# Interim Report
## From Aggregates to Agriculture

## 1 Introduction:

### 1.1 Report Summary

Information on the current status of agricultural rehabilitation of aggregate pits and quarries in Ontario is minimal. Since 1982, little information has been collected and collated regarding the state and extent of former aggregate sites returned to agricultural use. With interest in land restoration and farmland preservation increasing, research by The Ontario Aggregate Resources Corporation (TOARC) in 2013 focused on collecting information regarding the location, management and physical characteristics of sites rehabilitated to agriculture post-extraction. This report outlines the state of research on agricultural rehabilitation and the results of the first year of the TOARC study.

### 1.2 What is Agricultural Rehabilitation?

Rehabilitation of aggregate extraction sites, which usually refers to the grading, soil replacement and re-vegetation of pits and quarries, has been a requirement since the Pits and Quarries Control Act was made legislation in 1972 (Mackintosh and Hoffman, 1985). Because rehabilitation of land to its pre-extraction land use is encouraged, and high quality aggregate deposits often underlay soils with high capability for agriculture, rehabilitation to agriculture has been a relatively common practice in Ontario (Mackintosh and Mozuraitus, 1982). Agricultural rehabilitation, specifically, refers to the returning of land to an agricultural capability of equal or greater quality then prior to extraction.

### 1.3 History of Agricultural Rehabilitation

Interest in agricultural rehabilitation of aggregate extraction sites in Ontario has ebbed and flowed over the decades since 1970. In the 1970's an emphasis was placed on recreational uses for rehabilitated sites. Interest shifted to include agricultural rehabilitation in the 1980's as issues of farmland preservation due to increasing urbanization and land use pressures became more serious (Skelton Brumwell & Associates Inc. and Savanta Inc., 2009). Since aggregate sites are often located in rural areas on agricultural soils, rehabilitation to agriculture was seen as a positive and productive end-use. During the 1980s two publications by the Ministry of Natural Resources sought to address these issues and document rehabilitation methods and techniques suitable for agricultural lands (Table 1).

Table 1: Agricultural rehabilitation research in Ontario, author and year of publication.

| Research | Author | Year |
|---|---|---|
| Agriculture and the Aggregate Industry | E.E. Mackintosh and E.J.Mozuraitus | 1982 |
| Rehabilitation of Sand and Gravel Pits for Fruit Production in Ontario | E.E. Mackintosh and M.K. Hoffman | 1985 |

In the 1990's interest in agriculture as a rehabilitation option decreased as sustainability of rare and sensitive ecosystems (e.g. alvars, tall grass prairies, fens etc.) came into the spotlight (Skelton Brumwell & Associates Inc. and Savanta Inc., 2009). Today, however, a more balanced approach is sought, which integrates multiple end-uses. For example, agricultural land which integrates wildlife corridors will promote natural heritage as well as rural land uses. This type of thinking, along with an interest in agricultural land conservation has led to renewed interest in the techniques and planning required in agricultural rehabilitation of aggregate sites.

## 1.4 Past Research and Recommendations

Existing recommendations regarding agricultural rehabilitation in Ontario come from the Aggregate Resources Act (1990) and its predecessor the Pits and Quarries Control Act (1971) as well as the research performed in 1982 by Mackintosh and Mozuraitus for the Ontario Ministry of Natural Resources. The Act (1971, 1990) established a maximum slope steepness of 3:1 for pits and the retaining of soil and subsoil on-site if agriculture was the after-use of the site. Mackintosh and Mozuraitus, who looked at 63 sites that had been rehabilitated to agriculture, established the necessity of a minimum of 15-20 centimetres (cm) of topsoil for agricultural crops. A layer of soil material (topsoil + subsoil) of 1 metre (m) over a saturated zone was also indicated as essential. Furthermore, they suggested 12 steps to assure successful agricultural rehabilitation:

1. Pre-planning
2. Strip the topsoil, subsoil, and overburden separately
3. Strip small areas at a time
4. Move soil materials under dry conditions
5. Rehabilitate progressively
6. Grade and contour the pit floor
7. Replace overburden, subsoil, and topsoil in the correct sequence
8. Calculate volumes, depth, and areas to be covered carefully so as not to run out of soil material
9. Eliminate severe soil compaction
10. Create a post rehabilitation management plan
11. Use good agriculture practices
12. Be patient

Pre-planning is particularly important because changes to rehabilitation plans can be costly and complicated (Skelton Brumwell & Associates Inc. and Savanta Inc., 2009). Assessing the best after-uses for sites can be difficult, especially as science and society's demands change over time. For example a property operating for more than 30 years may have originally intended to be returned to an agricultural after-use; however, population growth or low soil capability for agriculture may cause a change to the after-use from agriculture to a better fit for the area (Trimble and Seibert, 2002). This demonstrates that returning land to its prior use may not always be the best option. Considering the quality of the land prior to extraction is an important part of pre-planning. If, however, the site is located on high quality agricultural land, agricultural rehabilitation should be considered as an after-use (Friedli et al., 1998).

How and when soil is moved is one of the most important factors in agricultural rehabilitation. Preserving the natural layers of topsoil and subsoil at a site is intrinsic to successful rehabilitation (Kaufmann et al., 2009b). Topsoil is the uppermost layer of soil that contains the greatest concentration of organic material (Brady and Weil, 1996). This layer is usually 15-30 cm in depth in agricultural soils where tillage has occurred (Mackintosh and Mozuraitus, 1982). Subsoil is directly below the topsoil and can be up to 1 m in depth (Mackintosh and Mozuraitus, 1982). This part of the soil can contain a significant amount of plant roots and is very susceptible to compaction due to the presence of more clay sized particles (Mackintosh and Mozuraitus, 1982). Since subsoil lacks the organic matter and microbial communities that are found in topsoil, mixing the soils can result in plant establishment problems (Strohmayer, 1999).

Soil quality can be defined as “the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation” (Karlen and Andrews, 2000). Research suggests that soil quality deteriorates when soil is stored in stockpiles or berms (Strohmayer, 1999). Soil structure can take hundreds of years to develop but it is destroyed as soon as soil is removed (Stahl, 2002). For example, removal of soil increases the bulk density, decreases water holding capacity and reduces microbial activity (Stahl, 2002). These problems can be exacerbated if the soil is moved with increased water content (Mackintosh and Mozuraitus, 1982). In addition, storing soil in stockpiles more than 1 m in depth creates an anaerobic environment which reduces microbial communities, soil organic matter, and seed viability (Davies, 1995). Mackintosh and Mozuraitus (1982) suggested that soil should not be stored for more than five or six years to avoid serious deterioration.

Once reapplied, soils lack structure and are susceptible to erosion (Veenhof and McBride, 1996). Kaufmann et al. (2009a) suggest that soils with poor aggregation are highly sensitive to compaction and water logging, which can lead to agricultural limitations. According to a number of European guidelines, soils can regain a level of structural integrity suitable for field crop production after three years if tillage and heavy traffic are avoided (Kaufmann et al., 2009a). Soil ripping or deep tillage can be used as a method to alleviate compacted zones prior to the reapplication of topsoil if the underlying material is severely compacted (Mackintosh and Mozuraitus, 1982).

A post-rehabilitation management plan is an important final step in the rehabilitation process. Most guidelines recommend planting of a cover crop or grassland that requires minimal management and traffic while providing the soil a jumpstart of soil organic matter, aggregation, and soil erosion control (Tobias, 2008). Tobias (2008) suggests five years of this type of extensive management; however this figure is not based on scientific findings.

In summary, the effect of aggregate extraction on soil physical, chemical and biological properties can be severe. Since biologically active and unpolluted soil is necessary for agriculture, much research has gone into conserving and restoring soil quality (Kaufmann et al., 2009). If not excavated, stored and managed properly, soil can become compacted, biologically imbalanced and unsuitable for agricultural uses. However, most guidelines regarding soil management and rehabilitation are not based on scientific research.

### 1.5 Space for Improvement

While rehabilitation has been a requirement in Ontario since 1971, the State of the Resources Report (SAROS, 2009) suggested that the effectiveness and sufficiency of this rehabilitation is still being criticized by the public and experts alike (Skelton Brumwell & Associates Inc. and Savanta Inc., 2009). Some of this lack of public trust may be due to rehabilitation decisions being based on discussions with stakeholders more than scientific findings and the lack of recommendations for rehabilitation in the Aggregate Resource Act (1990). Also, while there are strong examples of innovative rehabilitation design around the province, the complicated and expensive nature of rehabilitation plan amendments has contributed to a general lack of creativity and flexibility in rehabilitation design (Skelton Brumwell & Associates Inc. and Savanta Inc., 2009).

A fundamental conclusion of the 2009 SAROS study was that a diversity of stakeholders agree that rehabilitated land should be:

1. Compatible with surrounding land uses,
2. Returned back to its pre-extraction land use,
3. Useful, and
4. Left in a state as good as pre-extraction.

Agricultural end-uses could contribute importantly to rehabilitation projects in the province by following these guidelines. Unfortunately, there is no comprehensive information available as to the extent to which existing agricultural rehabilitation recommendations have been followed, or even locations where such rehabilitation has been attempted. The primary goal of this study is thus to systematically collect and apply information about previous and ongoing agricultural rehabilitation in order to close this knowledge gap and promote informed and productive rehabilitation decision-making within Ontario's aggregate production industry.

## 2 Research Questions and Objectives:

The research questions are:

1. How many sites are there where land used for aggregate extraction has been returned to an agricultural use; where are they located and what size are they?
2. Are the farms on the rehabilitated land as good as the farms prior to extraction?

The objectives of the research project for 2013 were to:

a. Document the location and extent of sand and gravel extraction sites in southern Ontario that have been rehabilitated to agriculture;
b. Contact producers and landowners to discuss extraction, rehabilitation, and current management practices;
c. Survey sites by visiting locations and assessing a prescribed set of physical qualities.

# 3 Methods:

## 3.1 Database development

Lists of former aggregate sites returned to agriculture were reviewed for inclusion in this study. These included surrendered sites procured from the MNR ALPS database, legacy pits from the TOARC eMAAP database, and wayside pits from the Ontario Ministry of Transportation (MTO). Information on end use of licensed sites from OSSGA was overlaid with this in the areas assessed in their 2012 and 2013 study of End Use, including: the GTA, City of Ottawa, Greenbelt Plan, Niagara Escarpment and Oak Ridges Moraine. Aggregate sites where progressive rehabilitation to agriculture occurred, or was occurring were added to the database of sites via calls from individual landowners and property managers as well as from information obtained from OSSGA's rehabilitation awards. Combining all this information (removing replication due to license amalgamation) resulted in a database of over 1700 sites.

Visits to MNR district offices were undertaken in March and April 2013 and February 2014. Aggregate Inspector's surrendered license files were viewed, taking note of stated end use on the rehabilitation plans. Rehabilitation plans citing agriculture as the prescribed end-use were noted and copied to assist in finding sites.

All sites were further examined using aerial photography and satellite imagery. Although the imagery was somewhat outdated, conclusions on end use were possible for many sites where there was a clear indication of no agricultural activity (e.g. large ponds, forested areas, residential developments). Where aerial photography and satellite imagery did not provide enough detail, field verifications were completed.

## 3.2 Field Surveys

Sites where the end use was unclear were mapped and visited by a field technician between May and November 2013. Figure 1 shows the Counties of Ontario where sites were visited. Sites east of Frontenac County were not visited due to time and personnel constraints during 2013. The counties shown in white were not included in the study area because it was anticipated that little agricultural production would be occurring and time constraints. For each site where agriculture was confirmed or possible, landowners were contacted. Site surveys and landowner questionnaires were completed with the permission of the landowner.

Surveys and questionnaires encompassed a range of information including; landowner contact information, site history (when known), rehabilitation techniques, current management practices, crop history, soil texture, stoniness, and surrounding land use. Crop type was broken down into four main categories: pasture, field crop, hay and other (including vineyard and orchard).

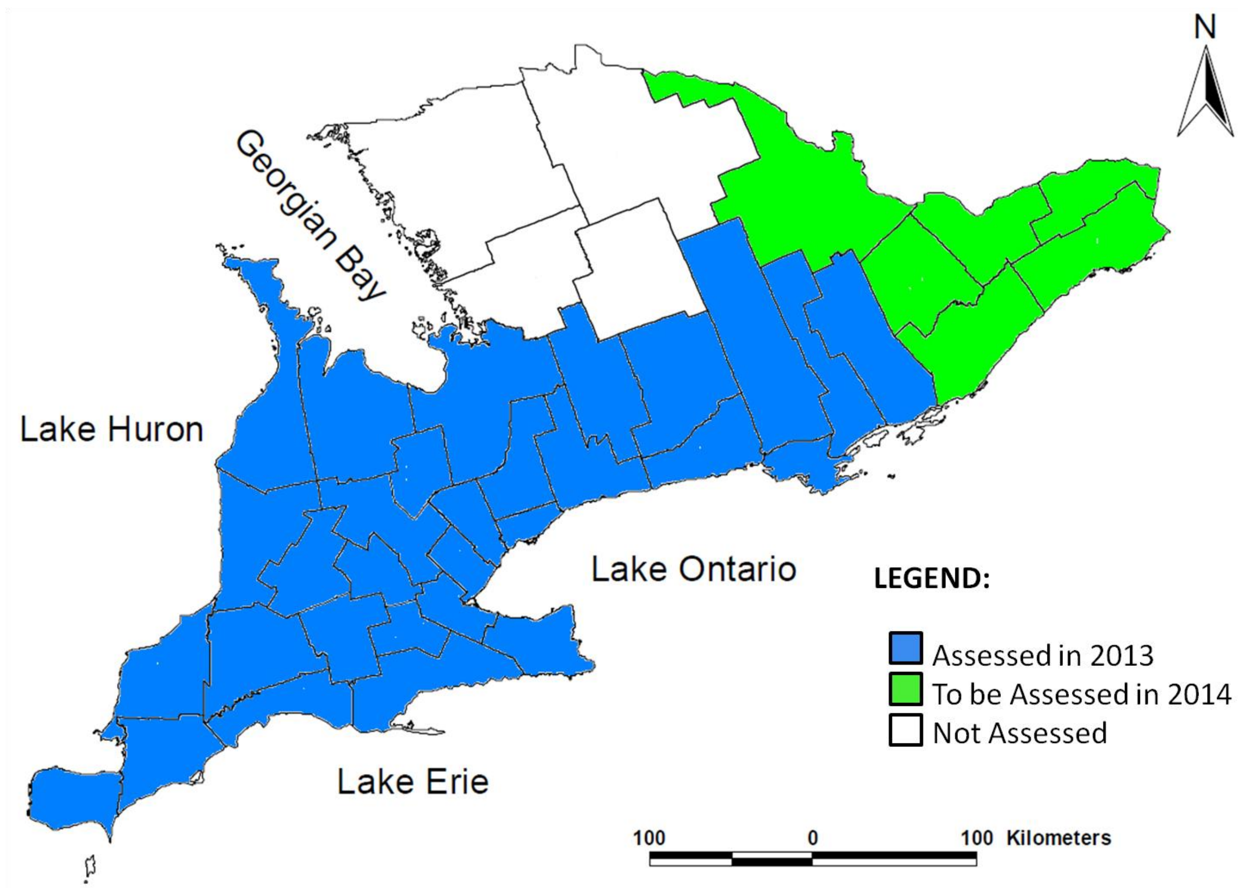



**Figure 1: Counties of Southern Ontario showing counties that were assessed in 2013.**

# 4 Results:

## 4.1 General Data:

Of the over 1400 sites assessed across 26 counties in Ontario in 2013, over 800 were confirmed to have no agriculture. These included sites where agriculture was in the rehabilitation plan but land use changed over time, or sites where the rehabilitation plan had no stated end use but was verified by MAAP staff to not have agriculture. Many of these sites were in urbanized or developing areas. 320 sites were labelled as 'attempts' (when contact with the landowner could not be established at the time of the site visit and no information on the exact location of the site could be ascertained). A total of 114 completed inventories and 64 incomplete inventories were performed. Complete inventories, were those where the landowner was successfully contacted and a site visit was carried out. If a landowner was not contacted or the site visit was not completed, the inventory was considered to be incomplete. ‘Incomplete’ sites differed from ‘attempts’ in that the rehabilitated area could be identified via a site plan, a neighbour’s confirmation, or obvious signs of rehabilitation.

All of the sites inventoried were pits where sand or gravel extraction had occurred, under a license (43%) or wayside permit (11%) or on abandoned sites where extraction had occurred without a license prior to 1990 (31%) (Figure 2). The license/permit status of fifteen percent of the sites inventoried was considered unknown. These were sites where information regarding the type of license (A or B)/permit could not be found.

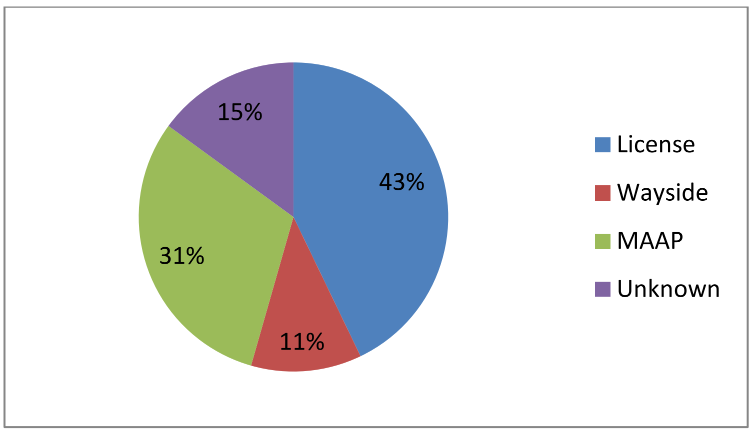
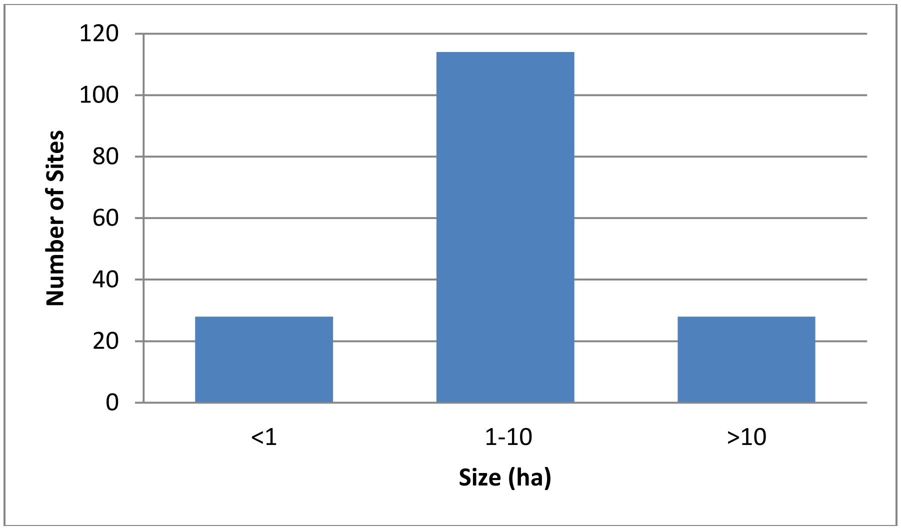



**Figure 2: License types of surveyed sites rehabilitated to agriculture.**

The 178 surveyed sites covered a total of 1086 ha of land that had been rehabilitated to agriculture. This includes 587 ha of land from completed inventories and 499 ha of land from incomplete inventories. Site size was divided into three categories: <1 ha, 1-10 ha and >10 ha. As shown in Figure 3, the majority of sites were between 1-10 ha, with almost equal amounts in the <1 ha and >10 ha categories.




***Sites included complete inventories and incomplete inventories where survey assessments could be carried out.**

**Figure 3: Size (in ha) of Sites Returned to Agriculture.**

Seventy-seven percent of the sites with confirmed agriculture were 100% agriculture, while 23% of the sites were mixed land uses. Where sites had mixed land uses, it was often a small percentage consisting of side slopes or wet bottom areas that could not be returned to agriculture.

The sites in the study encompass agricultural rehabilitation spanning from the 1960s to present. Surveyed sites were categorized into decades: 1970s (including anything before the 1970s), 1980s, 1990s, 2000s, and 2010s. Within the dataset, more agricultural rehabilitation projects have taken place since the beginning of the 1990s then before 1980 (Figure 4). This discrepancy may be due to the length of time since rehabilitation leading to changes in land-use or changes in landowners causing a loss of historical information.

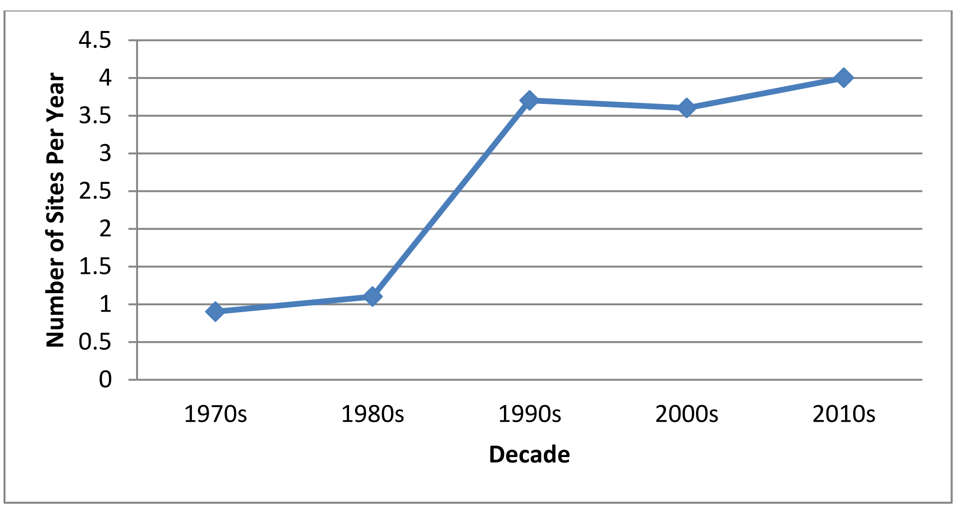



**Figure 4: Average number of sites rehabilitated per year in each decade since 1970.**

There were seven sites where the year of rehabilitation was unknown, and one site in the dataset where no rehabilitation had taken place. These sites were not included in Figure 4. The data in the 2010 decade represents the years 2010-2013, extrapolating that a similar trend would continue throughout the current decade.

The type of agricultural land use was also documented for all of the inventoried sites (Figure 5). Field crop (44%) included corn and other grains, soybeans, and other annual crops. Pasture (39%) represented areas where livestock was grazed and often was a permanent use due to physical constraints of these sites. Many of the sites had been planted to pasture and had not been replanted in more than five years.  Hay, which was defined in this study as grass or grass/legume mixtures which were cut two to three times per year for animal feed, made up only 14% of the sites assessed. The other (3%) category consisted solely of orchard and vineyard sites and sites that had been left fallow.

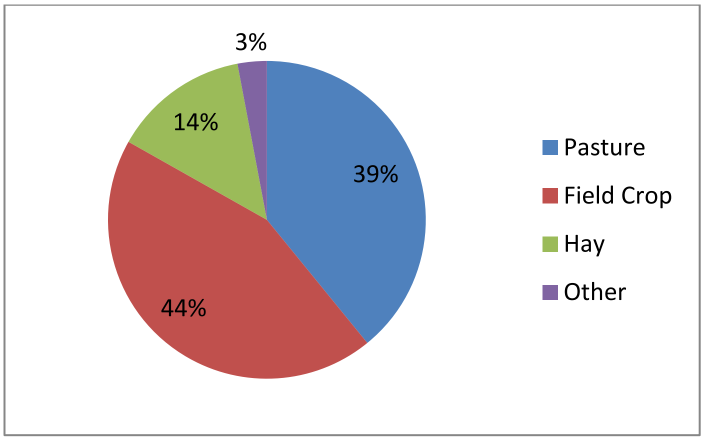



**Figure 5: Types of agriculture in complete and incomplete inventories.**

## 4.2 Rehabilitated Land Characteristics:

A number of parameters regarding rehabilitation practices were included in the landowner questionnaire or visually assessed. These included questions concerning:

- Slope height (m) and steepness (run:rise)
- Importation of fill
- Soil stoniness
- Soil texture

Most of the sites studied were sloped to <3:1 with slope heights of 1-3 m (Table 2).

**Table 2: Slope steepness and height in agricultural rehabilitation sites surveyed**

| Slope Steepness | Number of Sites* | Slope Height | Number of Sites |
|---|---|---|---|
| **<3:1** | 70 | **<1 m** | 44 |
| **3:1** | 29 | **1-3 m** | 69 |
| **2:1** | 38 | **>3 m** | 29 |

***Sites included complete inventories and incomplete inventories where survey assessments could be carried out.**

Farming systems that use machinery require slopes to be closer to 6:1 to 10:1 range for safety concerns. Slopes 3:1 or steeper which were reported on the study sites were usually unimproved pastures where the use of machinery was not necessary. Some of the sites had steep side slopes which were vegetated but not used for agricultural purposes.

Topsoil was removed or sold from many of the sites where extraction took place prior to 1990. Twenty-seven of the sites surveyed reported bringing in fill for rehabilitation, for grading or to replace topsoil that had been removed. This material was usually topsoil, subsoil or clean waste materials that were received from nearby construction projects or bought from off-site. Based on communication with landowners, three of the sites which reported the use of fill used construction waste. The remaining 90% of the sites used topsoil or subsoil received from nearby construction projects, ditches or bought from local suppliers. Figure 6 shows the number of sites importing fill per decade with the total number of sites assessed per decade. Three of the sites with imported fill had unknown dates of rehabilitation.

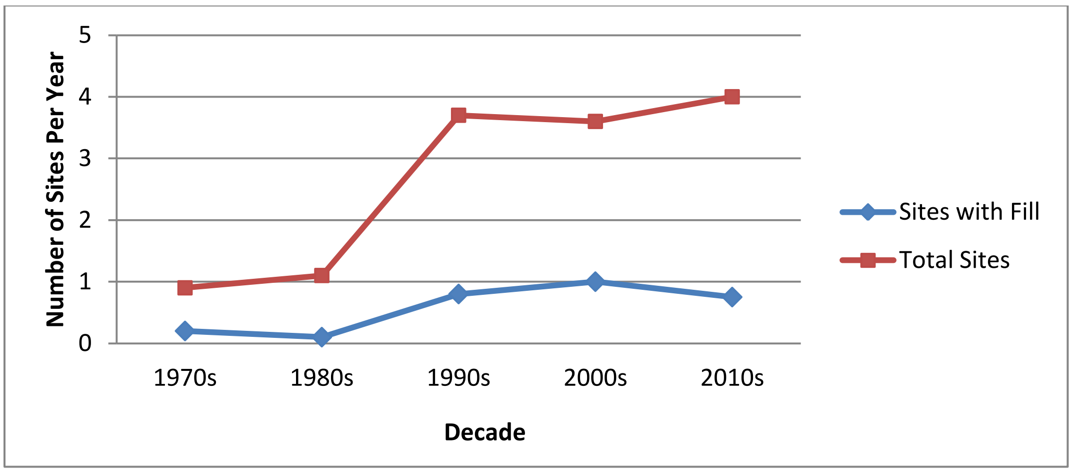



**Figure 6: Total number of sites and number of sites importing fill by year per decade.**

Stoniness is a common problem in rehabilitated gravel pits where soils tend to have a naturally high percentage of stones (Mackintosh and Mozuraitus, 1982). Rehabilitation programs and farm management often involves stonepicking (Skelton Brumwell & Associates Inc. and Savanta Inc., 2009).

Stoniness was estimated in five random quadrats measuring 1 m x 1 m at each site. Five categories (<10, 10-25, 25-50, 50-75, >75) were used to estimate the percentage of ground covered by stones. The average size of stones was also estimated to be <15 cm, 15-60 cm, or >60 cm in diameter. No sites were estimated in the >75% category of stoniness, while the majority of sites had an average of <10% stoniness (Figure 7).

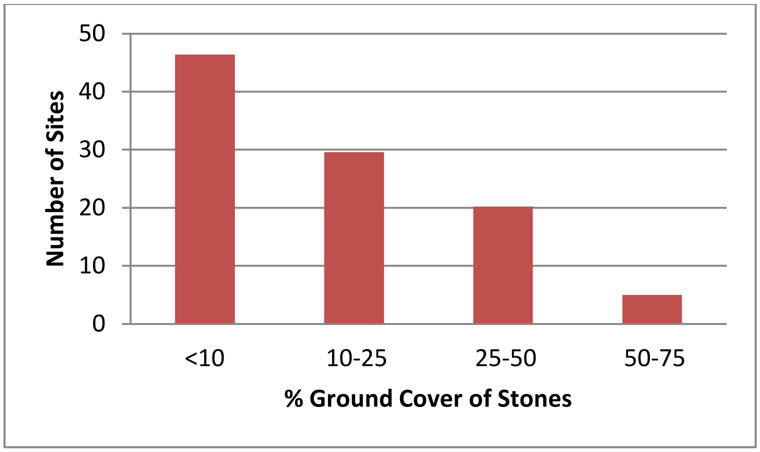



**Figure 7: Number of sites in each % ground covered with stones**

Eighty-eight percent of the completed inventories had average stone size of <15 cm in diameter (Figure 8). Another 11% had stones between 15-60 cm in diameter while a small minority of sites (<2%) had stones over 60 cm in diameter.

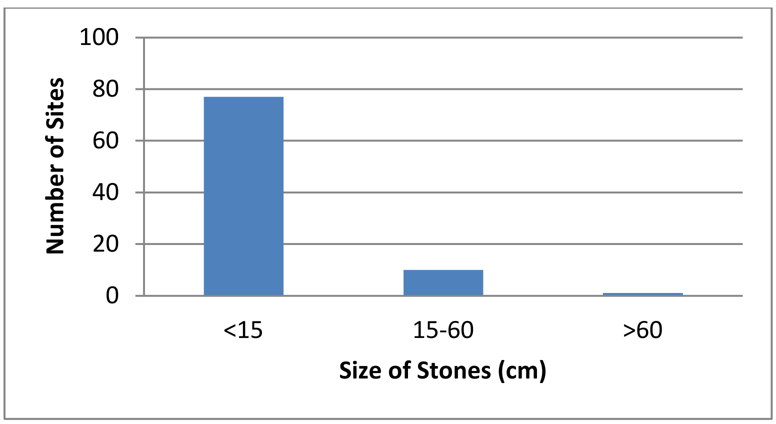



**Figure 8: Number of sites inventoried with average stone sizes in three categories.**

Soil texture can vary considerably in small areas due to the heterogeneous nature of soil. In this project, soil texture was assessed at three random locations across each inventoried site. Texture did vary between sites as well as within sites (Figure 9). The most common soil type found at rehabilitated sand and gravel extraction sites was sandy loam. Loamy sand and clay loam soils were also common.

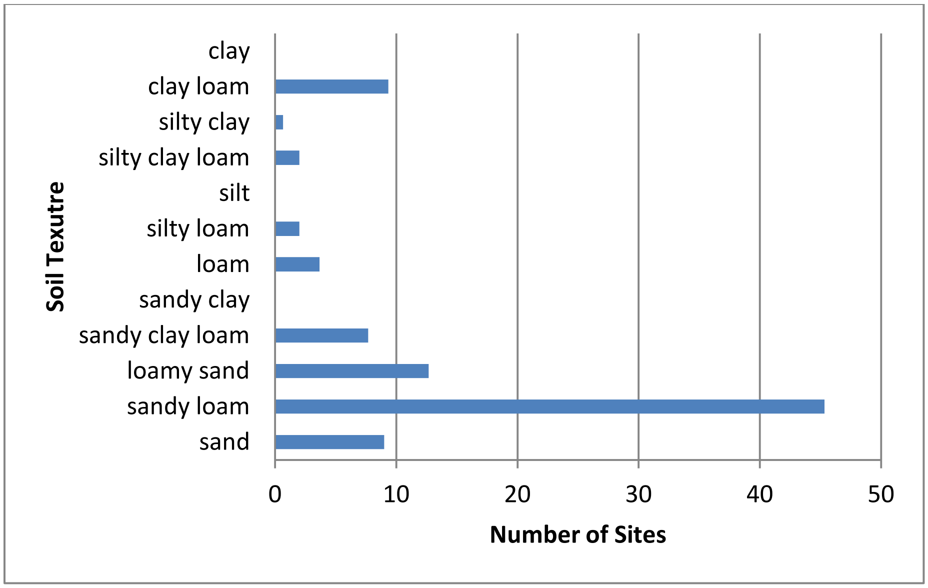



Figure 9: Number of sites inventoried with different soil textures.

## 4.3 Post-Rehabilitation Management Practices

A number of the questions in the landowner survey focused on management practices used by farmers on rehabilitated land. These included farmer rating of their land, the use of cover crops and soil amendments, and drainage tile installation.

Farmers were asked to rate (on a scale of one to ten) the overall quality of the land that had been rehabilitated and its use for agriculture. Sixty-six percent of farmers rated the land above a five, while 34% rated their land quality as less than five (Figure 10).

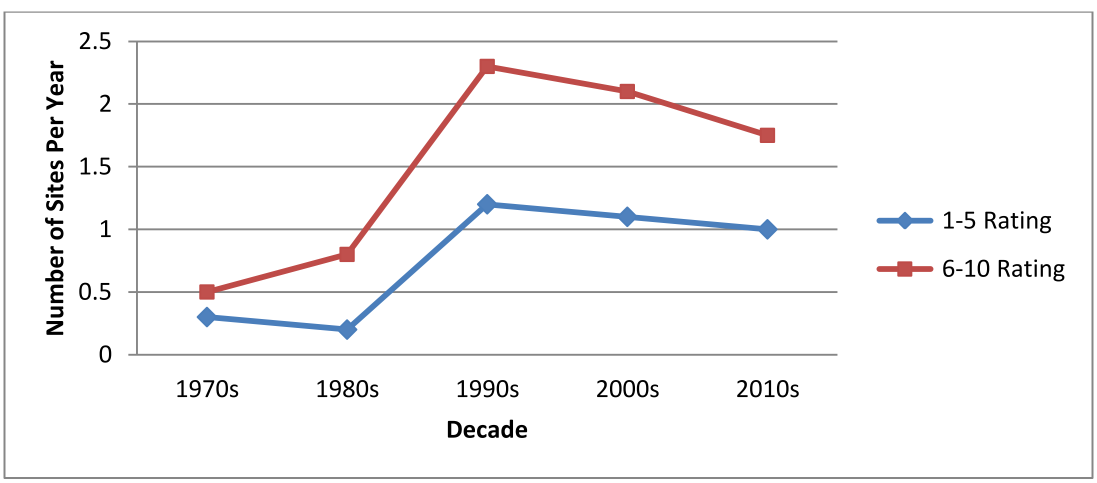



Figure 10: Farmer ratings of rehabilitated land by decade in categories 1-5 and 6-10.

While only 8% of the farmers surveyed rated the rehabilitated land as a 10, many farmers were optimistic that the land was improving and would become more productive over time. A few farmers were less positive, suggesting their land had been irreparably damaged by poor rehabilitation. Figure 11 shows a breakdown of the sites rated 6-10, showing the number of sites in each category.

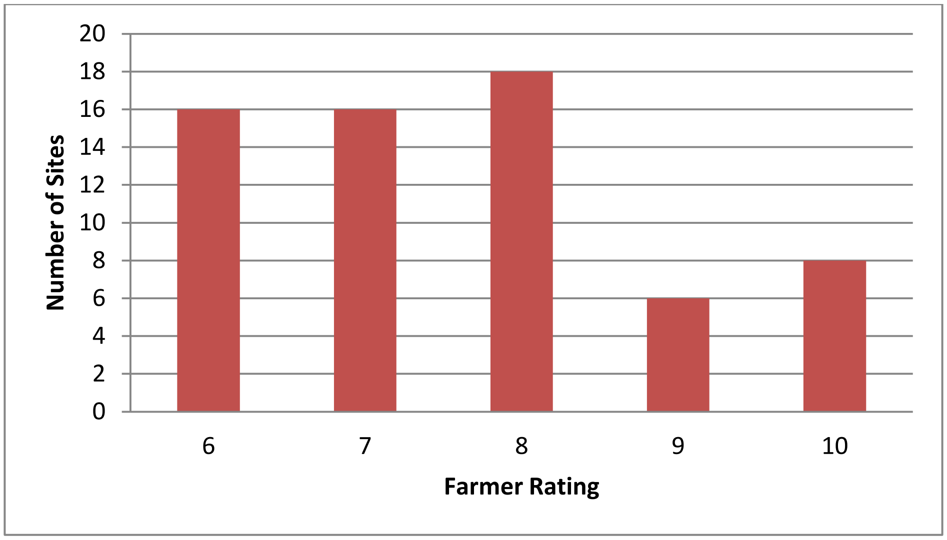



**Figure 11: Number of sites rated in each category of the 6-10 range**

Land management is important to soil and crop quality post rehabilitation. Cover crops and soil amendments are two ways in which farmers can increase the soil quality and thereby have a positive effect on crop yield (Figure 12).

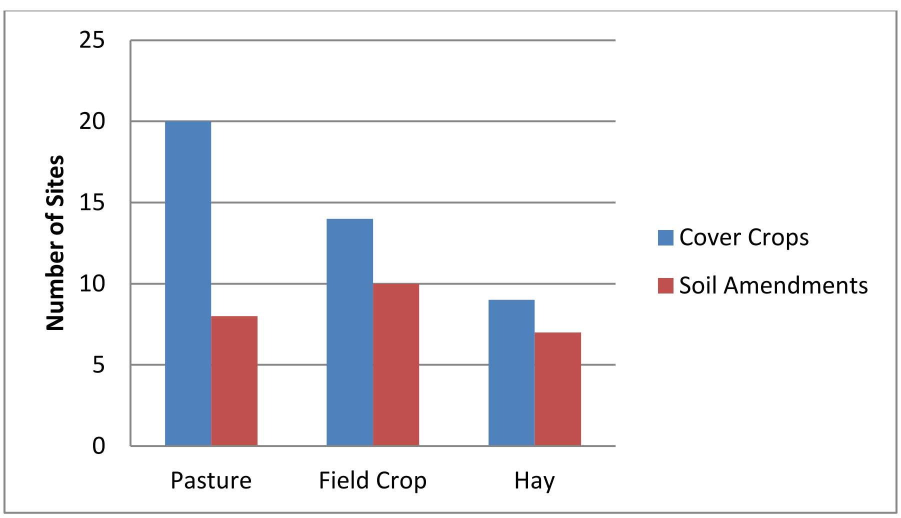



**Figure 12: Number of sites where farm managers used cover crops and soil amendments post rehabilitation.**

In this study, cover crops are considered crops that are grown for the protection and improvement of the soil. Cover crops have been shown to decrease soil erosion, increase soil organic matter and have a positive effect on soil structure (Tobias, 2008). Landowners at 42 of the sites surveyed used or had used cover crops as part of their post-rehabilitation management practices. These were mostly used on the sites where pasture and field crops were grown. In 24 of the 26 counties surveyed, farmers who used cover crops were more likely to rate their land above 5 then those who did not.

Soil amendments can improve the chemical and physical properties of soils by increasing nutrients, adding soil organic matter, and altering soil pH. In this study the most common soil amendment used was farmyard manure which was mixed into the soil at the time of rehabilitation or yearly as a fertilizer. Composted hay and lime were other soil amendments used by farmers. Farmers who used soil amendments were more likely to rate their rehabilitated land above 5 then farmers who did not use them.

Another common post management practice is to plant the rehabilitated land with hay for 2-5 years, then to plant it with field crops. This allows soil structure to re-form by adding organic matter and keeps the soil covered to avoid surface erosion.

Installing systematic drainage tiles is a common management practice used by farmers for land improvement. Of the sites surveyed, 20 sites confirmed installing drainage tiles post rehabilitation. Most of these were sites that were returned to field crops, or hay sites that will be returned to field crops after a number of years. Many of these sites were parts of larger fields and drainage tiles were installed throughout.

# 5 Summary and Recommendations for Future Research

The preliminary results shown here suggest that rehabilitation of aggregate extraction sites to agricultural uses has been occurring since the 1970's, encompass a large range of cropping systems, and that farmer satisfaction varies greatly. The differences in farmer satisfaction may come from variables such as management practices and rehabilitation techniques, but it should also be noted that there were some communication difficulties with landowners as well as landowner expectations from originally, lower classes of farmland.

In order to better understand the differences in these sites and farmer satisfaction, a quantitative research project looking at crop productivity and soil quality at a subset of sites will be undertaken in 2014. Work will be completed to fill in the gap in the eastern portion of the province which will allow for a better Ontario-wide view of agricultural rehabilitation. In addition, a list of management recommendations to update the Mackintosh and Mozuraitus (1982) study will be inferred.

# 6 References

Brady, N.C. and R.R. Weil. 1996. *The Nature and Properties of Soils*. Prentice-Hall Inc. Upper Saddle River, USA.

Davies, R., R. Hodgkinson, A. Younger and R. Chapman. 1995. Nitrogen loss from a soil restored after surface mining. Journal of Environmental Quality 24(6): 1215-1222.

Friedli, B., S. Tobias, and M. Fritsch. 1998. Quality assessment of restored soils: combination of classical soil science methods with ground penetrating radar and near infrared aerial photography? Soil & Tillage Research 46: 103-115.

Kaufmann, M., S. Tobias, and R. Schulin. 2009a. Development of the mechanical stability of a restored soil during the first 3 years of re-cultivation. Soil & Tillage Research 103: 127-136.

Kaufmann, M., S. Tobias, and R. Schulin. 2009b. Quality evaluation of restored soils with a fuzzy logic expert system. Geoderma 151: 290-302.

Mackintosh, E.E. and M.K. Hoffman. 1985. Rehabilitation of Sand and Gravel Pits for Fruit Production in Ontario. Ontario Ministry of Natural Resources, Mineral Resources Branch, Industrial Mineral Background Paper 6, 24pp.

Mackintosh, E.E. and E.J. Mozuraitus. 1982. Agriculture and the Aggregate Industry: Rehabilitation of Extracted Sand and gravel lands to an agricultural after-use. Ontario Ministry of Natural Resources, Mineral Resources Branch, Industrial Mineral Back ground Paper 3, 44pp.

Skelton Brumwell & Associates Inc. and Savanta Inc. 2009. Paper 6: Rehabilitation. State of the Aggregate Resource in Ontario Study. Ontario Ministry of Natural Resources 52659.

Stahl, P.D., B.L. Perryman, S. Sharmasarkar and L.C. Munn. 2002. Topsoil stockpiling versus exposure to traffic: a case study on in situ uranium wellfields. Restoration Ecology 10(1): 129-137.

Strohmayer, P. 1999. Soil stockpiling for reclamation and restoration activities after mining and construction. Restoration and Reclamation Review 4(7): 1-6.

Tobias, S., M. Haberecht, M. Stettler, M. Meyer and H. Ingensand. 2008. Assessing the reversibility of soil displacement after wheeling in situ on restored soils. Soil and Tillage Research 98: 81-93.

Trimble, K.D. and M. Seibert. 2002. An evolution of reclamation approaches through the life of a southern Ontario gravel pit. National Meeting of the American Society for Surface Mining and Reclamation, Lexington, KT, June 9-13, 2002.

Veenhof, D.W. and R.A. McBride. 1996. Overconsolidation in agricultural soils. I. Compression and consolidation behavior of remolded and structured soils. Soil Science Society of America Journal 60: 362-373.