.5**	**143.4**	**400.2**	**173.5**	**94.7**	**98.8**	**162.2**	**62.4**	**27.3**	**11.8**

*H – High Quality, A – Acceptable Quality, L – Low Quality, U – Unknown Quality

NOTE: Totals have been rounded and are therefore approximate

Of the ‘abundant’ reserves remaining, it is estimated that only about 331 million m^3, or 911 million tonnes, of the total is considered to be of higher quality. Considering that the ‘abundant’ reserves are located within only 15 of the quarries evaluated, the ability to supply the demand of higher quality aggregate in various market areas will continue to become increasingly difficult. In addition, when annual tonnage limits and internal customer demand from these quarries are taken into consideration, annual available supply to the general market is further limited.

6.0 MAPPING OF RESERVES RELATIVE TO MARKET DEMAND AREAS

While a market demand analysis is not considered to be part of the scope of this paper (Paper 5), some general conclusions can be drawn with respect to the location of the identified reserves relative to the Greater Toronto Area, which consumes approximately one third of Ontario’s total aggregate production. It should be noted that Paper 1 provides a more detailed examination of market demand with respect to aggregate supply.

6.1 Methodology

It is important to examine the question of the location of remaining reserves with respect to the GTA market. As such, the quarries that were categorized into having ‘abundant’, ‘moderate’ or ‘scarce’ resources, as outlined above in Section 5.2, were compared to the distance from the Vaughan Corporate City Center (VCCC), in order to examine the distribution of the reserves relative to the major consumer of aggregate in the province, the GTA. Travel distance rings of 25 km, 50 km, 75 km, 100 km, 125 km and 150 km were highlighted on Figure 3 relative to the VCCC. This provides seven categories of travel distances to the Toronto market; within 25 km, between 25 km and 50 km, between 50 km and 75 km, between 75 km and 100 km, between 100 km and 125 km, between 125 km and 150 km, and greater than 150 km. Once these travel distance rings were highlighted, the categorized quarries discussed in Section 5 as having ‘abundant’, ‘moderate’ or ‘scarce’ reserves were placed on the figure and their locations highlighted with respect to the travel distances from the VCCC. The results are provided in Section 6.2 below.

6.2 Results

As noted on Figure 3, there are no reserves located within 25km of the VCCC. Within the 25 km to 50 km ring around the VCCC there is an approximate reserve base of 108 million tonnes, of which approximately 103 million tonnes is considered to be higher quality and approximately 69 million tonnes of that total is available for concrete stone and manufactured sand, when assuming the two thirds breakdown discussed in Section 4.2. This is summarized for each of the rings as follows:

Distance Ring	Overall Reserves (million tonnes)	Total High Quality Reserves (million tonnes)	Available High Quality Reserves (million tonnes)
0 to 25 km	0	0	0
25 to 50 km	108	103	69
50 to 75 km	794	373	250
75 to 100 km	691	296	198
100 to 125 km	896	398	267
125 to 150 km	191	130	87
Greater than 150 km	695	175	117
Total	**3,375**	**1,473**	**988**

A total reserve base of approximately 328 million m^3, or 902 million tonnes, is located within 75 km of the VCCC. However, of this total only approximately 173 million m^3, or 476 million tonnes, are considered to be ‘high’ quality. Considering that a maximum production of about two-thirds of the total high quality reserves is achievable for production of concrete/asphalt grade stone and manufactured sand, this translates into approximately 116 million m^3, or 317 million tonnes, available within a 75 km distance of the Vaughan Corporate City Center.

The reserve base that lies within the 50 km to 75 km ring is located to the west, southwest of the VCCC. Between 75 km and 100 km the majority of the reserve base is located to the north of the VCCC, with some of the reserves also located in the Niagara area to the southwest. The remaining reserves of those that were evaluated are located at greater distances than 100 km from the VCCC and are more sporadically located.

It is important to note that these distances are generally based on a straight line measurement from the VCCC. Travel distances along approved trucking routes would increase these travel distances, in some cases substantially. As such, it is important to view these ‘rings’ as straight line distance rings and not travel distance rings.

The location of each of the quarries and their individual classification with respect to their reserve base (i.e., abundant, moderate or scarce) is provided in Appendix A. This information is considered to be confidential, however in reviewing the proximity of the reserves in relation to the GTA (VCCC) it is clear that the majority of the reserves that supply the GTA demand are originating from scarce to moderate reserve bases. A detailed listing for each licenced property in their respective municipality is also provided in Appendix A (see Table A.3) along with a figure (see Figure A.2) showing the locations of each property with their licence number.

7.0 OPPORTUNITIES TO MAXIMIZE RESOURCE USE WITHIN EXISTING LICENCES

The purpose of this component of Paper 5 is to describe various opportunities that exist to maximize resource use within existing licences. Increased resource availability will extend the life of existing pit and quarry sites and contribute to meeting societal demand for aggregate materials.

The 1992 State of the Resource Study (Planning Initiatives, 1992) identified that some areas of Southern Ontario (Sarnia/Windsor/Chatham, Greater Toronto Area, Brantford/Hamilton/ Niagara) were moving towards a critical shortage of aggregate supply due to difficulty and the length of time to obtain new approvals. One response was revisions to the Aggregate Resources Act (ARA) licence application process: the Province issued Aggregate Resources of Ontario Provincial Standards (AROPS) under the ARA, in 1997. AROPS was intended to provide all stakeholders with greater certainty and streamline the approvals process.

Since the 1992 Study, for the key Greater Toronto Area (GTA) market, resource replacement has not kept up with resource depletion. Currently, the depletion to replacement ratio is in the order of 2.5:1. This reflects that a significant number of existing licences that serve the GTA are ‘grandfathered’ licences, and were issued under the Pits and Quarries Control Act in the 1970’s. It is also apparent that new resource supply in the GTA has occurred primarily through expansions or extensions to existing approvals, as opposed to greenfield applications.

As close to market supplies continue to decline, there will be increasing pressure to maximize resource use within existing licenced operations. The quantities potentially available cannot replace or significantly delay the need for new licenced supply. Regardless, it is prudent to consider the potential for additional resource from existing licenced sites and how those reserves may be maximized in the future.

7.1 Various Methods

A range of possible methods for maximizing the amount of aggregate reserves in existing operations are described in the summary table in Section 7.5. In general, these methods include, or relate to:

- varying excavation setbacks to increase extraction area;
- increasing excavation depth;
- extraction of road allowances;
- importation of material for blending purposes; and
- varying standard rehabilitation requirements.

Pit and quarry sites licenced under the Aggregate Resources Act (ARA) are characterized primarily by the type of operation, pit or quarry (or both), whether they extract from above or below the water table, and their geographic extent or licenced area. In terms of how much aggregate is potentially made available at these sites, the key parameters are the extent (size) of the extraction area and the depth to which extraction can occur. These parameters are controlled by ARA standard operating requirements and individual Site Plans that regulate the operations of pits and quarries. In general, regulatory and policy provisions exist to permit variations to excavation setbacks and standard rehabilitation requirements, as considered appropriate by MNR at the local level in accordance with Aggregate Resources Program policies and procedures.

To maximize the amount of aggregate that is available from existing sites, the most readily available means are to increase the amount of extraction area and/or, increase the depth. However, there are several considerations which must be addressed when assessing an increase to the extraction envelope (area and depth); and there are limits to how much increase can be realized.

Resource maximization is also enhanced if on-site aggregate material is used for aggregate product, and not utilized in the rehabilitation of the site. A key provision of the ARA is that rehabilitation be carried out on a progressive, and ultimately final, basis. The operator is required to use material retained on-site to complete the rehabilitation obligations. Given the dimensions of the excavation area, significant quantities of material can be required for rehabilitation, beyond the material that is available from stripping of overburden. This can be reduced where material available from off-site sources can be imported for rehabilitation as permitted by the site plan; or, through varying the rehabilitation requirements that reduce the volume of material required.

7.2 Varying Excavation Setbacks

The AROPS requires each Site Plan to indicate how much area may be extracted (to a maximum) and to what depth (or elevation). In simple terms, the extraction area is the licenced area less areas not to be extracted, which would include excavation setbacks. These regulatory excavation setbacks (AROPS) are:

- 15 m from the boundary of a site;
- 30 m from the boundary of site that abuts a highway, land in use or zoned for residential purposes; and
- 30 m from a body of water, except for on-site extraction related ponds.

The definition of highway in the ARA includes an unopened road allowance.

MNR's Aggregate Resources Program Policies and Procedures (ARPPP) manual describes the intent of excavation setbacks as follows:

> *"Property owners adjacent to licenced sites are entitled to the buffers provided by the setback provisions of the operational standards. Their interests and concerns must be considered when dealing with variations in setback widths".*

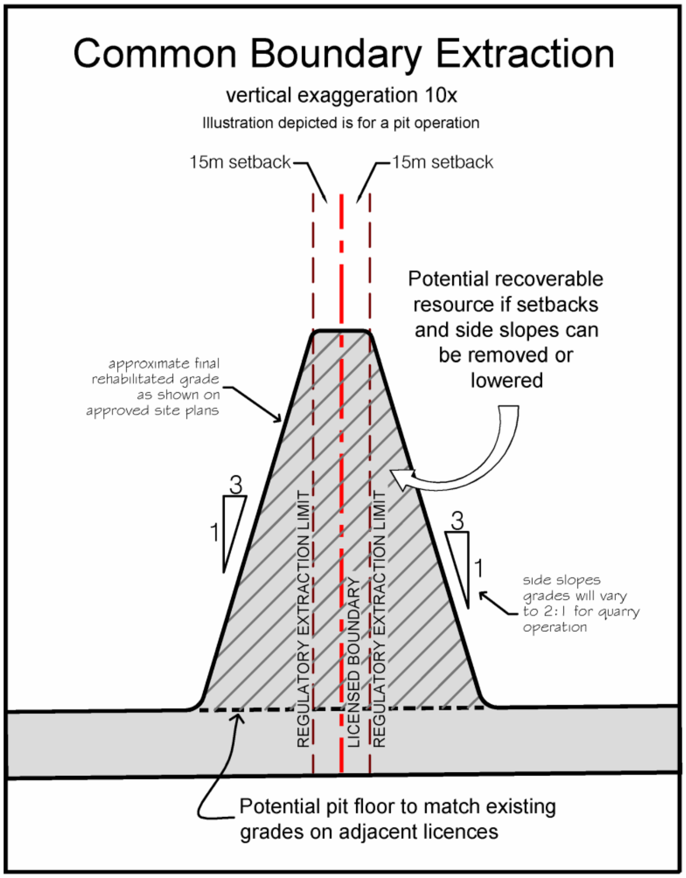
Given the nature of the pit or quarry land use, which involves the physical excavation of land, usually in below grade situations, the need to protect adjacent property from physical impacts of extraction such as erosion and, in general, slope failure is readily apparent. In addition, setbacks have been implemented in order to further protect the surrounding land uses from environmental and social impacts. Permission of the adjacent landowner is usually required if setbacks are to be reduced.

The AROPS prescribed setback locations and distances have been compared with setback provisions, known usually as ordinances, in the United States and other parts of Canada. The Ontario prescribed distances are in excess of those prescribed in British Columbia, which requires a minimum setback of 5 m from the property line of an aggregate operation (British Columbia, 2007); and, Alberta, where the recommended setback from the property line is 3 m in pits (Alberta, 2004). The Ontario prescribed distances are generally representative of those in the U.S., although given the very local level of regulation in the U.S., there is a wide variation in setback (ordinance) distances. There is further commonality between Ontario and U.S. jurisdictions in that setback distances can be varied (i.e., reduced or eliminated) under certain conditions.

Excavation setbacks also result from site specific studies that are completed as part of the licence application process. Commonly, the recommendations of reports in natural environment, ground or surface water, noise, blasting (quarries only), and archaeology may require excavation setbacks to be put in place to protect the subject environmental or social features from unacceptable impacts or to ensure impacts on adjacent land uses (noise, vibration) are within specified limits.

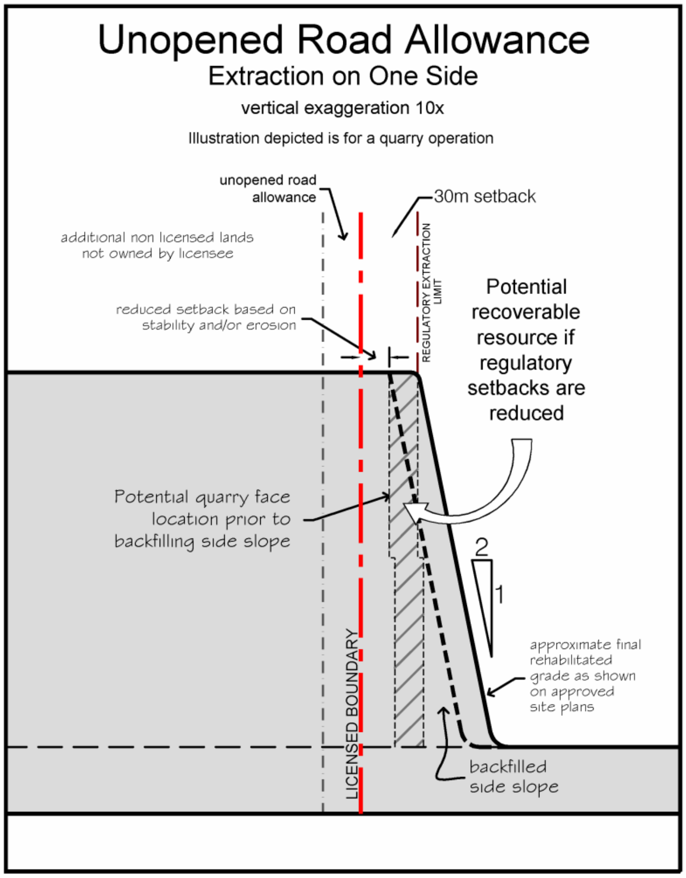
Variations to these types of setbacks could be applied for with the support of monitoring data or impact evaluation, carried out by professionals. Should the data indicate the actual effects from extraction on the feature are less than what was anticipated at the time the setback was determined, it would give cause to re-evaluate the setback distance and reduce it to something more appropriate.

MNR policies do allow for the variation in excavation setbacks under appropriate circumstances. The most common type of variation is to eliminate the setback between two licenced operations. These are known as common boundary agreements. However, reaching this type of agreement does require the agreement of both operations, including an agreement to mine the deposit to a common elevation in the area of the former setback. This is depicted below.



It should be noted that the graphics provided are for illustrative purposes only and are not to scale.

Another common setback variation is alongside an unopened road allowance. Provided there is no intent on behalf of the municipality to construct a road, the road allowance limits are treated more as a private property boundary, and the setback can be reduced from 30 m to 15 m or less with the consent of the road authority. This is depicted on the following illustration.



7.3 Increasing Excavation Depth

Under AROPS, the depth of extraction at a licenced site is specified by the Site Plan through an indication of specific final elevations for extraction and rehabilitation. These elevations will be a reflection of the extent of the deposit and whether the site is to be operated above or below the water table.

Aggregate resources in pit sites can be quite variable. It is usually the presence of non-viable materials such as thick sequences of till, clay or silt that will limit the depth of extraction at a pit site. For limestone/dolostone quarries, the depth of extraction is limited by the presence of rock formations that are less suitable for aggregate purposes. The appearance and characteristics of these formations are well documented in the scientific literature. Accordingly, opportunities to deepen existing sites may be limited by these geological factors; and, most operators would ensure that no viable resource that is available for extraction by their Site Plan is left unextracted.

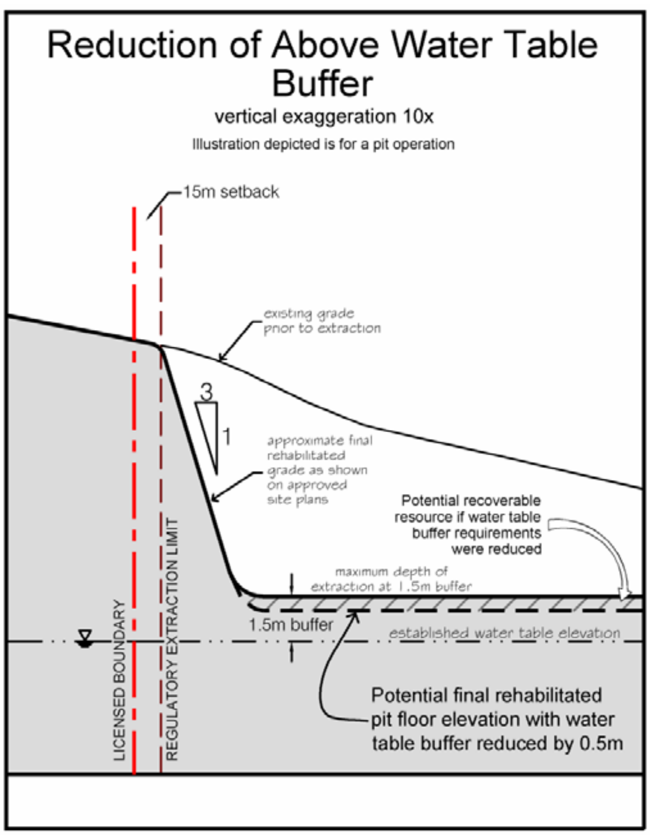
The above discussion may be considered as generalizations that would apply to most sites. However, there will be some sites where the resource does exist below the Site Plan prescribed floor elevation, or where the water table is lower; and that is where the potential exists to increase the depth to gain additional reserves. Specific MNR policies and procedures that would provide for certainty and consistency in Site Plan amendments to increase the depth of extraction in these circumstances would facilitate a more complete use of licenced reserves.

A significant feature of AROPS is that it includes a buffer or separation distance for sites that are above water table. The AROPS requirement is that an above water table pit must remain at least 1.5 m from the established groundwater table, and an above water table quarry must remain 2 m above. The potential exists, therefore, to increase reserves for sites above the water table by reducing the amount (vertical thickness) of buffer to which the operation must adhere. It is recognized that a hydrogeological assessment may be required as part of this process.

These buffer distances were developed as part of the AROPS standardized approach to regulating extraction operations. The premise behind the buffer is to recognize that the water table does fluctuate over time, and to facilitate rehabilitation. For example, water tables are typically higher in the spring time due to snow melt and precipitation (commonly referred to as the seasonally high water table). Conversely, the water table may be lowest in the summer, particularly if precipitation has been minimal for that year or for previous summers. In the case of limestone/dolostone quarries, geotechnical factors such as quarry floor buckling (pop-ups) are also a consideration.

Other jurisdictions were checked for similar buffer provisions. Distances of between 1.5 m and 3 m were found for Australia and the United States, indicating the Ontario setbacks are not atypical.

An illustration of the reduction of the above water table buffer is provided below.



A revision of AROPS could allow for a decrease in the buffer requirement. An approval to reduce the buffer could be granted on the basis of:

- reliable monitoring data to indicate the water table is stable;
- assessment for potential additional incremental effects on other water or natural heritage resources or water supply wells;
- geotechnical/rock stability issues in the case of quarries; and
- availability of sufficient overburden and topsoil to allow removal of the resource materials from the pit/quarry floor.

It should be noted that the question of the ability of the remaining material to act as a filter for contamination is a common question that is asked in relation to above water table pits and quarries.

7.4 Extraction of Road Allowances

More significant volumes of material can be made available for extraction where municipal road allowances on one side of a licenced operation or between licenced operations are excavated. The material in the road allowance and the adjacent excavation setback(s) would then become available. Additional benefits include reduced rehabilitation requirements, and for a road allowance between two licenced areas, a gentler, more natural looking rehabilitated landscape.

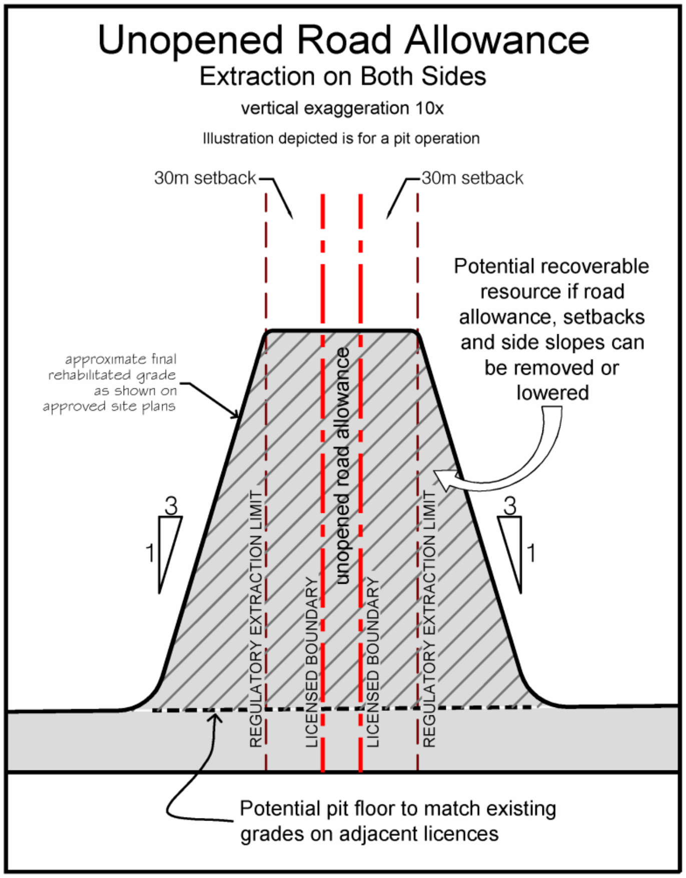
Extraction of road allowances in Ontario must have approval of the public agencies having jurisdiction, and generally requires an ARA licence, but has occurred, on occasion, without the requirement of a licence in order to improve the road. In some cases, travelled roads are temporarily closed by the municipality and lowered, thereby allowing for the reduction and lowering of the abutting excavation setback. This type of practice can provide, or be associated with improved road usage and safety, if for example a road is particularly steep.

In other cases, the road allowances involved are unopened and not publicly travelled. In another variation, where adjacent lands are already licenced and the municipality retains ownership of the road allowance, then extraction is permitted without a licence.

Road allowance extraction would realize benefits to the municipality as the material within the road allowance belongs to it. In cases where this type of extraction has occurred, the aggregate operator makes arrangements with the municipality concerning the quantity of resource and its extraction and disposition. It is common that the operator may make available an equivalent amount of material to the municipality for their use. In some cases, there may be outright payment for the excavated volume of material, with additional considerations to address extraction, processing, stockpiling and haulage.

Where road allowances are officially closed under the Municipal Act, they are no longer considered road allowances. These former road allowances can be sold to the adjacent landowner, being the aggregate operator/licensee. For extraction to occur, licences are required.

Again, an illustration of this example is provided below.



7.5 Imported Material For Blending Purposes

An opportunity exists to increase reserves from some pit or quarry sites by carrying out blending. This is the mixing of different types of somewhat deficient aggregate material, either naturally occurring or resulting from a processing operation, to produce a more viable product, and increase marketability for the operator.

Pit sites would generally be the focus of this approach, due to the inherent variability that exists in some types of surficial deposit areas, based on local geological variations. Limestone/dolostone quarry sites are generally more homogeneous with more uniform physical characteristics.

Surficial geological material would exhibit changes in bedding, particle size/shape/soundness and constituent minerals. For example, a large surficial deposit may be comprised of stone rich aggregate in one area and fine sand aggregate in another. These factors play an important role in determining the aggregate potential of a deposit. For the pit operator, they have ramifications to efficient extraction, processing requirements, and the ultimate end-use of the material.

Crushed stone quarries could also be relevant to the blending process (i.e., multiple bench quarries extracting more than one geological formation with varying quality), but for this Paper, the more specific process to produce manufactured sand was reviewed.

The Ontario Provincial Standard Specification (OPSS) defines "manufactured sand" as sand produced by the crushing and further processing (i.e., washing, grading, classifying, of quarried rock, boulders, cobbles, or gravel) from which the natural fine aggregate has been removed.

Manufactured sand is produced using fine materials left-over from a crushed stone aggregates processing operation, which is often considered part of the waste stream. Manufactured sand, produced in a dedicated, quality-controlled processing stream, has historically been used as fine aggregate in asphalt and concrete manufacturing and the creation of mortar sand. Accordingly, the use of manufactured sand would reduce reliance and need for natural sands for these uses, thereby extending the life of natural sand deposits and using a product in the quarries that would otherwise be treated as a by-product and in most cases left on site.

However, in order to improve the handling and usability of manufactured sand from quarries, it is often mixed, or blended, with natural sand aggregates from pits.

Dedicated government policy concerning the transfer of materials between pit/quarry sites for blending purposes will facilitate the practice. This will allow for more complete utilization of resource material at extraction sites. Coupled with this would be an initiative to research the regional opportunities for blending in established surficial deposit areas. This in turn could lead to the development of dedicated blended aggregate specifications for certain applications.

7.6 Varying Standard Rehabilitation Requirements

A discussion on reduced slope requirements for rehabilitation and the potential for importation of off-site material is provided in the following sections.

7.6.1 Reduced Slope Requirements

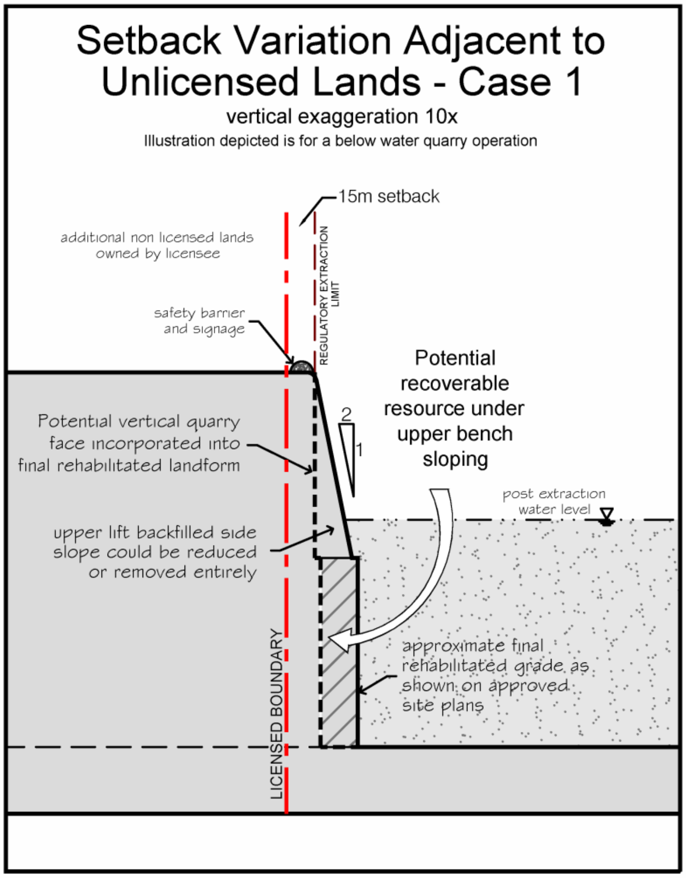
Rehabilitation of pit/quarry faces is usually carried out by ensuring the final pit or quarry face is sloped to the required gradient, and covered with soil such that a permanent vegetation cover (trees or grass) can be established. AROPS Site Plan standards require an indication as to how the slope is to be constructed. Floor rehabilitation is also required, except where below water.

For pits, faces are to be sloped to a minimum gradient of 3 to 1 (horizontal to vertical). For quarries, the slope requirement is 2 to 1. MNR policy permits on an individual site by site basis, that sloping requirements can be varied such that complete sloping is not required. It should be noted that for quarry faces below the water table, it is established practice to allow vertical faces provided public safety issues are taken into consideration in the design.

Slopes can be varied when benefits are recognized to having a more diverse post-extractive landscape, and where that is not necessarily achieved by strict adherence to the AROPS requirements.

The benefit to the operation from a reserves point of view is that less material is required to be retained for sloping purposes, and aggregate availability is correspondingly increased.

Vertical bedrock faces are a common feature of the environment in escarpment terrains. Allowing quarry slope rehabilitation to include full or partial sheer walls would result in more bedrock being available for extraction, and this technique has been implemented at several quarry sites including within the Niagara Escarpment Plan Area to complement natural escarpment faces. An example of this is depicted below.



7.6.2 Importation of Fill for Rehabilitation

MNR's general practice is that rehabilitation be accomplished through the use of on-site material. Importation of fill material is permitted in some operations; for example, where it can be proven that on-site material is insufficient to complete the rehabilitation, as approved by the Site Plan. MNR policy requires that material imported from off-site for rehabilitation purposes (complete or partial backfill) shall be "clean and inert" according to Environmental Protection Act (EPA) criteria, or that the material not be classified as a "waste". It should be noted that achieving the criteria for "inert fill" is particularly challenging as native soils around the Province typically exceed various parameters listed on the MOE Table 1 Acceptance Guidelines, by which inert fill is regulated. Consideration should be given to the acceptance of Table 2 material in order to increase the potential for finding suitable volumes of material for rehabilitation.

In accordance with the on-site material practice, MNR's default position is that sloping be accomplished by retaining material adjacent to (i.e., prior to extraction reaching) the regulatory excavation setback. This is known as the "cut and fill" method. The width of material to be retained would vary based on the height of the face that is to be sloped, and on the slope gradient. Such a practice results in the use of otherwise extractable aggregate and results in a loss of that material to the production stream. Depending on the individual geometry of a pit or quarry excavation that requires sloping, the amount of material lost from production can be quite significant.

MNR has recognized the fact that using aggregate material for rehabilitation is not the best use of the material. As a result, policies are in place that allow for sloping to occur by other means. If there is sufficient material elsewhere on the site, of inferior quality or not suitable for aggregate, then it can be used as complete or partial backfill for the slope that is to be created. This eliminates the need to retain aggregate material for sloping purposes, and the higher cost of rehabilitation (trucking and handling) is off-set by the additional product that is gained. However, this policy is still predicated on the use of on-site material.

Reliance on on-site material helps to ensure that material exists to complete the rehabilitation and that it occurs in a timely manner. However, it does commonly necessitate the use of aggregate reserve materials for rehabilitation purposes.

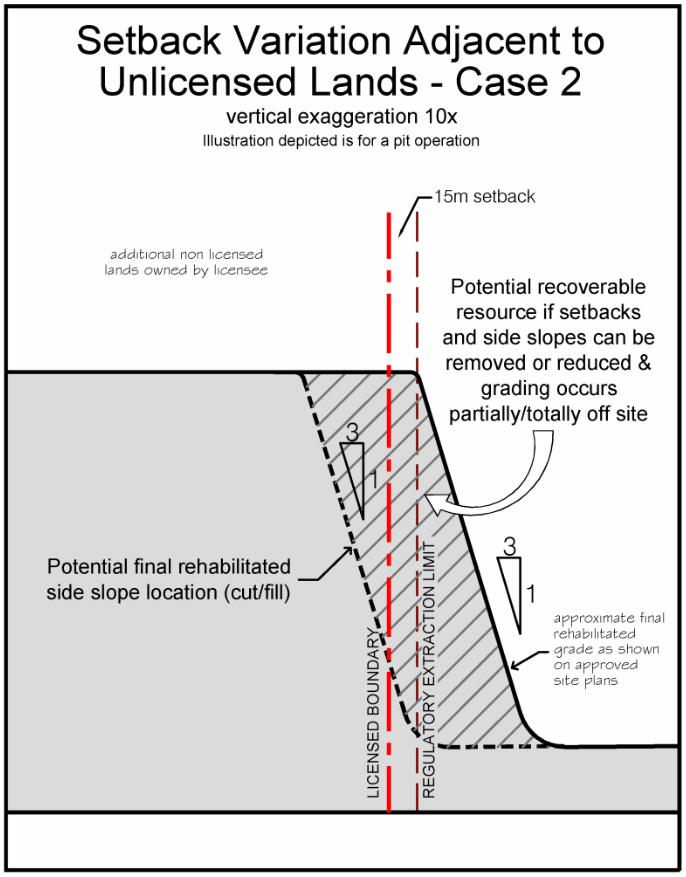
Considerable aggregate material could be added to the production stream if more off-site, clean and inert fill material was allowed for use in rehabilitation. In addition, having locations where backfill material can be taken would be of benefit to the construction industry, which must dispose of inert fill generated by a variety of construction projects.

A cautionary note is that the current “brownfield” legislative framework may discourage an operator from accepting clean inert fill into an ARA licence. This should be researched further as part of any comprehensive solution.

7.6.3 Use of Setback Areas or Adjacent Lands for Sideslope Rehabilitation

If rehabilitation of extraction faces can be accomplished using material within the setback or even adjacent lands, then additional material becomes available for extraction. The volume of material available would vary based on the length and depth of the subject face, and whether material is available from other sources (on-site or off-site) to supplement material at the pit or quarry face.

A variation to this theme that would permit total extraction of the setback in cases where the unlicenced land/material adjacent to the extraction site could be used to supply material for sloping purposes. This is illustrated below.



This type of arrangement would be possible only in certain situations, most likely where the licensee owns the adjacent lands. Given that the unlicenced material is being excavated for sloping purposes, MNR would have to take the position that the primary purpose is not the production of aggregate, and, as a result, the licencing provisions do not apply. However, municipal zoning by-laws would need to be addressed. Given the subject lands necessary for sloping would not be licenced, they would not be under an extractive zoning. Use of the lands for sloping would be considered as site grading which normally falls within the definition of development, and is something that could require a zoning change.

7.7 Quantification of Additional Resource Availability

A range of possible methods to maximize the amount of aggregate reserves in existing operations have been discussed in the previous sections and are summarized in the following table.

In the 'Comments' section of the table, each technique is identified as a potential opportunity (+), constraint (-) or neutral which does not have a symbol attached to it.

Option	Description	Comments
1	***Extraction (lowering) of municipal untravelled/unimproved road allowances***	■ where no potential exists for a road to be constructed or where municipality can use material (+) ■ licenced area on both sides or abutting one side of road allowance (+) ■ contractual/financial arrangements between licensee and municipality may be necessary to address compensation for material to be extracted (-)
2	***Total or partial extraction of regulatory excavation setbacks***	■ setbacks may be adjacent to road allowances, owned or non-owned private land, watercourses, other environmental feature, where degree (width) of setback may be in excess of what is required to protect the feature ■ there may be opportunities to relocate the feature so that setback is not required (+) ■ ARA Section 66 to address conflict with municipal side-yard provisions in Zoning By-law (+)
3	***Reduction in widths of regulatory excavation setbacks***	■ in bedrock versus sand/gravel on basis of stability or erosion characteristics of material ■ different setback widths based on type of adjacent land use ■ may conflict with municipal side-yards provisions in Zoning By-law and necessitate an amendment (-)
4	***Use of non-licenced land adjacent to licenced boundary for purposes of providing material for sloping which would occur either on-site or partially/totally off-site***	■ agreement required with adjacent landowner (-) ■ sloping would occur either on-site or partially/totally off-site (+) ■ material for rehabilitation only, not production (-) ■ compensation may be required between licensee and landowner (-) ■ issues of compliance with municipal zoning by-laws could result (-)
5	***Greater flexibility in importation of material for rehabilitation purposes or production purposes***	■ could 'free-up' a substitute for aggregate material retained on-site for rehabilitation ■ could supplement on-site material for production purposes if blended with on-site poor material (+) ■ clean and inert fill requirements (MOE) (-) ■ MOE and municipal criteria ■ testing at source of fill ■ would be of benefit to construction industry (+)
6	***Steeper rehabilitated slope gradients (i.e. 2:1 and 3:1) and/or greater use of total/partial vertical faces during quarry rehabilitation***	■ requires less on-site material for rehabilitation (+) ■ can result in reduced loss of otherwise extractable reserves under upper bench sloping (+)

Option	Description	Comments
7	***Decrease above water table buffer requirements (1.5 m or 2.0 m)***	■ possibility of reduction in areas where water table elevation variability is not high or high water table situations (above floor) are only short-term (+) ■ may require a higher level of monitoring, etc (-) ■ small increase in extractive depth over large floor area could result in significantly increased reserve availability (+) ■ requires revision of AROPS (-)
8	***Increased use of requirement for detailed sub-surface geological data technology in pit/quarry design, operation (improved beneficiation e.g., wash plant processes)***	■ allows for optimal blending qualities, size distributions, particle strengths and other qualitative and quantitative measures that otherwise lead to wastage (+) ■ identifies areas where suitable materials (poor quality) exist on-site for backfilling needs, thereby eliminating the need to keep higher quality aggregate for sloping purposes (+) NOTE: may only be applicable to specialized operations such as metallurgical stone, lime, cement and, silica sand (-)
9	***Extraction (lowering) of traveled road allowances***	■ may require detouring for existing traffic (-) ■ may require entirely new traffic route (-) ■ contractual/financial arrangements between licensee and municipality may be necessary to address compensation for material to be extracted (-) ■ formal municipal approvals (under Municipal Act, Planning Act) may be required (-) ■ may require licence application under ARA (-) ■ effective method to deal with unsafe or poor road geometry (+)

To provide some indication of the type of increase that could be achieved with the implementation of these techniques, the following table includes an assessment of tonnage and percent gain for a hypothetical extraction site, with a licenced area of 40 hectares and an extraction depth of 20 metres. Both a pit site and a quarry site are considered.

Based on a representative 40 ha site (861 m x 470 m) and an extraction depth of 20 m, the following additional reserves of sand/gravel (s/g) and bedrock could be realized.

Method	*Potential Gain*				*Comments*
	Thousand Tonnes		*Percent Gain*		
	Bed.	*S&G*	*Bed.*	*S&G*	
1. Reduce all setbacks by 5 m	633	390	4%	4%	Potential gain would increase corresponding to reduction of setback.
2. Reduce road allowance setback by 15 m	18	11	0.1%	0.1%	With permission of road authority. Setback could be reduced to nil if road is not “open”.
3. Remove setbacks and road allowance between licenced areas	2,592	1,808	16%	19%	Includes gains from extraction areas on both side of the road allowance, by: elimination of rehabilitation requirement; extraction of material in (former) setbacks; extraction of material in road allowance.
4. Reduce floor to water table buffer by 0.5 metres	414	244	2.5%	2.5%	Where monitoring data and assessment indicate a stable water table.
5. Increased depth with/without extraction below water table	4,145	2,442	25%	25%	Assumes a 5 m increase in depth. Will only be applicable at those sites where resource deposit extends below approve depth of extraction.
6. Complete side-slope rehabilitation without use of on-site material	2,598	2,440	14%	25%	For example, use of imported fill, allowance for vertical faces and/or creation and extension of slopes in adjacent land.

7.8 Summary

The most productive/expedient techniques to maximize the amount of aggregate reserves at typical existing licenced operations are:

- to vary (reduce/eliminate) excavation setbacks;
- extract to a greater depth;

- to rehabilitate the site through the use of imported material, which will substitute, in part or in full, the material that would have to be retained on-site to undertake rehabilitation; and
- extraction of road allowances between licenced sites.

These techniques are considered good candidates for enhanced implementation at existing pit/quarry sites taking into account issues raised and the potential significance of additional aggregate availability.

Benefits would extend beyond the immediate increase in aggregates availability, and would include improved/accelerated rehabilitation, municipal revenue (in material or monetary compensation) and locations for placement of excess fill.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations for Paper 5 of the SAROS project, which was carried out to evaluate existing reserves on currently licenced properties in Areas 2, 3, 4 and portions of 5, are provided below.

8.1 Conclusions

A detailed examination of the remaining reserves in limestone and dolostone quarries located in CPCA Areas 2, 3, 4 and a portion of 5 was carried out under Paper 5 of the SAROS project. Conclusions of the study have been provided below:

1) A total of 97 licenced sites with areas greater than 20 ha were evaluated. Individual quarries of less than 20 ha were not evaluated.

2) Determining quality of remaining resources is particularly challenging without site specific information. Generalizations with respect to expected quality of reserves had to be made. Based on this experience, it would be even more difficult to carry out a similar assessment of sand and gravel reserves due to the variability of sand and gravel deposits, even with a high level of field verification, particularly for a licenced property in which a large proportion remains unextracted.

3) The 97 quarries evaluated comprise approximately 9,000 hectares of licenced reserves, however only approximately 7,200 hectares is permitted for extraction. This represents, on average, approximately 80% of the licenced reserves.

4) A reserve estimate totalling approximately 1.25 billion m^3, or 3.44 billion tonnes of stone, was calculated for the 97 properties, indicating an average of approximately 0.5 million tonnes per extractable hectare.

5) Of the total reserve estimate of 1.25 billion m^3, or 3.44 billion tonnes, only about 536 million m^3, or 1.47 billion tonnes, or about 43%, is considered to be of high quality, suitable for use in concrete or asphalt. The remaining reserves are of lower or unknown quality. Of this, a maximum of approximately 359 million m^3, or 987 million tonnes would be directly available for concrete/asphalt grade stone and manufactured sand.

6) There are an estimated 876 million m^3/2.41 billion tonnes of reserves located in quarries within the study area that would be considered to have ‘abundant’ reserves. In addition there is approximately 279 million m^3/767 million tonnes of reserves located within quarries that would be considered to be in a moderate reserve situation and an additional approximate 96 million m^3/264 million tonnes of reserves located within quarries where the resource situation would be considered scarce. Approximately 70% of the reserve base that is considered to be ‘abundant’ is found in only 15 quarries, or 15% of the total number of quarries evaluated. The remaining 82 quarries, or 85% of those evaluated, have either a ‘scarce’ or ‘moderate’ reserve base.

7) Approximately 68% of the calculated reserves are located at straightline distances of greater than 75 km from the Vaughan Corporate City Center (VCCC), which represents a high growth area of the GTA. If travel distances were considered, based on available haul routes from the individual sources, the total reserve base located greater than 75 km from the VCCC would be greatly increased. A total reserve base of approximately 328 million m^3, or 902 million tonnes, is located within 75 km of the VCCC. However, of this total only approximately 173 million m^3, or 476 million tonnes, are considered to be ‘high’ quality. Considering that a maximum production of about two-thirds of the total high quality reserves is achievable for production of concrete/asphalt grade stone and manufactured sand, this translates into approximately 116 million m^3, or 317 million tonnes, available within a 75 km distance of the VCCC.

8) The most productive/expedient techniques to maximize the amount of aggregate reserves in existing operations are: to reduce/eliminate the width of excavation setbacks, allow for deeper excavation, remove road allowances where available and to rehabilitate the site through the use of imported material, which will substitute in part or in full, the material that would have to be retained on-site to undertake rehabilitation.

While the total reserve base of 1.25 billion m^3, or 3.44 billion tonnes, appears to be a large number, it is important to understand that:

- only about 43% of this total is considered to be of high quality;
- the majority of these reserves are being located at greater distances from the markets that are demanding them, as the ‘close to market’ sources continue to become depleted;
- the reserves that are considered to be ‘abundant’ are located within relatively few operations (only 15 of the 97 sites), the majority (11 of the 15 sites) of which are located at greater distances from the largest market demand area, the GTA; and
- the supply to the GTA market area is coming from sites that are considered to have scarce to moderate reserve bases, which are being exhausted at a greater rate than they are being replenished through the granting of new licences by the Province.

The result of this will be an increasing supply of aggregate coming from sources at greater distances, as those which are currently located close to the market are being exhausted.

8.2 Recommendations

The following recommendations are made based on the findings of the Paper 5 study on the remaining reserves in existing licences within CPCA Areas 2, 3, 4 and portions of 5.

1) An extension of the study of existing reserves to include all quarries in CPCA Market Areas 1 to 6 in order to provide a more comprehensive understanding of the reserve situation in Ontario relative to the other market demand areas.

2) Considering the contribution of sand and gravel resources to the overall supply of aggregate in Ontario, a comprehensive study of the licenced reserves of sand and gravel pits within the GGH (CPCA Areas 2, 3, 4 and the southern portion of 5) is recommended in the short-term, despite the difficulties identified, in order to provide a complete understanding of aggregate supply in southern Ontario. If it is decided to proceed with a project to determine reserves in sand and gravel pits in an efficient and cost-effective manner, the following suggestions are made:

   a) a licence area of not less than 40 hectares be the minimum area for evaluation; and

   b) Category 3 (Class "A" pit above water) operations only be considered for evaluation, unless resources inventory or other geoscience-based documents are available for Category 1(Class "A" pit below water) operations.

In the longer term, a study of licenced reserves of sand and gravel within CPCA Areas 1 and 6 would also be an important contribution.

3) A more formal recognition of identified aggregate resource deposits, similar to KRAs or MRZs in Australia and California, should be considered, particularly for sources of aggregate that are considered to be of provincial significance.

4) The Province of Ontario should consider the following:

   a) formal recognition of identified 'high priority' aggregate resource areas of known quantity and quality (based on sound geoscientific investigation); and

   b) formal acceptance of these high priority aggregate resource areas where licence applications would be encouraged (or at least not unduly hindered), with the recognition that such high priority areas be as close to market areas as possible.

5) In order to improve any future evaluation of licenced reserves, the following changes to Site Plan requirements would be beneficial:

   a) that all Licence boundaries, setback limits and other significant features be accurately delineated by recognized survey methods and coordinates (e.g., UTM);

   b) that all rock strata being extracted be clearly identified, including below the quarry floor where possible, for example on cross-sections;

   c) that all spot elevations and contour lines be tied to a recognized geodetic datum; and

d) that unambiguous elevations of the quarry floor (i.e., maximum depth of extraction), prior to rehabilitation, be identified.

6) In order to maintain and enhance the licenced reserve estimates, as provided in this report, the following are suggested:

   a) that all calculations be updated annually on the basis of production tonnages provided to TOARC; and

   b) that CPCA Areas 1 and 6 be included in any subsequent study of limestone and dolostone reserves.

7) That portions of CPCA Areas 7 and 8, and in particular, Manitoulin Island and areas in the vicinities of North Bay, Sudbury and Thunder Bay, be included in any subsequent study of limestone and dolostone reserves.

9.0 LIMITATIONS

This report was prepared for the exclusive use of the Ontario Ministry of Natural Resources for the purpose of identifying remaining reserves in selected quarries in certain market areas in the Province of Ontario. The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and geosciences professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

In preparing the report, Golder and MHBC have assumed that the information provided by other parties was factual and accurate. To the extent that Golder and MHBC relied on the information provided by others, Golder and MHBC disclaim any responsibility for errors resulting there from. Golder and MHBC also accept no responsibility for any deficiency, misstatement or inaccuracy contained in the report as a result of omissions, misinterpretations.

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Report Signature Page

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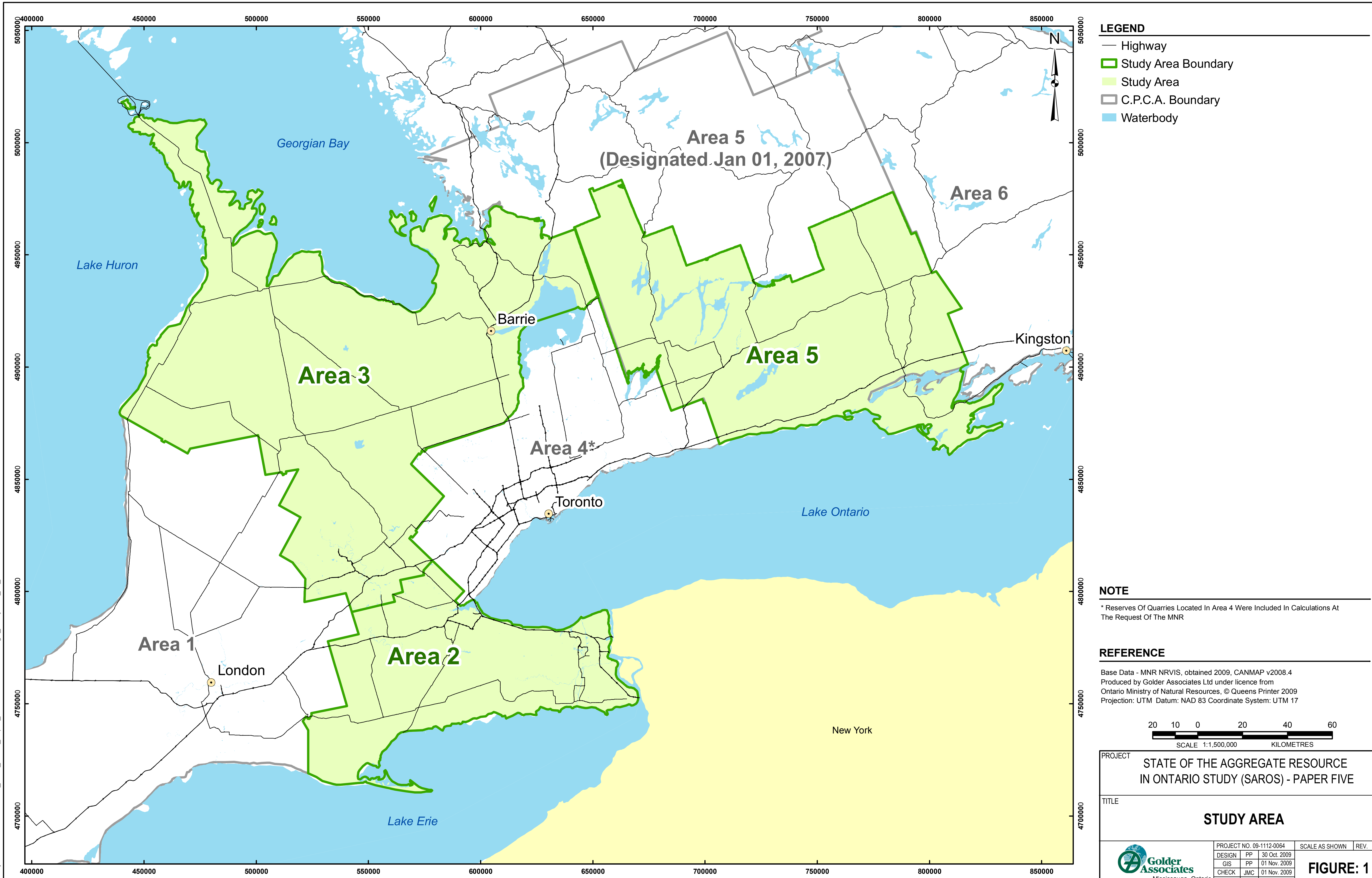
FIGURES



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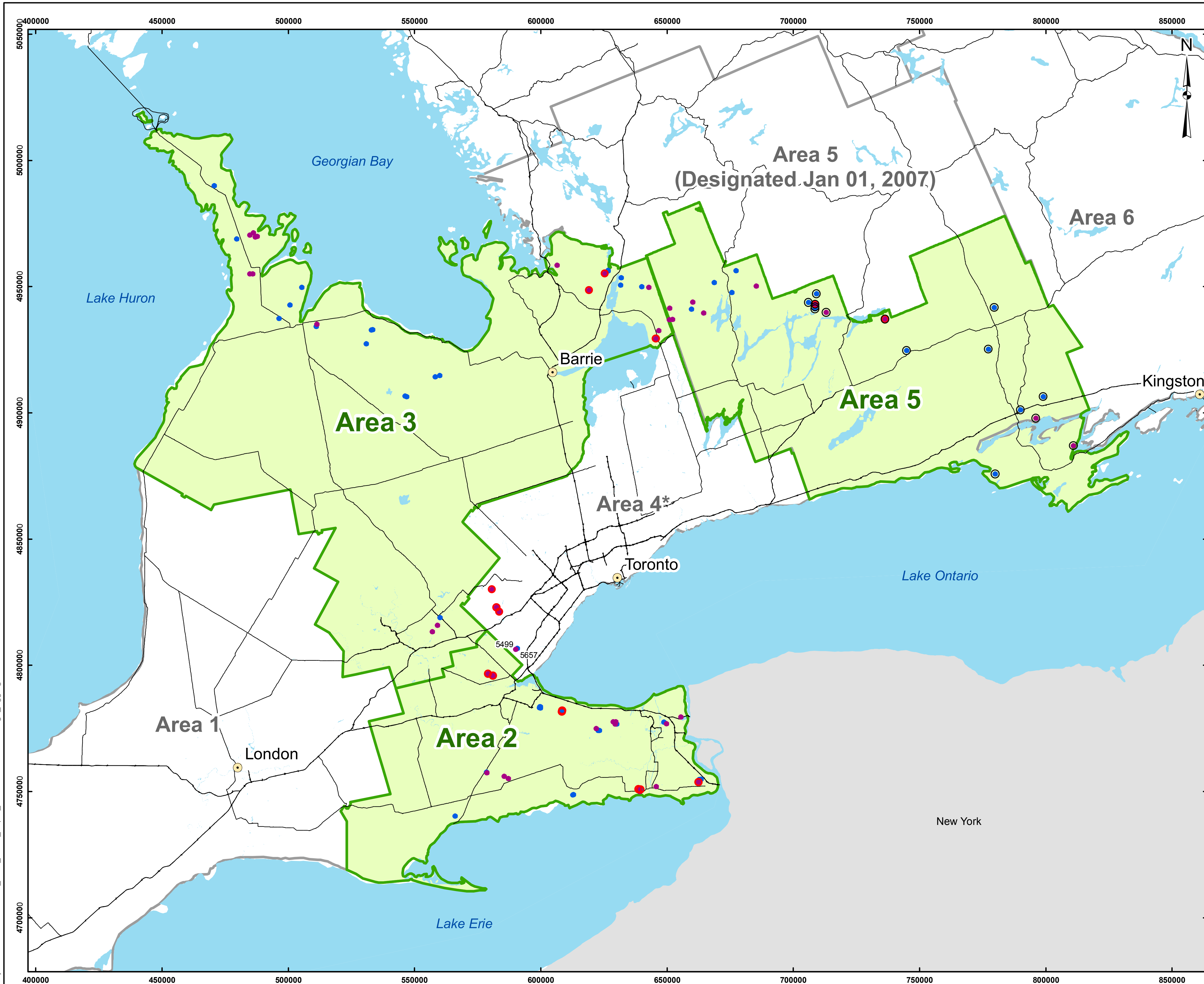

LEGEND

- DTM Test Site
- Site Verification Visit
- Aggregate Property Size
  - 20 - 60 ha
  - > 60 ha
- Highway
- Study Area Boundary
- Waterbody
- C.P.C.A. Boundary
- Study Area

NOTE

* Reserves Of Quarries Located In Area 4 Were Included In Calculations At The Request Of The MNR

REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2008.4
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Projection: UTM Datum: NAD 83 Coordinate System: UTM 17

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PROJECT
STATE OF THE AGGREGATE RESOURCE IN ONTARIO STUDY (SAROS) - PAPER FIVE

TITLE
AGGREGATE SITE LOCATIONS

Golder Associates
Mississauga, Ontario

PROJECT NO. 09-1112-0064			SCALE AS SHOWN	REV. 0.0
DESIGN	PP	30 Oct. 2009	**FIGURE: 2**	
GIS	PP	01 Nov. 2009		
CHECK	JMC	01 Nov. 2009		
REVIEW	WC	01 Nov. 2009		

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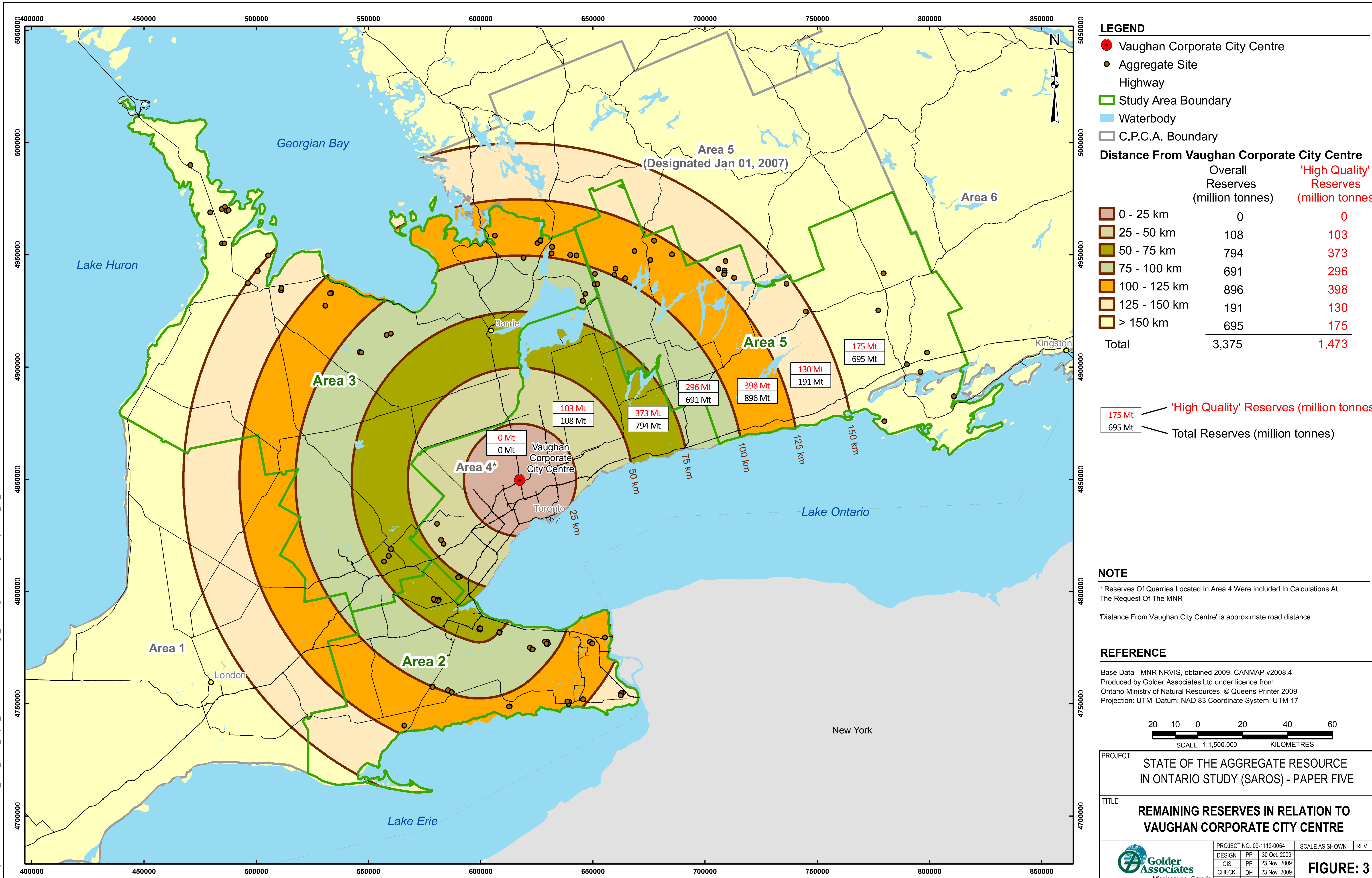

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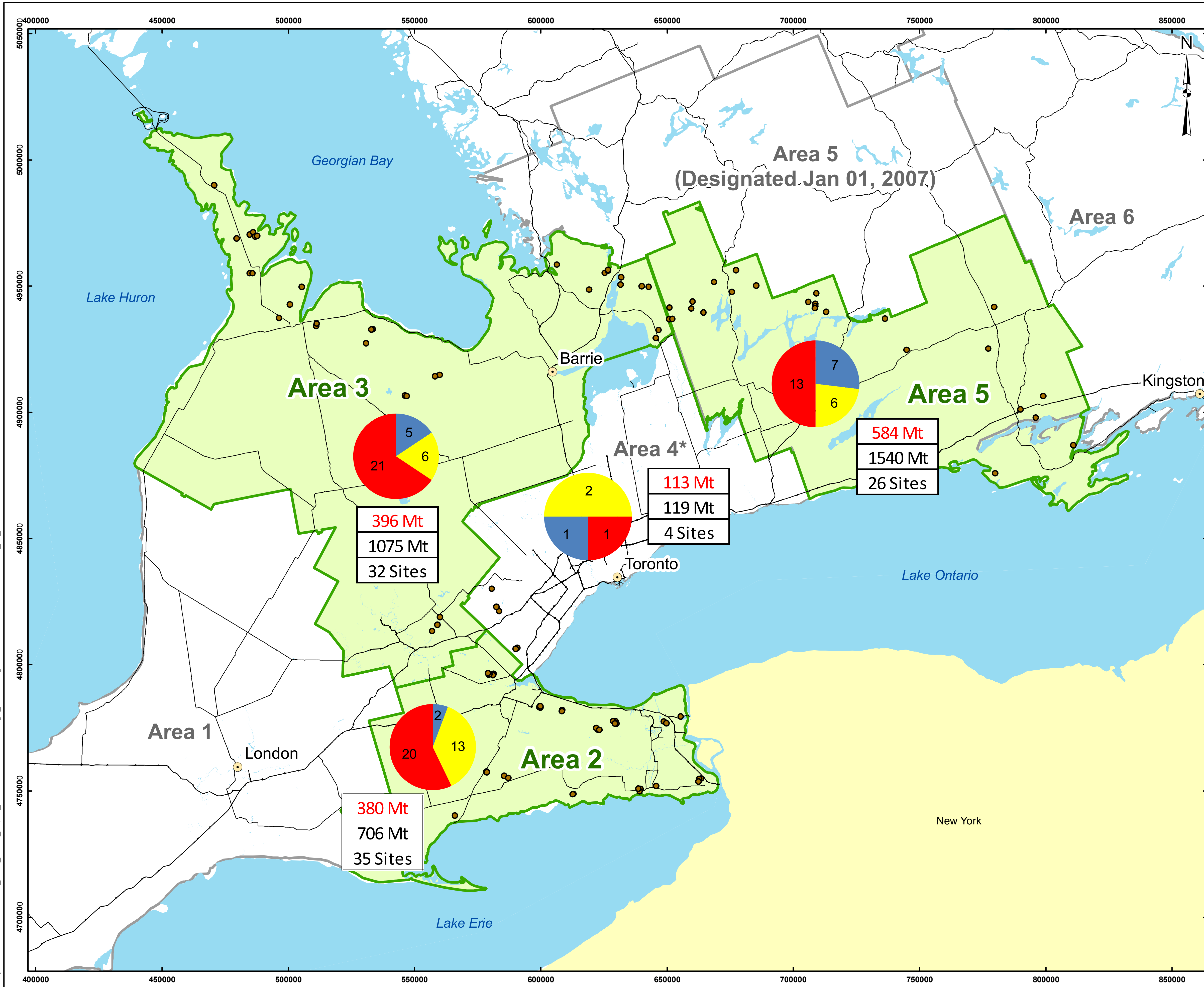

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LEGEND

- Aggregate Site
- Highway
- Study Area Boundary
- Study Area
- C.P.C.A. Boundary
- Waterbody

# of Sites With Moderate Reserves (14 - 55 Mt)

# of Sites with Relatively Abundant Reserves (> 55 Mt)

# of Sites With Relatively Scarce Reserves (< 14 Mt)

380 Mt — Total High Qualtiy Aggregate

706 Mt — Total Aggregate Tonnage In Area

35 Sites — Total Number of Aggregate Sites In Area

CPCA Area	Abundance (> 20 million m³)	Moderate (5-20 million m³)	Scarcity (< 5 million m³)
Area 2	2	13	20
Area 3	5	6	21
Area 4	1	2	1
Area 5	7	6	13
Total	15	27	55

NOTE

* Reserves Of Quarries Located In Area 4 Were Included In Calculations At The Request Of The MNR

REFERENCE

Base Data - MNR NRVIS, obtained 2009, CANMAP v2008.4
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Projection: UTM Datum: NAD 83 Coordinate System: UTM 17

20 10 0 20 40 60
SCALE 1:1,500,000 KILOMETRES

PROJECT
STATE OF THE AGGREGATE RESOURCE IN ONTARIO STUDY (SAROS) - PAPER FIVE

TITLE
REMAINING RESERVES AND THEIR RELATIVE ABUNDANCE AND SCARCITY

Golder Associates
Mississauga, Ontario

PROJECT NO. 09-1112-0064			SCALE AS SHOWN	REV. 0.0
DESIGN	PP	30 Oct. 2009		
GIS	PP	24 Nov. 2009		
CHECK	JMC	24 Nov. 2009		
REVIEW	WC	24 Nov. 2009		

FIGURE: 4

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