Literature & Background Review Summary Report

The Development of Best Management Practices for Aggregate Site Rehabilitation

Prepared by:

MacNaughton Hermsen Britton Clarkson Planning Limited (MHBC) & Dr. Paul J. Richardson

For:

The Ontario Ministry of Natural Resources and Forestry

March 2018
# Table of Contents

1. Introduction ............................................................................................................................ 4  
2. Aggregate Rehabilitation in Ontario .................................................................................. 5  
3. Jurisdictional Scan .................................................................................................................. 7  
   3.1 Canada .................................................................................................................................. 7  
   3.1.1 Alberta ................................................................................................................................ 7  
   3.1.2 British Columbia ............................................................................................................. 8  
   3.1.3 Northwest Territories (Northern Canada) ........................................................................ 9  
3.2 United Kingdom .................................................................................................................... 10  
3.3 Australia .............................................................................................................................. 10  
   3.3.1 New South Wales ........................................................................................................... 11  
   3.3.2 Queensland ................................................................................................................... 11  
   3.3.3 Victoria ......................................................................................................................... 12  
3.4 United States ....................................................................................................................... 12  
   3.4.1 New York ....................................................................................................................... 12  
   3.4.2 Minnesota ..................................................................................................................... 13  
   3.4.3 Wisconsin ...................................................................................................................... 13  
   3.4.4 Oregon / Washington ................................................................................................. 14  
4. Policy Review ......................................................................................................................... 15  
   4.1 Provincial Policy & Legislation .......................................................................................... 16  
   4.1.1 Aggregate Resources Act and Provincial Standards .................................................. 16  
   4.1.2 Provincial Policy Statement ....................................................................................... 16  
   4.1.3 Provincial Plans .......................................................................................................... 17  
   4.1.4 The Greenbelt Plan (2017) ...................................................................................... 18  
   4.1.5 Oak Ridges Moraine Conservation Plan (2017) .................................................... 18  
   4.1.6 Growth Plan (2017) ................................................................................................. 20  
   4.1.7 Niagara Escarpment Plan (2017) ........................................................................... 20  
   4.1.8 Lake Simcoe Protection Plan (2017) ...................................................................... 22  
4.2 Provincial Strategic Plans & Policy .................................................................................... 23  
4.3 Municipal Official Plan Review .......................................................................................... 31  
5. Literature & Background Review ......................................................................................... 42
5.1 Summary of Scientific Literature Review ............................................................. 42
5.2 Summary of Grey Literature Review ................................................................. 46
  5.2.1 Academia ........................................................................................................ 46
  5.2.2 Non-Government Organizations ................................................................. 48
  5.2.3 Industry .......................................................................................................... 50
6 Review of Existing Aggregate Site Best Management Practices from Ontario ...... 52
  6.1 Government of Ontario Aggregate Rehabilitation Publications .................... 52
  6.2 Aggregate Rehabilitation Research and BMPs from TOARC ......................... 59
  6.3 Industry Developed Rehabilitation BMPs and Aggregate Research ............. 63
7 Stakeholder Identification & Outreach ................................................................. 65
8 Identified Rehabilitation End-Uses & Next Steps .................................................... 66
Reference List .................................................................................................................. 68
Appendix A - Case Studies ......................................................................................... 73
Appendix B - Scientific Literature Review ............................................................... 94

Table 1: Summary of Aggregate Rehabilitation Policies in Ontario's Provincial Plans ..... 22
Table 2: Government of Ontario Strategic Plans ..................................................... 24
Table 3: Summary of Municipal Official Plan Review ............................................. 32
Table 4: Review of Government of Ontario Aggregate Rehabilitation Publications from the 1980s ................................................................. 53
Table 5: Review of BMPs and Rehabilitation Research from TOARC .................... 59
Table 6: Identified Rehabilitation End-Uses ............................................................. 67

Figure 1: Policy Framework in Ontario for Aggregate Rehabilitation .................... 15
Figure 2: Aggregate Rehabilitation Policies from the PPS (2014) ............................ 17
1 Introduction

The Ministry of Natural Resources and Forestry (MNRF) has commissioned a project to develop a series of best management practices (BMPs) for the rehabilitation of mineral aggregate extraction sites to various land uses (not including agriculture\(^1\)) that align with local land uses. MHBC Planning in conjunction with Dr. Paul Richardson, Research Associate & Adjunct Professor with the University of Waterloo, were retained to undertake this project for the MNRF.

As part of the project, this Literature & Background Review Summary Report have been prepared to review and assemble information relating to the development of Best Management Practices (BMPs) for Aggregate Site Rehabilitation in Ontario. This information will be used to support the development of Best Management Practices guidance documents that will provide step-by-step information to operators on how to undertake rehabilitation for specific end-uses.

The Literature Review Summary Report is composed of the following sections:

- An introduction to Aggregate Rehabilitation in Ontario;
- A Jurisdictional Scan to identify practices used in jurisdictions with similar geography and climate;
- A Policy Review to understand the legislative and regulatory framework for Aggregate Rehabilitation in Ontario;
- A review of Scientific Literature and Grey Literature\(^2\) to understand the best available science and information on aggregate rehabilitation best management practices, from a range of sources;
- A review of the existing Best Management Practices for Aggregate Site Rehabilitation in Ontario
- A list of identified rehabilitation end-uses
- A summary of 5 Final Rehabilitation Case-studies
- A Reference List

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1 The development of Agricultural Rehabilitation BMPs was subject to a separate Ontario Ministry of Agriculture, Food, and Rural Affairs in 2016.

2 Non-scholarly documents produced by all levels of government, academia, business organizations and industry members in print and electronic formats
2 Aggregate Rehabilitation in Ontario

Aggregate extraction generally refers to the removal of sand, gravel, clay, and bedrock from pits and quarries through surface-mining. Most of Ontario’s pits and quarries are regulated under the Aggregate Resources Act which is overseen by the Ministry of Natural Resources and Forestry. In order to operate a pit or quarry, a Licence or Permit is issued which authorizes extraction to occur in accordance with a Site Plan, which also establishes a legal requirement that extracted and/or other disturbed areas be rehabilitated.

The term “rehabilitation” has been widely used and broadly interpreted in many different industries. For the purposes of this Project, the definition of rehabilitation from the Aggregate Resources Act (R.S.O, 1990) (ARA) is used. The ARA defines rehabilitation as, “means to treat land from which aggregate has been excavated so that the use or condition of the land is,

(a) restored to its former use or condition, or;

(b) changed to another use or condition that is or will be compatible with the use of adjacent land.”

The rehabilitation of pits and quarries refers to the grading, replacement of soil, and revegetation of the land (or lake-edge for pits and quarries operated below the water table), in order to transform the depleted pit or quarry to an acceptable post-extractive land-use. In Ontario, there is a long-standing history of provincial policy and legislation related to the requirement for rehabilitation of aggregate extraction sites and is one of the main purposes of Provincial Legislation and Policy.
Over the past 30 years, the evolving policy framework has consistently acknowledged aggregate extraction as an interim land use, where rehabilitation is undertaken to return or convert the land to a subsequent, productive land use. The Pits and Quarries Control Act of 1971 legislated the requirement for pit and quarry rehabilitation to occur in Ontario and, since that time, there has been ongoing advancement in the techniques, science, and monitoring of aggregate rehabilitation.

Generally, aggregate rehabilitation includes sloping and grading, backfilling and overburden replacement, topsoil replacement, and the establishment of self-sustaining vegetation. This represents the minimum template for aggregate site rehabilitation and many Licence Holders and operators go above and beyond these requirements, either as a requirement of Licence approval or in an effort to be a good steward of the land.

As a land-use, the aggregate extraction industry faces widespread public and political scrutiny. Rehabilitation offers an opportunity to re-establish and improve pre-existing site conditions, create unique landforms and habitats, and achieve Provincial conservation and environmental objectives. There are hundreds of pits and quarries located across Ontario that have been fully rehabilitated, so that they are now unrecognizable as former extraction sites. Many of these sites are used as recreational areas such as golf course, parks and open spaces in our communities, provide fish and wildlife habitat, and are returned to productive farmland.

Since rehabilitation has become a regulatory requirement, there has been a gradual evolution from rehabilitation of pits and quarries to meet minimum requirements (what is often referred to as “slope and seed”), to the rehabilitation of pits and quarries to achieve a greater positive ecological and social outcomes, such as the creation of habitat for species at risk or outdoor recreation facilities for use by the community.

The rehabilitation of natural features and functions within extraction sites can result in ecosystems that provide similar ecological functions, connectivity, and biodiversity as undisturbed sites, while also offering a significant opportunity for public access and outdoor recreation. The positive effects of successful rehabilitation can extend far...
beyond the geographical boundaries of any particular site and can influence environmental and social dynamics at regional scales. Aggregate site rehabilitation can achieve diverse environmental and social goals that can be achieved through science-based and innovative rehabilitation techniques. The information collected from the Jurisdictional Scan, Policy Review, Literature and Background Review, and Case-Studies will represent the best-available information for aggregate site rehabilitation in Ontario and similar jurisdictions. This information will be used to develop and update a series of aggregate rehabilitation Best Management Practices that can be implemented by Licence Holders and operators to undertake successful aggregate site rehabilitation for specific end-uses.

3 Jurisdictional Scan

Approaches to rehabilitation and associated best management practices in other Canadian Provincial and international jurisdictions have been reviewed. Australia, the United Kingdom and the United States all support thriving aggregate industries and have similar economic, social and, in certain regions, environmental characteristics to Ontario. It should be noted that in the guidance information that has been published by government agencies, there is a definite focus on pit sites as opposed to quarry sites.

3.1 Canada

In Canada, non-renewable natural resources are under the jurisdiction of the provinces and territories. As such, regulation of mineral aggregate extraction and subsequent rehabilitation fall under these levels of government.

3.1.1 Alberta

Alberta Environment’s Guide to the Code of Practice for Pits, published in 2004, is a guidance document intended to provide a broad overview of Alberta Environment’s requirements with respect to sand and gravel pits, larger than 5 ha in size, on private land.

The Guide lays out in detail the various and specific reclamation related BMPs to ensure the operation is in accordance with the Code, such as:

- The Activities Plan (i.e. equivalent to ARA site plan) must be kept at the pit and that all persons carrying out activities at the pit must be made aware of the Plan and the Code of Practice.

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• The Activities Plan should indicate what monitoring program will be carried out to ensure that the plan for inactive pits is effective.
• The Activities Plan should include methods for controlling and eliminating weeds associated with operating and reclaiming the pit.
• The nature of pre-extraction on-site soil conditions must be assessed.
• Reclamation should focus on restoring gentle landforms, establishing equivalent drainage and reconstructing an acceptable soil.
• Several specific measures are outlined for lands to be returned to an agricultural use.

The Guide places significant emphasis on topsoil and subsoil stripping (salvaging), stockpiling and ultimately, its replacement during the reclamation phase, and post-replacement care and management.

In an October 2010 publication prepared by Golder Associates for the Government of Alberta, Best Management Practices User Manual For Aggregate Operators On Public Land, a chapter is devoted to Reclamation Planning. It addresses:

• Reclamation Plan Development;
• Planning for End Uses;
• Native grasslands, forested lands, wildlife habitat and wetlands.

Best management practices covering operating and reclamation techniques, and their inter-relation, are provided. These address matters such as soil stripping, handling and replacement, revegetation, weed management, stormwater management and erosion control.

While the Manual is specifically written for operations on public land, it is acknowledged that some BMPs may be applicable to private land operations also.

3.1.2 British Columbia

An April 2002 publication from the British Columbia Ministry of Energy & Mines, Aggregate Operators Best Management Practices Handbook for British Columbia, Volume II, contains BMP guidance for reclamation activities at pit and quarry sites. The specific activities or functions addressed are:

• backfilling;
• berm construction;
• grading;
• tillage (agricultural after-use);
• topsoil management; and,
• vegetation cover.

The Alberta Publication contains several chapters dealing with reclamation. One chapter deals broadly with practices and measures that can prevent environmental impacts during operations and reclamation, and addresses some of the problems that can result from these activities. Another chapter addresses selection of the best end land use, and there follows six other chapters which deal with specific and more detailed information on that end land use, these being:

- agriculture;
- forestry;
- wildlife habitat;
- fish habitat;
- recreation; and,
- residential or industrial.

### 3.1.3 Northwest Territories (Northern Canada)

The Government of the Northwest Territories (NWT) has published the *Northern Land Use Guidelines, Pits and Quarries*, for use by the owners/operators of aggregate extraction sites which provides best practices for the operation of pits and quarries. The Guidelines are largely based on earlier guidance material developed and published by Aboriginal Affairs and Northern Development Canada in the 1980s. These were intended for use by operators of small to medium-scale projects to carry out their activities in northern Canada in an environmentally sensitive manner.

The NWT Guidelines contain chapters on the planning and design, and closure and reclamation of pits and quarries. Progressive reclamation is considered a part of BMP site planning and design. Site cleanup, landscape reconstruction, drainage and erosion control, revegetation and reclamation monitoring are considered part of BMP for closure and reclamation. The basic objective of the Guidelines is to return the site to a natural condition that blends in with the surrounding topography and landscape.

Guidance and practices are provided for each of the component steps towards reclamation, with the clear and non-technical descriptions and illustrations intended for the small-medium sized operator and with regards to the typical landscape and lack of population. In that respect, much of what is presented would be transferable to Northern Ontario, with the Guidelines’ permafrost related considerations being an exception.
Interestingly, the Guidelines do not make any clear reference to backfilling, and ultimate sloping, of quarry faces.

3.2 United Kingdom

Aggregate extraction in the U.K. is managed by the Department for Communities and Local Government (DCLG). The guiding document, Planning Practice Guidance - Minerals (PPGM), outlines the relevant policies for mineral aggregate extraction.

The Minerals Planning Guidance 7: Reclamation of mineral workings document from the U.K. Department of Communities and Local Government provides updated advice on the planning considerations, consultations and conditions necessary for rehabilitation. Though now superseded by the Department’s Planning Practice Guidance on Minerals, the Minerals Planning Guidance 7 provided more detail on the processes of restoring land to agriculture.

The publication Reclamation Planning in Hardrock Quarries: A Guide to Good Practice, Final Draft Report, was published in 2004 by the Mineral Industry Research Organisation, and sponsored by the British Government. The objective of the report is to provide guidance on methodology to achieve reclamation in quarry sites, including the formation of new landscape features and associated ecologies. The report is based on observations at 25 hard rock quarries in England. It is specifically acknowledged that while the guidance is based on legislation and quarry practice in England, many findings would be applicable elsewhere.

The report identifies the various considerations involved in quarry reclamation as follows:

- Opportunities and constraints in the context of geological influences;
- The aims and objectives of a reclamation plan;
- Aspects of a detailed site investigation (environmental assessment, surveys and mapping);
- The features of a reclamation proposal, including landscape considerations, soil handling, designing for ecology and ecological reclamation techniques; and,
- Aftercare and long-term management.

3.3 Australia

States and federal territories in Australia have jurisdiction over natural resources and thus have their own policies regarding aggregate extraction.
3.3.1 New South Wales

New South Wales’s Department of Primary Industries is responsible for extractive industries like aggregate operations and published a factsheet titled *Agriculture Issues for Extractive Industry Development*. The factsheet describes principles that should be followed when planning for agriculture and extractive industries, such as:

- Extractive industries are designed and managed to minimise environmental impacts
- Land use conflicts are minimised, amenity values are protected and the expectations of local communities are managed
- Rehabilitation is undertaken progressively and any permanent changes to productive capacity are clearly justified

A variety of checklist requirements for extractive industry developments on agricultural land are outlined in the factsheet:

- Agricultural Resource Impacts
- Water Resources
- Transport and Access Changes
- Rehabilitation Plans
- Consultation
- Mitigation and Monitoring
- Strategic Planning

The Rehabilitation Plans checklist specifies that “rehabilitation of the site must be to a standard that minimises any long-term impacts on surrounding land uses and optimises sustainable future land use”.

3.3.2 Queensland

The state of Queensland’s Department of Infrastructure, Local Government and Planning Regional Planning Interests Act 2014 (RPI Act) protects areas of regional interest from inappropriate development and assists with resolving land use conflict between activities that contribute to the State’s economy.

The Queensland Department of Environment and Heritage Protection published a *Guideline for Rehabilitation requirements for mining resource activities*. The guideline provides information on both progressive and final rehabilitation requirements for site-specific resource project operating in Queensland under the Environment Protection Act 1994.
3.3.3 Victoria

The Mineral Resources (Sustainable Development) Act 1990 includes requirements for land covered by mining licenses. The licensee must prepare a statement of the economic significance of their work. Part 7 of the Act focuses on rehabilitation of land on which mining licenses are approved and requires that:

The holder of a mining/exploration license must rehabilitate land in accordance with the rehabilitation plan approved by the Department Head.

The rehabilitation plan must take into account:

- Any special characteristics of the land;
- The surrounding environment;
- The desirability or otherwise of returning agricultural land to a state that is as close as is reasonably possible to its state before the mining licence or extractive industry work authority was granted;
- Any potential long-term degradation of the environment.

3.4 United States

Various American states regulate the aggregate extraction industry through statutory tools such as codes and ordinances, and these generally all include regulations concerning rehabilitation, or reclamation as it is known in the US. Several states which bear geographic, climatic and vegetation similarities to Ontario provide additional guidance to mine owners and operators with respect to reclamation. These are discussed below.

3.4.1 New York

The New York State Revegetation Procedures Manual: Surface Mining Reclamation was issued by the New York State Department of Environmental Conservation (DEC), Division of Mineral Resources in May 2005. It contains a comprehensive discussion of reclamation techniques for pit sites where unconsolidated material, sand and gravel, is removed. The Manual is designed to supplement the State’s reclamation regulations. It predominantly addresses issues of site preparation and planting of local climate-oriented vegetation such as grasses, forbs, shrubs and trees which are suitable for ground conditions that result from mining operations. The document is a collaboration by knowledgeable individuals at the State, information from USDA’s Plants database, Cornell University, the New York State Museum, the U.S. Forest Service, the USDA Natural Resource Conservation Service, and other academic sources.

The Manual discusses:
• regulatory requirements;
• how to minimize impacts of site preparation and mining on topsoil & land productivity;
• plant selection for reclamation with a specific section on climate and topographic factors;
• seeding and planting techniques;
• assessment procedures; and,
• revegetation examples for selected land uses of cropland, wildlife habitat and woodland.

The Manual contains an extensive presentation of References and Suggested Readings, Tables, Figures and Appendices which provide more specific information such as recommended seed mixes, temperature zones, grass and tree species lists.

3.4.2 Minnesota

In July 1992, the Minnesota Department of Natural Resources released A Handbook for Reclaiming Sand and Gravel Pits in Minnesota which provides a technical background on reclaiming sand and gravel pits and contains general reclamation guidelines. Recommendations for mining plans, a “combination of maps and written information that describe every aspect of the proposed operation from inventory of the gravel resource to post mining management of the site”, are also included. Progressive rehabilitation is a method that is recommended and includes final site grading, reapplication of reserved topsoil and the establishment of vegetative cover as each stage is concluded. The following steps for reclamation to non-managed end uses are also described:

• Clearing and disposing of vegetation;
• Stripping and reserving topsoil;
• Construction of a berm from overburden material;
• Designating a working face in the pit and directing activity at that face until depletion;
• Final grading of the pit face and other slopes to 3:1;
• Reapplication of topsoil;
• Seeding with a nurse crop of oats to stabilize the surface from erosion;
• Allowing for natural revegetation in combination with tree plantings and seeding of native grasses.

3.4.3 Wisconsin

A Guide to Developing Reclamation Plans for Nonmetallic Mining Sites in Wisconsin was produced by the Wisconsin Department of Natural Resources, Bureau of Waste Management in 2002 to assist non-metallic mine operators in preparing reclamation
plans for mining sites. Reclamation measures that are required to be included in reclamation plans include:

- Earthwork and grading – description of proposed earthwork and reclamation
- Topsoil – methods of topsoil or topsoil substitute material removal, storage, stabilization and conservation
- Topography – map showing anticipated topography of the reclaimed site
- Structures – map showing surface structures
- Cost - estimated cost of reclamation for each stage of the project
- Re-vegetation Plan – timing and methods of seed bed preparation, rates and kinds of soil amendments, seed application timing, methods and rates, mulching, netting and any other soil and slope stabilization techniques
- Re-vegetation standards – to show that a sustainable stand of vegetation has been established which will support the approved post-mining land use
- Erosion control
- Interim reclamation (optional)

3.4.4 Oregon / Washington


The report describes in general the importance of various types of mapping, and its specific features, to facilitate long range planning for both resource extraction and timely reclamation. It contains several more chapters dealing with aspects of ensuring successful rehabilitation. Storm-Water and Erosion Control and Landslides and Slope Failures are covered in detail.

The most notable section of the report deals with Operation and Reclamation Strategies. The following strategy types are discussed: post-mining, interim, concurrent (progressive or continuous); and, segmental. The relationship of operational strategies such as the mining program (plan); and, site preparation including removal of vegetation and removal/storage of soils, to rehabilitation are discussed. Specific contexts and techniques are described for Restoring Landforms, Reclamation Techniques for Quarries; and, Revegetation. The Restoring Landforms section has specific wildlife related discussions focussed on ponds, physical habitat construction, and wetlands.
4 Policy Review

The rehabilitation of aggregate sites is required at both the Provincial and Local policy level as illustrated Figure 1.

Both Provincial and local policy provide broad objectives for aggregate rehabilitation, including:

- Promoting land use compatibility;
- Mitigating the impacts of extraction; and,
- Preparing the land for a subsequent land use.

This policy framework outlines the legal tools that require rehabilitation to occur.

The purpose of Best Management Practices is to provide guidelines for Licence Holders and Operators on “how to” undertake rehabilitation in order to meet the legal requirement while also achieving broader social, economic, and environmental objectives.

![Figure 1: Policy Framework in Ontario for Aggregate Rehabilitation](image-url)
4.1 Provincial Policy & Legislation

4.1.1 Aggregate Resources Act and Provincial Standards

Most of Ontario’s pits and quarries are regulated under the Aggregate Resources Act. In Northern Ontario, there are some areas of private land that are not covered by the Act. In these areas, the local municipality may regulate pit and quarry operations through local Zoning By-Laws.

The Aggregate Resources Act requires that pits and quarries undertake rehabilitation and recognizes two types of rehabilitation – Progressive Rehabilitation and Final Rehabilitation.

“final rehabilitation” means rehabilitation in accordance with this Act, the regulations, the site plan and the conditions of the licence or permit performed after the excavation of aggregate and the progressive rehabilitation, if any, have been completed; and

“progressive rehabilitation” means rehabilitation done sequentially, within a reasonable time, in accordance with this Act, the regulations, the site plan and the conditions of the licence or permit during the period that aggregate is being excavated;

Once Licenced, all pits and quarries are required to undergo progressive and final rehabilitation in accordance with their Site Plans and cannot surrender the Licence, until rehabilitation is completed to the satisfaction of the Ministry of Natural Resources and Forestry. MNRF staff have can use a number of enforcement tools to ensure that License holders and operators comply with the rehabilitation requirements of their Site Plan.

The Aggregate Resources of Ontario: Provincial Standards set-out the requirements for the delivery of the Aggregate Resources Act. The Provincial Standards require Site Plan for both pits and quarries to outline how progressive and final rehabilitation will be undertaken on the Licence/Permit. These Standards represent minimum requirements only for operational considerations such as slope creation, overburden storage, extraction sequencing, and erosion control and do not speak to Best Management Practices for the creation of specific end-uses and rehabilitated land-forms.

4.1.2 Provincial Policy Statement

The Provincial Policy Statement (PPS) is issued under Section 3 of the Planning Act and came into effect April 30, 2014, replacing the previous 2005 PPS. The PPS applies to all
land in Ontario subject to the Planning Act and provides direction on matters of provincial interest related to land use planning and development. Section 3 of the Planning Act requires that decisions affecting planning matters “shall be consistent with policy statements issued under the Act”.

Section 2.5 of the PPS provides policy direction for the protection, long-term use, identification and, conservation of mineral aggregate resources in Ontario. The PPS includes specific policies for aggregate site rehabilitation that supplement the requirements of Aggregate Resources Act, including:

![Figure 2: Aggregate Rehabilitation Policies from the PPS (2014)](image)

Specific rehabilitation policies for extraction and rehabilitation in Prime Agricultural Areas are also provided. The PPS provides broad, over-arching policy direction only, and does not offer any direction as to how rehabilitation efforts should be undertaken by Licence Holders and operators.

4.1.3 Provincial Plans

Similarly to the PPS, a number of Ontario’s Provincial Plans provide broad policy guidance for
aggregate site extraction and rehabilitation in Southern Ontario. However, these plans are also intended to provide more specific land use and resource management planning direction in an effort to protect the ecological and hydrological integrity of natural features and functions that are located within the specific Provincial Plan Areas. Although these policies are still general in nature and do not speak to how rehabilitation should be undertaken, specific rehabilitation end-use priorities are identified, as summarized in Table 3 on Page 22.

4.1.4 The Greenbelt Plan (2017)

First introduced in 2005, the Greenbelt Plan applies to approximately 1.8 million acres of land in the Greater Golden Horseshoe and southern Ontario. The Greenbelt Plan identifies where urbanization and development should not occur in order to provide permanent protection to the agricultural land base and the ecological features and functions of the Greenbelt Plan Area:

Within the Greenbelt Plan Area, aggregate rehabilitation is required in accordance with the following policies:

- Progressive and final rehabilitation efforts will contribute to the goals of the Greenbelt Plan (4.3.2.5.b)
- The disturbed area of a site shall be rehabilitated to a state of equal or greater ecological value and, for the entire site, long-term ecological integrity shall be maintained or enhanced (4.3.2.6.a)
- Aquatic areas remaining after extraction are to be rehabilitated to aquatic enhancement (4.3.2.6.c)
- In the Natural Heritage System, where there is no extraction below the water table, an amount of land equal to that under natural vegetated cover prior to extraction, and no less than 35 percent of the land subject to each license in the Natural Heritage System, is to be rehabilitated to forest cover (4.3.2.7.a)
- Where there is extraction below the water table, no less than 35 percent of the non-aquatic portion of the land subject to each license in the Natural Heritage System is to be rehabilitated to forest cover (4.3.2.7.b)
- Rehabilitation shall be implemented so that the connectivity of the key natural heritage features and the key hydrologic features on the site and on adjacent lands shall be maintained or enhanced (4.3.2.7.c)
- Operators are encouraged to consider and provide for public access to former aggregate sites upon final rehabilitation, where appropriate (4.3.2.8)
- Additional policies for agricultural rehabilitation (see 4.3.2.9)

4.1.5 Oak Ridges Moraine Conservation Plan (2017)

The Oak Ridges Moraine is a geological landform in south central Ontario stretching from the Niagara Escarpment in Caledon in the west to Northumberland County in the east
The moraine has a unique concentration of environmental, geological and hydrological features. This includes sand and gravel resources and by virtue of the location of the moraine relative to the GTA, this represents a close to market supply of sand and gravel aggregates.

The Oak Ridges Moraine Conservation Plan (ORMCP) provides land use and resource management direction for lands and water within the Plan Area. Aggregate extraction is permitted within Natural Linkage Areas and Countryside Areas.

Within the ORMCP, aggregate rehabilitation is required in accordance with the following policies:

- Municipalities and the mineral aggregate industry are encouraged to work together to develop and implement comprehensive rehabilitation plans for parts of the Plan Area that are affected by mineral aggregate operations (s.36)
- An application for a mineral aggregate operation or wayside pit shall not be approved unless the applicant demonstrates...that as much of the site as possible will be rehabilitated:
  - (i) in the case of land in a prime agricultural area, by restoring the land so that it can be used for agriculture, and (ii) in all other cases, by establishing or restoring natural self-sustaining vegetation; (35.1.b.)
  - if there are key natural heritage features on the site or on adjacent land, that their health, diversity, size and connectivity will be maintained and, where possible, improved or restored; (35.1.c)
- For applications for mineral aggregate operations in a Natural Linkage Area, the applicant must demonstrate:
  - that the site will be rehabilitated in stages as quickly as possible; and
  - that the entire site will be rehabilitated,
  - in the case of land in a prime agricultural area, by restoring the land so that the average soil quality of each area is substantially returned to its previous level, and
  - in all other cases, by establishing or restoring natural self-sustaining vegetation.
- An application for a mineral aggregate operation or wayside pit with respect to land in a landform conservation area (Category 1 or 2) shall not be approved unless the applicant demonstrates:
  - (a) that the area from which mineral aggregates are extracted will be rehabilitated to establish a landform character that blends in with the landform patterns of the adjacent land; and that the long-term ecological
integrity of the Plan Area will be maintained, or where possible improved or restored. (35.1.6.)

4.1.6 Growth Plan (2017)

The Greater Golden Horseshoe is located in southern Ontario, Centred around the City of Toronto, and covers almost 32,000 square kilometres including large cities, rapidly growing suburban municipalities, mid-sized centres, small towns and villages, and rural areas.

The Growth Plan for the Greater Golden Horseshoe is a long-term plan that works together the Greenbelt Plan, the Oak Ridges Moraine Conservation Plan and the Niagara Escarpment Plan to manage growth, build complete communities, curb sprawl and protect the natural environment.

In 2017, the Growth Plan was revised and relevant aggregate rehabilitation policies for the Growth Plan mimic those of the Greenbelt Plan discussed in section 4.1.4.

4.1.7 Niagara Escarpment Plan (2017)

The Niagara Escarpment includes a variety of topographic features and land uses extending 725 km from Queenston in Niagara Region in the south to Tobermory in Bruce County in the north. The Niagara Escarpment Plan (NEP) provides for the maintenance of the Niagara Escarpment and surrounding land as a continuous natural environment, and to ensure only such development occurs as is compatible with that natural environment. The NEP is administered by the Niagara Escarpment Commission.

With respect to aggregate site rehabilitation, “in the evaluation of applications for amendment to the Niagara Escarpment Plan to re-designate Escarpment Rural Area to Mineral Resource Extraction Area, the following matters, in addition to all other relevant policies of this Plan, will be considered (1.2.2.3):

- protection of the Escarpment environment;
- opportunities for achieving the objectives of the Niagara Escarpment Planning and Development Act through the final rehabilitation of the site;
- the protection of prime agricultural areas, the capability of the land for agricultural uses, and its potential for rehabilitation for agricultural uses; and
- Opportunities to include rehabilitated lands in the Niagara Escarpment Parks and Open Space System.”

In addition, some of the key rehabilitation objectives of the Mineral Resource Extraction Area are (1.9.1):

- To encourage progressive rehabilitation of mineral aggregate operations;
• To encourage rehabilitated mineral aggregate operations to be restored to a state that is of equal or greater ecological or agricultural value than the original characteristics of the site;
• To ensure that, after a licence is surrendered, the land is re-designated to a land use designation that is compatible with the rehabilitation of the site, the designation criteria of adjacent lands, the surrounding Escarpment environment and existing land uses in the area; and,
• To encourage, where possible, the integration of rehabilitated lands into the Niagara Escarpment Parks and Open Space System.

Specific rehabilitation requirements are outlined in the NEC, including (2.9.3):

a) natural heritage and hydrologic features and functions shall be restored or enhanced;
b) aquatic areas remaining after extraction shall be rehabilitated as representative of the natural ecosystem in that particular setting or eco-district, and the combined terrestrial and aquatic rehabilitation shall protect and where possible enhance the ecological value of the site;
c) excess topsoil and overburden are to be retained and stabilized for future rehabilitation;
d) all excavated pit and quarry walls are to be sloped and rehabilitated in accordance with best practices. On sites where a higher standard of rehabilitation is justified (e.g., to improve land use compatibility) or on sites where topsoil and/or land fill material is scarce, alternative approaches to slope standards may be applied. Sections of pit or quarry faces may be left exposed for aesthetic or educational purposes or to create habitat diversity in an approved rehabilitation plan;
e) vegetation, including seeding, crops, trees and shrubs, shall be planted as soon as possible as part of progressive rehabilitation of the pit or quarry;
f) rehabilitation of the site shall contribute to the open landscape character and be compatible with the surrounding scenic resources;
g) in prime agricultural areas, other than specialty crop areas, Mineral Resource Extraction Areas shall be rehabilitated to a condition in which substantially the same areas and same average soil capability for agriculture are restored;
h) in specialty crop areas, Mineral Resource Extraction Areas shall be returned or rehabilitated to a condition in which substantially the same areas and same average soil capability for agriculture are restored, the same range and productivity of specialty crops common in the area can be achieved, and, where applicable, the microclimate on which the site and surrounding area may be dependent for specialty crop production are maintained or restored;
i) in prime agricultural areas, where rehabilitation to the conditions set out in (g) and (h) above is not possible or feasible due to the depth of planned extraction or due to the presence of a substantial deposit of high quality mineral aggregate
resources below the water table warranting extraction, agricultural rehabilitation in the remaining areas will be maximized as a first priority;

j) in areas with below-water table extraction, mineral aggregate operations requiring perpetual water management after rehabilitation is complete should be avoided but may be considered where it can be demonstrated that such actions would support other public water management needs; and,

k) comprehensive rehabilitation shall be considered and encouraged where feasible.

4.1.8 Lake Simcoe Protection Plan (2017)

The Lake Simcoe Protection Plan is a comprehensive plan to protect and restore the ecological health of Lake Simcoe and its watershed. The Plan addresses long term environmental issues in the Lake Simcoe and its watershed.

In regard to mineral aggregate operations, every application for a new mineral aggregate operation must demonstrate (6.44-DP):

a. How the connectivity between key natural heritage features and key hydrologic features will be maintained before, during and after the extraction of mineral aggregates; and

b. How the operator could immediately replace or restore any habitat that would be lost from the site with equivalent habitat on another part of the site or on adjacent lands.

Table 1: Summary of Aggregate Rehabilitation Policies in Ontario’s Provincial Plans

<table>
<thead>
<tr>
<th>Provincial Plan</th>
<th>Key Rehabilitation Priorities/Objectives</th>
<th>Specific End-Use Identified</th>
</tr>
</thead>
</table>
| **Greenbelt Plan (2017)** | • Maintain and enhance ecological integrity  
• equal or greater ecological value  
• Connectivity  
• Public Access | • Forest  
• Agriculture  
• Ecological Value/Ecological Integrity  
• Aquatic Ecosystems  
• Public Use |
| **Oak Ridges Moraine Conservation Plan (2017)** | • Equal or greater ecological or agricultural value  
• Maintain, restore, or improve ecological integrity  
• Rehabilitate as quickly as possible | • Agriculture  
• Natural Heritage  
• Ecological Value/Ecological Integrity |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain and enhance ecological integrity</td>
<td>Restoration and enhancement natural heritage features</td>
<td>Connectivity</td>
</tr>
<tr>
<td>equal or greater ecological value</td>
<td>to equal or greater ecological value</td>
<td>Replace or restore habitat</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Use of native vegetation</td>
<td>None identified</td>
</tr>
<tr>
<td>Public Access</td>
<td>Comprehensive rehabilitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compatibility with surrounding land-uses</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equal or greater ecological value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Terrestrial and aquatic Rehabilitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public Use and Open Space</td>
</tr>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

### 4.2 Provincial Strategic Plans & Policy

In the last 10 years, the Government of Ontario has released a number Strategic Plans and policy documents that have focused on managing and conserving Ontario’s natural resources. These Plans define the problem and outline strategic objectives and priorities, for the management and response to the Province’s environment and ecological concerns.

Aggregate site rehabilitation presents an opportunity to create unique landscapes and specialized habitats. As outlined in Table 2, specific aggregate rehabilitation end-uses can create habitat to help achieve Provincial objectives and priorities.
Table 2: Government of Ontario Strategic Plans

<table>
<thead>
<tr>
<th>Provincial Document</th>
<th>Document Summary / Key Objectives</th>
<th>Key Priorities that relate to Aggregate Rehabilitation</th>
<th>Rehabilitation End-Uses that could achieve Key Priorities</th>
</tr>
</thead>
</table>
| Wetland Conservation Strategy for Ontario 2016-2030 | Building on over 30 years of positive achievements in conserving Ontario’s wetlands, a Wetland Conservation Strategy for Ontario is a framework to guide the future of wetland conservation across the province. The intent of the Strategy is to establish a common focus to protect wetlands, so that Ontario can achieve greater success in a more efficient and effective manner. | • By 2030 achieve a net gain in wetland area and function where wetland loss has been the greatest  
• Establish and strengthen partnerships to focus and maximize conservation efforts for Ontario’s wetlands and encourage people, communities and organizations collaborating and working together to improve wetland conservation.  
• Develop and advance public awareness of, appreciation for and connection to Ontario’s wetlands so that people will be inspired and empowered to value and conserve Ontario’s wetlands.  
• Increase knowledge about Ontario’s wetlands including their status, distribution, functions, and vulnerability to gain better knowledge is available and used to make | • Wetlands  
• Aquatic habitat |
<table>
<thead>
<tr>
<th>Literature &amp; Background Review Summary Report</th>
<th>Aggregate Rehabilitation Best Management Practices</th>
<th>March 2018</th>
</tr>
</thead>
</table>

**Management of Excess Soil**

*Updated: June 6, 2017*
*Published: April 5, 2016*

Excess soil must be managed in a sustainable manner in order to maintain a healthy economy while protecting the environment. Many development activities often result in the need to manage large quantities of excess soil. The MOE also promotes the reuse of excavated soil from civil construction projects at the site where the soil is excavated, or reuse of excess soil at other similar civil construction projects.

- Excess soil can be used in the rehabilitation of pits and quarries, in accordance with Excess Fill Best Management Practices.
- In some cases, excess fill can be used to enhance the rehabilitation capability of the site.
- The use of excess soil in rehabilitation can be used to: create specialized landforms and topography, reduce the grade of side slopes, and increase soil depth across the site.

**Ontario’s Pollinator Health Action Plan**

Published in 2016

Worldwide, there are signs that managed bees and wild pollinators are under stress and in a number of cases, in decline. At the same time, the need for

- Pollinator habitat in Ontario is any area that provides nectar and pollen resources, nesting/overwintering sites or larval host plants that support
- Natural pollinator habitat that includes nesting sites and flowering plants

**Literature & Background Review Summary Report**

Aggregate Rehabilitation Best Management Practices

March 2018

decisions to improve wetland conservation.

- Develop **conservation** approaches and improve policy tools to conserve the area and function of Ontario’s wetlands in order for Ontario to have a strong and effective foundation to conserve and stop the net loss of wetlands.
Pollination services for many agricultural crops continue to grow. Some Ontario-specific research indicates that the province is experiencing similar declines while facing increasing demands for pollination services, particularly from managed bees. Several causes or “stressors” are thought to be responsible for their decline and can be grouped into four broad categories: Diseases, Pests and Genetics; Exposure to Pesticides; Reduced Habitat and Poor Nutrition; and Climate Change and Weather.

| Pollinator habitat can occur in natural areas as well as in agricultural and built-up settings. |
| Pollinator habitat is being threatened by degradation, fragmentation and direct loss. The majority of habitat impacts have occurred in southern Ontario where the loss of natural habitats has been greatest. |
| Alternative Land Use Services (ALUS) is a community-developed, farmer delivered program that gives Canadians the opportunity to play an active role in building a healthier environment by providing support to farmers to enhance and maintain ecosystem services. ALUS partners with farmers to retain and restore natural areas. These rehabilitated areas have natural benefits such as creating habitat for fish and wildlife, species at risk and native pollinators. |
**Ontario’s Invasive Species Strategic Plan**

Published in 2012

Invasive species are a growing environmental and economic threat to Ontario. The ecological effects of invasive species are often irreversible and, once established, they are extremely difficult and costly to control and eradicate.

- Work with neighbouring jurisdictions and other partners to protect healthy ecosystems and rehabilitate degraded ecosystems, building resilience and helping to prevent invasive species from becoming established.
- Management measures include eradication, containment, and control measures that need to be implemented once new invasive species have been found in a region.
- Goals of Ontario Invasive Species Strategic Plan are to: **Prevent** harmful introductions, **Detect** and identify invasive species, **Respond** rapidly to invasive species, and **Manage and Adapt** - implement innovative management actions and take practical steps to protect against impacts of invasive species.

**Ontario’s Climate Change Strategy and Action Plan 2016-2020**

Updated: October 25, 2017
Published: June 8, 2016

Ontario’s Climate Change Action Plan is a five year plan that will help Ontario fight climate change over the long term.

- Ontario intends to establish a green bank to deploy and finance readily available low-carbon energy technologies to reduce carbon pollution from Ontario buildings. The
<table>
<thead>
<tr>
<th>Naturally Resilient: MNRF’s Natural Resource Climate Adaptation Strategy 2017-2021</th>
<th>Climate change is creating an increasingly complex operating environment and introducing uncertainty for the MNRF in fulfillment of its responsibilities. This may present significant challenges for delivery of the ministry’s mandate. Naturally Resilient will ensure the ministry is well-positioned to reduce its vulnerabilities, fulfill its mandate, and address the impacts of climate change – thereby safeguarding valuable resources and the services they provide, as well as the communities and economies that depend on them.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Although rehabilitation of aggregate sites is not explicitly discussed, the case is made for the importance of consistent, reliable ecosystem services where Ontarians live – from flood control and nutrient recycling to providing refuge for biodiversity including pollinators and at-risk species – in the face of climate change. The best strategies to achieve this in densely occupied southern Ontario is to strategically restore, create and reconnect fragmented woodlands, grasslands and wetlands. Aggregate rehabilitation has much to offer in this regard, and should coordinate with the agencies and stakeholders in these fields, which are identified in the document.</td>
</tr>
<tr>
<td></td>
<td>• Woodlands (deciduous and mixed-wood forests)</td>
</tr>
<tr>
<td></td>
<td>• Wetlands</td>
</tr>
<tr>
<td></td>
<td>• Grasslands, meadows</td>
</tr>
<tr>
<td></td>
<td>• Ecosystems providing cultural and natural services simultaneously</td>
</tr>
</tbody>
</table>
| **Species at Risk Program Status (2008-2015)** | The document describes the government’s commitments and efforts to support Ontario’s species at risk, and reports on progress toward the protection and recovery of the 13 species whose government response statements were finalized in 2010. Supporting information about the legislative requirements and relevant policies and procedures that help to protect and recover species at risk in Ontario are outlined. | • Species specific habitat creation and management  
• Government led actions for Species recovery  
• Ongoing research and monitoring  
• Collaboration with stakeholders  
• Support Efforts to Create an Overall Benefit for Species at Risk | • Specialized and enhanced habitat creation |
| --- | --- | --- | --- |
| **Ontario's Biodiversity 2011**  
Ontario Biodiversity Council  
Published: 2011 | Ontario’s Biodiversity Strategy, 2011 is the guiding framework for coordinating the conservation of our province’s rich variety of life and ecosystems. It builds on the positive achievements of Ontario’s 2005 Strategy and sets out new and updated direction for the next 10 years.  
Three goals define the conservation path proposed in this Strategy:  
**Goal 1: Mainstream biodiversity by incorporating biodiversity** | • The Strategy highlights four strategic directions that reflect the critical components required to conserve Ontario’s biodiversity:  
• Engage People – change attitudes and behaviour so that we value biodiversity appropriately and include it in our everyday decision making  
• Reduce Threats - improve the condition of species and ecosystems and help prevent further biodiversity loss by reducing the extent of significant threats to | • All types of natural and aquatic rehabilitation |
considerations into decision making across the province, in different sectors and in our homes, workplaces and schools.

Goal 2: Protect, restore and recover Ontario’s genetic, species and ecosystem diversity and related ecosystem functions and processes.

Goal 3: Use Ontario’s biological assets sustainably.

| **Ontario’s Provincial Fish Strategy – Fish for the Future** |
| **Published 2015** |

This is a guiding document for managing fisheries resources in Ontario. It identifies provincial fisheries goals, objectives and tactics to achieve them. The main purposes of the strategy are to improve the conservation and management of Ontario’s fisheries resources; and to promote, facilitate and encourage fishing as an activity that contributes to the nutritional needs, and the social, cultural and economic well-being of individuals and communities in Ontario.

- Improve the conservation and management of fisheries and the ecosystems on which fish communities depend; and
- Promote, facilitate and encourage fishing as an activity that contributes to the nutritional needs and the social, cultural and economic well-being of individuals and communities in Ontario.

- Aquaculture / Fisheries rehabilitation and aquatic rehabilitation

biodiversity and the impacts of existing threats.

- Enhance Resilience - increasing their capacity of ecosystems to cope with change
- Improve Knowledge - better understand how Ontario’s many plants, animals and micro-organisms contribute to broader ecological functions and to the health of our environment
4.3 Municipal Official Plan Review

As part of the Literature review a number of Municipal Official Plans were reviewed for the purpose of identifying any local policies that may guide or provide specific direction for aggregate extraction rehabilitation. The Official Plans of the Top-Aggregate producing municipalities were reviewed, as identified in the 2016 TOARC Production Statistics Report. This included a combination of Upper-tier, Lower-Tier, and Single-Tier municipal Official Plans. Table 3 summarizes the results of the Municipal Official Plan Review.
Table 3: Summary of Municipal Official Plan Review

<table>
<thead>
<tr>
<th>Official Plan</th>
<th>Policy Analysis</th>
<th>Specific End-Uses Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Ottawa Official Plan</td>
<td>General rehabilitation policies only that re-state the requirements of the</td>
<td>None identified</td>
</tr>
<tr>
<td>As Adopted by Council – May 2003</td>
<td>Provincial Policy Statement and Aggregate Resources Act.</td>
<td></td>
</tr>
<tr>
<td>City of Kawartha Lakes</td>
<td>General rehabilitation policies only that require consideration for</td>
<td>None identified</td>
</tr>
<tr>
<td>Official Plan Updated 2012</td>
<td>surrounding land uses.</td>
<td></td>
</tr>
<tr>
<td>Rural Hamilton Official Plan</td>
<td>Policies of the PPS, ARA and Greenbelt Plan are incorporated in the OP Policies.</td>
<td>• Agriculture</td>
</tr>
<tr>
<td>Effective Date March 7, 2012</td>
<td>Includes some specific rehabilitation policies, including:</td>
<td>• Public Use (Recreation)</td>
</tr>
<tr>
<td></td>
<td>• Operators shall be encouraged to consider and plan to provide for public</td>
<td>• Final landforms that reflect pre-extraction cultural heritage</td>
</tr>
<tr>
<td></td>
<td>access to former aggregate sites upon final rehabilitation</td>
<td>values</td>
</tr>
<tr>
<td></td>
<td>• The rehabilitation of areas impacted by mineral aggregate resource</td>
<td></td>
</tr>
<tr>
<td></td>
<td>extraction operations shall reflect and conserve elements of the pre-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>extraction character of the significant cultural heritage resources where</td>
<td></td>
</tr>
<tr>
<td></td>
<td>possible</td>
<td></td>
</tr>
<tr>
<td>Township of North Dumfries</td>
<td>Includes policies of the PPS in regard to Agricultural rehabilitation and the</td>
<td>• Encourages comprehensive rehabilitation of multiple properties</td>
</tr>
<tr>
<td>Office Consolidation,</td>
<td>Policies of the Region of Waterloo Official Plan also apply.</td>
<td>• Agriculture</td>
</tr>
<tr>
<td>February 2016</td>
<td>Specific aggregate rehabilitation policies, include:</td>
<td>• Net Gain of Natural Heritage Features/Ecological Restoration</td>
</tr>
<tr>
<td></td>
<td>• The development of comprehensive rehabilitation plans for multiple</td>
<td></td>
</tr>
<tr>
<td></td>
<td>properties.</td>
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</tr>
</tbody>
</table>
- The requirement for final rehabilitation to comply with land use designation contained in the Official Plan and be compatible with the character of surrounding land uses.
- Any new mineral aggregate operations and subsequent rehabilitation located between the top of bank plus the applicable regulatory setbacks and the Grand River, will only be permitted where it is clear that the extraction proposal and subsequent rehabilitation of the lands will result in a net environmental gain.
- New mineral aggregate extraction within the prime agricultural area and rural areas designations will be permitted only if agricultural rehabilitation is maximized.
- In the prime agricultural areas designation, rehabilitation to agriculture will be the first priority.
- Replacement habitat to be of greater extent and/or ecological value as part of the rehabilitation plans to promote a net ecological gain.
- Rehabilitation of any area once occupied by natural features or identified as potential enhancement/restoration and/or corridor/linkage areas is completed as early as possible in the life of the extraction operation.

<table>
<thead>
<tr>
<th>Region of Waterloo</th>
<th>Includes policies of the PPS for aggregate rehabilitation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Comprehensive Rehabilitation</td>
</tr>
<tr>
<td></td>
<td>Agriculture</td>
</tr>
</tbody>
</table>
Specific aggregate rehabilitation policies, include:

- Core Environmental Feature affected by the mineral aggregate extraction will be replaced or restored within a reasonable period of time with habitat of greater extent and/or ecological value as part of the rehabilitation plans, to promote, where possible, a net ecological gain, or in the case of habitat of endangered or threatened species, compliance with provincial and federal requirements have been achieved;
- rehabilitation of any area once occupied by natural features or identified as potential enhancement/restoration and/or corridor/linkage areas is completed as early as possible in the life of the extraction operation.
- final rehabilitation will comply with the land use designations contained in this Plan and Area Municipal official plan, and be compatible with the character of surrounding land uses;
- In the Prime Agricultural Area designation, rehabilitation to agriculture will be the first priority.
- Where multiple mineral aggregate operations are located in close proximity to one another, owners/applicants to jointly

| Net Gain of Natural Heritage Features/Ecological Restoration |
| **Regional Municipality of Halton (2009)** Interim Office Consolidation Based on Amendment 38, December 16, 2009, As Adopted by Regional Council. | Includes policies of the PPS and Greenbelt Plan for aggregate rehabilitation Specific aggregate rehabilitation policies include: - Require the rehabilitation of all such sites to form part of the Greenbelt or Regional Natural Heritage System or the Agricultural Area, with the proposed after-uses being in conformity with the applicable policies of that land use designation. - In some cases, require any application for a new or expanded mineral aggregate operation to consider a “net environmental gain” approach to the preservation and enhancement of the Greenbelt and/or Regional Natural Heritage System | - Net environmental gain for ecological features and functions. - Transfer of ownership from privately owned rehabilitated or enhances lands to a public body - Enhancement to the Greenbelt and/or Regional Natural Heritage Systems, including: increase in the spatial extent of the Greenbelt and/or Regional Natural Heritage Systems, increase in biological and habitat diversity, enhancement of ecological system function, enhancement of wildlife habitat, [v] enhancement of natural succession, creation of new wetlands or woodlands, enhancement of riparian corridors, enhancement of groundwater recharge or discharge areas, and establishment or enhancement of linkages between significant natural heritage features and areas. |
| Municipality of Clarington Adopted by Clarington Council November 1, 2016 | Includes policies of the PPS, Greenbelt Plan, and Oak Ridges Moraine for aggregate rehabilitation: - The municipality will seek to ensure the rehabilitation of pits and quarries occurs in a comprehensive manner which is sensitive to surrounding land uses and landscapes, mitigates negative impacts to the furthest | - Forest Cover - Creation of appropriate landforms - Integration of rehabilitation plans for existing Licenses. - Dedication of lands to a public authority - Enhancement of ecological integrity, including maintenance, enhancement or establishment of linkages |
extent possible, and reflects the underlying land use designation on Map.

- The Municipality, in consultation with the Region of Durham, the Province and the aggregate industry, may prepare area-wide rehabilitation plans for the Oak Ridges Moraine and the Lake Iroquois Beach.
- A rehabilitation plan which provides for the creation of appropriate landforms and restores ecological functions, which conforms to the permanent land use designation of this Plan, and which takes into account the objectives of any applicable area-wide rehabilitation plan approved by the Municipality, and which includes interim and/or progressive rehabilitation.

<table>
<thead>
<tr>
<th><strong>County of Wellington</strong></th>
<th>The rehabilitation plan must be compatible with the long term uses permitted by the surrounding official plan designations; Agricultural Rehabilitation is required on lands designated Prime Agricultural Area and Secondary Agricultural Area. For the Greenbelt Plan Area within the County of Wellington, the policies of the Greenbelt Plan apply.</th>
<th>Agricultural rehabilitation Within the Greenbelt Plan Area public access, equal or greater ecological value; comprehensive rehabilitation planning.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Consolidation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November 9, 2017</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Simcoe County</strong></th>
<th>For extraction in a local natural heritage system or natural heritage feature, proposed rehabilitation should include elements intended to contribute to the local natural heritage system.</th>
<th>Agricultural rehabilitation Restoration of ecological features and functions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>As approved by the Ontario Municipal Board as of December 29, 2016</td>
<td></td>
<td></td>
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</tbody>
</table>
Progressive and final rehabilitation shall be required to accommodate subsequent land uses, to promote land use compatibility, and to recognize the interim nature of extraction. Final rehabilitation shall take surrounding land use and approved land use designations into consideration.

Agricultural rehabilitation is required in prime agricultural areas.

<table>
<thead>
<tr>
<th>County of Oxford Official Plan</th>
<th>Ensure that rehabilitation of pits and quarries is carried out in an environmentally sensitive manner to an appropriate after-use which is consistent with the long-term intent of this Plan.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To ensure quarry extraction is viewed as an interim use of land and to promote comprehensive and integrated rehabilitation within and between licences providing significant social and environmental benefits to the County.</td>
</tr>
<tr>
<td></td>
<td>County Council and/or the Area Council is satisfied that the proposed rehabilitation scheme will provide net environmental gain. Net environmental gain results in a positive contribution to the state of the natural environment as a result of rehabilitation initiatives associated with extraction.</td>
</tr>
<tr>
<td></td>
<td>Confirmation that the proposed rehabilitation scheme is technically feasible, environmentally sound and is capable of being implemented.</td>
</tr>
<tr>
<td></td>
<td>Agriculture</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation which provides significant social and environmental benefits</td>
</tr>
<tr>
<td></td>
<td>Wetland systems</td>
</tr>
<tr>
<td></td>
<td>Wildlife habitat and linkages</td>
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<td></td>
<td>Reforestation</td>
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<td></td>
<td>Surface Water Systems</td>
</tr>
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<td></td>
<td>Passive Recreation</td>
</tr>
<tr>
<td></td>
<td>Rehabilitation that results in a net environmental gain</td>
</tr>
<tr>
<td></td>
<td>Enhancement to groundwater recharge and discharge</td>
</tr>
<tr>
<td></td>
<td>Enhancement to on-site and off-site aquatic enhancement</td>
</tr>
<tr>
<td></td>
<td>Integrated rehabilitation plans</td>
</tr>
</tbody>
</table>
In recognition that a significant proportion of the limestone resource in Oxford County is overlain by prime agricultural areas, County Council has established the following after-use priorities where quarry extraction occurs on these lands (Policy 3.4.1.3.4):

- Rehabilitation of the lands to agricultural uses is the first priority, where this is technically feasible. Where rehabilitation to agriculture is achievable, such rehabilitation will be carried out whereby substantially the same areas and same average soil quality for agriculture are restored.
- Notwithstanding this requirement, where surface natural resources such as woodlands, wetlands and surface water features are situated on prime agricultural lands and would be removed by extraction, the first rehabilitation priority is to replace these features.
- Where it can be shown that it is not feasible to return the lands to Classes 1 to 3 agricultural capability, according to the Canada Land Inventory, and in keeping with the principle of net environmental gain as established in this Section, second priority shall be given to rehabilitation which provide significant social and environmental benefits, including but not limited to the
following: wetlands systems, wildlife habitat and linkages, reforestation, surface water systems, passive recreation.

- In recognition that there may be specific areas where rehabilitation to agriculture or conservation/passive recreation purposes may not be feasible or appropriate given surrounding land uses, County Council and Area Councils may consider after-uses for commercial and industrial development, active recreation or non-farm residential development.

Rehabilitation which is considered to be a net environmental gain will result in increased biological diversity, system function, wildlife habitat and in the creation of environmental features such as wetlands, water systems and wooded areas. The following initiatives will be promoted through rehabilitation schemes for extraction operations to achieve a net environmental gain:

- enhancements to groundwater recharge and discharge, where feasible;
- where practical and desirable, given the location of extraction, interconnections between rivers, flood plain pools and wetland linkages will be created to enhance both on and off-site aquatic habitat;
- **biological diversity** - the expansion of fish, amphibian, reptile, mammal, insect, bird and vegetation variety, will be enhanced through rehabilitation by techniques such as topographic variation, creation of micro-climatic zones, providing standing or flowing surface water on a permanent or seasonal basis, providing water bodies that incorporate shallows for fish habitat and reproduction and which have uneven bottoms and low angled, sinuous shorelines, islands and peninsulas to increase the land/water interface. Other measures include the use of native species, natural succession supplemented by clustered planting and the use of a variety of soil types and overburden types;
- where practical, rehabilitation shall be implemented to be beneficial to improved water quality and the creation of other natural features such as wetlands and upland forests. Where practical and technically feasible, the proposed rehabilitation schemes and after-use of adjacent licensed areas will be compatible and complementary. Such rehabilitation will be integrated with adjacent approved schemes on the basis of: final elevations of the land, the compatibility and consistency of biological
- Improvements, linkages between water features, compatibility of surface drainage systems, phasing strategy.
- Where integrated rehabilitation plans between multiple licenses are approved, County Council and Area Councils will support mutual extraction to the shared licence boundary.
5 Literature & Background Review

5.1 Summary of Scientific Literature Review

An in-depth scientific literature review search was completed which resulted in the compilation of 156 relevant papers. These papers were reviewed and the key findings of organized and summarized into a total of 15 “research themes”. The complete Scientific Literature Review is included in Appendix B – Scientific Literature Review.

The following is a summary of the ‘Key Findings’ of the Scientific Literature Review.

1. “Big-Picture” Planning and Resilience to Global Change
   - Looking at habitat patterns and resistance of the landscape to rehabilitation interventions, the cost efficiency was greatest when the goal is biodiversity, due to lower landscape resistance to this option. (Corry, Laforêtaza & Brown 2010).
   - For restoration to be successful it must transcend the traditional boundaries of ecological science. (Khater et al. 2012).
   - The substantial ecological and societal benefits of fostering high conservation value can outweigh the climate-change mitigation associated with a faster carbon sink but less diverse ecosystem (Wilker et al. 2016).
   - The collective and cumulative benefits arising from a naturalized area after-use vs public park indicate that a naturalized area after-use is more valuable investment for both nature and society (Blaen, MacDonald & Bradbury 2016).
   - “Next-level” aggregate rehabilitation practices will require planning for management of multiple sites simultaneously, such that recovery processes occurring at one location can complement those occurring at other, potentially interacting (e.g. through species migrations) locations in the region (Tang et al. 2011).
   - Efforts to rehabilitate extraction sites can be significantly hampered by establishment of undesirable invasive species, such as aggressive and opportunistic ruderal plants. (Gilardelli et al. 2016).
   - The poor germination of native species hydro-seeding mixtures vs commercially-available exotic species traditionally used in rehabilitation, may be relatively easy to solve, by simply reducing the proportion of generalist natives in the seed mix and being more rigorous in species selection considerations (Oliveira et al. 2014).
   - Rehabilitation success may be simpler to achieve than previously thought. Potentially expensive and complex efforts to stimulate soil development
and revegetation may not offer any significant advantage over simply planting the shrubs and letting nature take its course (Oliveira et al. 2011, Muzzi & Mongardi 2016).

- The creation of bee habitat is sufficient to establish bee communities when there are naturally occurring colonies of bees nearby; however, steps to ensure constant nectar sources (i.e. flower blooms) throughout the entire growing season, and maintaining open habitat for nesting is required (Onuferko et al. 2018).
- Alvar plant communities can be established with high diversity thanks in part to the strong degree of habitat heterogeneity characterizing quarry floors, and that interactions between heterogeneity and species diversity enhanced the productivity and resilience of resultant plant communities when disturbed by extreme drought (Richardson, Horrocks & Larson 2010; Richardson, MacDougall & Larson 2012).

2. Species-Sorting, Environmental Filtering and Succession

- The accurate knowledge of ecological processes, environmental conditions and the traits of species in local and regional pools can help managers predict and drive succession towards desired outcomes (Kompala-Baba & Baba 2013).
- The single most important factor dictating the outcome of succession is the nature of the surrounding vegetation (Prach et al. 2011; Prach et al. 2013; Prach et al. 2014; Prach et al. 2015).
- Studies of succession in rehabilitated Chinese quarries planted with exotic woody species over 214 years indicated that although the non-native canopy cover had a prolonged impact, a high diversity of native woody species established in the understory quickly, within about 10 years (Zhang, Zhuang & Chu 2013).
- Other research on the wide variety of successional stages found at post-industrial sites in the Czech Republic (including abandoned and rehabilitated aggregate pits and quarries) found that the success of different plant species in different environments could be predicted from particular seed traits, especially seed mass, longevity, and method of dispersal (Horackova, Rehounkova & Prach 2016).

3. Conservation Value of Aggregate Sites

- Biophysical sampling of small and medium-sized sand and sand-gravel pits these environments and their surroundings showed that active sand pits and recently disused sites provide essential habitat to an incredible diversity of animal species, especially insects and other arthropods (Heneberg & Rezac 2014).
- Limestone quarries (as opposed to sand-gravel pits) undergoing spontaneous succession in the Czech Republic region have been found to host a tremendous diversity of spider species (Tropek & Konvicka 2008) as
well as numerous other arthropods and plants, including many red-listed and dryland specialist species (Tropek et al. 2010).

4. Technosols, Amendments, Planting & Seeding

- In a reclaimed limestone quarry in the Rocky Mountains of Alberta, the diversity of native trees and shrubs was improved most by transplanting nursery-grown stock in fall, leading to establishment of 5 of 7 species, and good survival by 3 of these. Spring plantings were less successful due in part to grazing and trampling by herbivores during the sensitive early growth period, and application of seeds, topsoil seed banks from nearby forest floors, and transplantation of wildling plants from local surroundings were largely unsuccessful. Amending the reclaimed quarry substrate (mineral substrates leftover from extraction) with wood shavings or clean fill had no impact on planting success (Cohen-Fernandez & Naeth 2013b).

- In an experimental sowing of hardy grasses and legumes on limestone quarry terraces in Greece, germination, density and cover of vegetation was increased by 65% when mulching with wheat straw was applied (Abraham, Kostopoulou & Koukoura 2009).

- The performance of a native Hydroseeding mix may be improved somewhat by adjusting species selection and seeding levels to fit the hydroseeding conditions (Clemente et al. 2016).

- In the tropical mountain grasslands of Brazil, hay transfer from the target grasslands was largely ineffective for establishing vegetation. Direct planting of target native trees and shrubs was considerably more successful (Le Stradic et al. 2014).

- Spanish researchers investigating microbial activity in technosols found that addition of dewatered sewage sludge to substrates collected from working limestone quarries increased the level of microbial biomass and respiration as well as soil carbohydrate content when applied, with significant effects maintained after 9 months of laboratory incubation (Jimenez et al. 2007). Nearby studies on other technosols found that sewage applications were of some environmental health concern, especially the risk of sulfate and nitrate contamination, but proper engineering of technosol construction, treatment and monitoring can reduce the need for alarm (Jordan et al. 2017).

- Less-dense, slower-growing but drought-tolerant plants are more desirable for the control of bank erosion than fast-growing, not drought tolerant plants (Josa, Jorba & Vallejo 2012).

- A field experiment at a dry Spanish quarry where establishment of woody species was the goal found that increasing water availability could benefit target species by overcoming a resource limitation, but it could also indirectly harm target species by stimulating growth of herbaceous species.
which compete with the targets for multiple resources (Soliveres, Moneris & Cortina 2012).

- Experimental rehabilitation of the largest slate quarry in Europe (in Wales, UK) investigated potential constraints on native woody species establishment imposed by nutrient and water limitations, alone and in combination. Different treatments designed to overcome both limitation simultaneously (addition or organic waste, and addition of boulder clay) strongly enhanced growth. (Williamson et al. 2011).

- Italian researchers, seeking to learn if fine-particle waste from stone cutting can be effectively disposed of by incorporating it into quarry rehabilitation found that mixing-in organic material to improve the fertility and quality of stone wastes, reduced hydrocarbons and metal content and produced technosols that demonstrated no phytotoxicity after 8 years on the quarry floor (Dino, Passarella & Ajmone-Marsan 2015).

- In a dry tropical ecoregion of Venezuela, out of 8 possible combinations of irrigation, fertilizer addition, and application of a water-retaining polymer gel, the use of hydrogel only was found to result in the greatest level of survival and growth (Fajardo et al. 2013).

5. **Soil Relocation, Storage and Development**

- Topsoil relocation and replacement is crucial to vegetation establishment (Burke 2008) (Chenot et al. 2018) (Ferreira & Vieira 2017).

- Sewage sludge applications in quarry rehabilitation may be a powerful tool to enhance carbon sequestration and mitigate climate change (Walter & Calvo 2009), (Ortiz et al. 2012), (Silva et al. 2013), and (Ojeda et al. 2015).

6. **Slope Stabilization**

- A combination of engineering techniques and vegetation can be used to stabilize slopes (Beikircher, Florineth & Mayr 2010), (Federica et al. 2017).

- Innovative Chinese research on quarry slope stabilization tested the potential for using highly stress-tolerant rock-climbing plant species as pioneer vegetation in areas that are too steep to support soil, such as cliff-faces. Two of the three species tested showed little need for soil, as they could cling to rock surfaces using tendrils or air roots, and survival success was high when seedlings were transplanted to holes which were artificially drilled into the steep rocky slopes (Wang et al. 2009; Wang, Wu & Liu 2009).

7. **Wetland Creation**

- Calcareous fens are highly desirable ecosystems when it comes to both mitigating and adapting to climate change and can be created through aggregate rehabilitation using hydrogeological manipulations, topsoil replacement, and vegetation planting (Duval, Waddington & Branfireun 2010).

- Aggregate extraction and rehabilitation in riparian or lowland areas has potential to create ponds or other wetlands with high value as songbird
habitat, but the role of climatic variability (e.g. rainfall, spring flooding) in providing this service is not well known. British researchers monitoring bird productivity (ratio of young to old birds captured) in a rehabilitated gravel pit over 18 years found that year-to-year climatic variation played as strong a role as local land management in shaping the productivity of both resident and migrant birds (16 species in total) (Harrison & Whitehouse 2012).

8. Approaches to Rehabilitation in the North

- Climate change is changing the environmental conditions of the boreal forest, which will affect the types of ecosystems that can be re-established at a given site (Audet, Pinno, and Thiffault 2015).
- In mine site reclamation in Northern Alberta, planting shrubs was found to accelerate forest floor development. Shrub cover aided reforestation by mitigating water stress through reduced solar radiation to the floor and helped prevent browsing mortality (Rowland et al 2009).
- For arctic and subarctic sites the conditions increase the need to use native plant species and to use their succession strategies to develop appropriate rehabilitation plans for gravel sites (Johnson 1987)
- The mining industry should plan for the post-operational phase of mines to accommodate changing climatic conditions (Pearce et al 2010).

5.2 Summary of Grey Literature Review

For the purposes of this Report, ‘grey literature’ is the term applied to non-scholarly documents produced by all levels of government, academia, business organizations and industry members in print and electronic formats.

The emphasis in this Project is on rehabilitation BMPs in the context of advancing beyond the basic and simplified “Slope and Seed” approach to rehabilitation. This therefore entails researching an advanced level of documentary information, some of which may be untested or even experimental. As such, it is information that falls into the category of ‘grey literature’, sourced primarily from academic institutions, non-government organizations, and industry (represented by individual members, collective associations or contracted consultants). Ontario specific industry aggregate research and BMPs are included in section 6.3.

5.2.1 Academia


The paper broadly and generally discusses Reclamation and Quarry Landscape Elements (landform and vegetation). It then details the various techniques for
Reclamation such as Rollover Slopes, Backfilling, Bench Planting, Restoration Blasting, and Natural Recovery. Relevant photographs of sites where the techniques have been used are provided. The advantages and disadvantages of each technique are analyzed.

**Restoring Habitats of High Conservation Value after Quarying, Best Practice Manual**
(Williamson, J., Rowe, E., Rendell, T., Healey, J., Jones, D. and Nason, M., Institute of Environmental Science, University of Wales, Bangor. 2003).

The purpose of this Manual is to provide a background to the principles of ecological restoration and how to use these appropriately in the re-creation of biodiverse habitats as well as Practical guidance on plant establishment to promote habitat development.

The Manual notes that it is most relevant to quarries but the ecological principles can be equally applied to gravel or sand pits or any uncontaminated, post-industrial land with a topsoil deficit. The Manual deals with restoration from the viewpoints of both industry and ecologists – it is intended to be equally useful to both disciplines, facilitated by a glossary of technical terms.

**Wildlife Values of Gravel Pits** (Miscellaneous Publication 17, University of Minnesota, 1982)

The Report is the Proceedings from a Symposium entitled Wildlife Values of Gravel Pits held by the University of Minnesota in June of 1982.

Even in 1980, it was recognized by the Symposium organisers that in the face of declining habitats, gravel pits were seen as a developing opportunity and one with significant potentials in view of their extensiveness and proximity to population centres. Over the three day Symposium, 34 papers were presented by knowledgeable individuals brought together to discuss their ideas and experiences relating to fish and wildlife values, and environmental education uses of sand and gravel pits. The papers covered 14 US states, Canada and Great Britain, with an overriding focus on actual examples and practical methodologies to achieve the desired outcomes.

**Wild Bee Pasture as an Innovative Element of Restoration in Quarries** (Martina Brockard, Olena Torchyk, Technical University of Munich)

The report is a 2011/2012 Term Paper by two senior students at the Technical University of Munich. The authors devised a ‘renaturation’ concept for the Burglengenfeld Quarry, which is operated by HeidelbergCement company and has a hundred year-old history behind it. The aim of their project was to prepare and put into practice a concept for setting up a wild bee pasture in a disused area of the quarry.

The authors understand the modern-day landscape has become more monotonous due to increasing urbanization and intensification of agriculture, rendering it biologically impoverished. As a result, many species of wild bees are no longer able to find a place
offering a chance of survival and the majority of native wild bees are acutely threatened or have already become extinct.

The authors recognised the opportunity to create a wild bee pasture in the Burglengenfeld Quarry, which could potentially offer an optimal living environment for wild bees, where they are able to profit from warmer temperatures and a longer vegetation period.

5.2.2 Non-Government Organizations

The RSPB website [Nature After Minerals](#) (NAM) provides extensive and topical information on numerous mineral sites where the restoration benefits wildlife as well as creating places for people to enjoy. Nature After Minerals is an RSPB/Natural England partnership, with support from the minerals industry.

The website provides access to an overview publication entitled *[Nature After Minerals: how mineral site restoration can benefit people and wildlife.]* The report, authored by the RSPB, lays out the organization’s vision, based on their project experience and partnerships with industry, of large-scale habitats being created on mineral sites for people and for wildlife.

The website’s section on Advice is broken down into three parts, being Habitat, Species and Planning Advice.

‘Habitat’ consists of general guidance for specific end-uses including:

- Habitat Creation on Active Quarries (safeguarding soils, natural regeneration, artificial sand martin bank creation);
- Habitat Creation at a Landscape Scale;
- Open Mosaic Habitat (natural regeneration);
- Wetland (wet grassland, reedbeds, standing open waters, island creation, artificial raft creation);
- Grassland (various lowland and upland types suited to soil conditions);
- Heathland (lowland and upland);
- Woodland (floodplain, upland mixed ash, upland oak, lowland beech and yew, lowland wood-pasture and parkland);
- Coastal (saline lagoons, grazing marsh, vegetated shingle);
- Agriculture (biodiversity enhancement in arable restorations).

‘Species’ consists of general guidance for

- Birds (Willow Tit, Twite, and Sand Martin)
- Mammals (Otter)
- Invertebrates (bumble bees).
In addition, the website has an extensive collection of over 90 Case Study documents, broadly categorized by reclamation strategy.

- Habitat Creation: 60 case studies;
- Species Conservation: 11
- Ecosystem Services: 12
- Resource Management (soil safeguarding, land-forming, water control): 10

The Case Studies are notable for the high degree of specific information that is provided. Each Case Study generally provides ownership and property information, and details on the site’s background, planning history, reclamation strategy, long-term management and public benefits.

**Introducing an Ecosystem Approach to Quarry Restoration** (Cranfield University, for the Natural Environment Research Council, July 2013),

This report illustrates how an ecosystem services approach can offer a systematic framework to enhance, structure, and communicate the benefits which restored land provides to society. The Report provides information to enable the minerals products industry to evaluate and begin to develop an ecosystem services approach to quarry restoration.

The Report discusses the types of ecosystem services that restored quarries can (potentially) generate and the associated public benefits specifically for four common habitat types: heathlands, grasslands, wetlands and farmland. The report gives examples of how ecosystem services from these habitats may be valued. A number of business opportunities and threats are considered in relation to ecosystem service trends.

A lack of formal reporting and centralised recording of habitats created through restoration is noted as current industry deficiency.


This report has been prepared under contract to the Minerals and Nature Conservation Forum. It works to raise awareness and promote action for biodiversity and geodiversity in England’s minerals industry.

This report was completed in order to develop a methodology that could be used to assess the overall impact of aggregate/silica sand extraction in any given area and should be used at a strategic planning level, but also in directing more local decisions on quarry location and restoration schemes.

The purpose of this guide is not to discuss the development of new sites, but to provide guidance on how to maximise the opportunities for wildlife through site restoration and the management of active sites.

This BMP guide aims to help site managers, minerals planners and ecological consultants make the most of the biodiversity opportunities that aggregate sites present, with a focus on invertebrates.

The publication notes that more can be done to maximise the benefits for invertebrate biodiversity and that managing for invertebrates is often a simpler, lower cost option, and can easily be incorporated into existing site restoration plans.

5.2.3 Industry

Several of the leading multinational corporations which predominate the global construction aggregate industry, and/or the industry associations that represent them, have developed their own ecologically-based rehabilitation plans and programs. Some of this may have come about as a result of Governmental mandates, but others will be the result of internal corporate initiatives, in response to increased awareness of, and concern for, the environment.

Some, undoubtedly, will also have their genesis as the result of a much more local perspective, namely that of ensuring the continued functioning of existing operations and, safeguarding as much as possible, the successful application for a new operation. The locational context for both existing and new operations being that it is likely in proximity to existing urban development, a benchmark requirement of a low unit value and high bulk mineral resource commodity, such as construction aggregates.

**Guidelines on Quarry Rehabilitation** (Cement Sustainability Initiative (CSI), Biodiversity and land stewardship, December 2011)

The Guidelines are based on the understanding that the impacts of extraction can be successfully addressed and mitigated through the development and implementation of an effective quarry rehabilitation plan; and further, that in some cases, the effective implementation of a well-designed rehabilitation plan can result in significant environmental and social benefits. The Guidelines provide information on:

- Post-closure land use planning
- Going beyond legal compliance
- Engaging stakeholders
- Assessment of baseline conditions
- Development of the Rehabilitation Plan
- Monitoring and implementing corrective measures

Case studies are presented, which highlight quarry rehabilitation activities from a range of quarry types and local habitats around the world.
The Lafarge – Biodiversity Review, Focus on Protecting Ecosystems, 2010 publication documents and highlights the company’s objectives and achievements in promoting biodiversity at its operating and former quarry sites since the 1970’s. Several impressive examples from around the world of the corporate initiative’s success are presented.

Key factors in this initiative include recognizing the stress that biodiversity is under, and taking local initiatives which address those stresses to a partnership approach for their potential resolution.

In October 2012, as the result of a partnership with the World Wildlife Fund for Nature (WWF), Lafarge published Working with nature: Biodiversity Guidance for Lafarge sites. The Guidance is intended for use by local managers in order to integrate their site, where practical, with the living environment. It contains a detailed, iterative-based approach to considering biodiversity values prior to, during, and post-extraction activity. Summary information on 18 case studies relevant to plant or extraction sites is presented.

The Cement Sector: A Strategic Contributor to Europe’s Future (The Boston Consulting Group, 2013)

Section 3.3.4 of the Report is entitled ‘Contributing to biodiversity and ecosystem services’. It speaks to and highlights the factor that despite the best-laid plans, it is imperative that an ecologically-based rehabilitation plan benefit from consultation and partnerships with specialists in the field, whether they be from industry, academia or NGOs. The Report notes that quarrying and biodiversity are compatible through correct resource management before, during and after extraction and that ecosystems are sometimes even enhanced post-rehabilitation in comparison with the site prior to the initiation of extraction activities.

The document Promotion of Biodiversity at the Mineral Extraction Sites of Heidelberg Cement produced by Hiedelberg Cement sets out principles for modern, professional restoration, which significantly contribute to the promotion of biodiversity.

This 2008 Guideline, stated as being applicable to Europe, includes detailed practical guidance on the various types of after-uses that can be achieved both during and at the end of the extraction process. The level of detail extends to defining more discrete terminology such as Restoration (being the most general term), Reclamation, Recreation (i.e. Re-Creation), Renaturation, and Rehabilitation.

The bulk of the Guidance Document is taken-up with a discussion of the varied types of habitat which can exist at extraction sites (e.g. Commercial Forests or Wetland). These are then further described/discussed in terms of their presence Worldwide, General Characteristics, Significance for Biodiversity, Value-defining Habitat Structures and their Qualities, Protection and Promotion of Biodiversity, and Proceeding (i.e. actual implementation of the biodiversity effort).
GWP Consultants, in partnership with David Jarvis Associates, released Appendix 4-2: Principles of design for sand and gravel quarries. This appendix is part of a greater “Quarry Design Handbook” and outlines the processes sand and gravel operations undertake in the U.K. The document describes BMPs that can be utilized during the restoration stage of the operation. Some of these best management practices include:

- Restoration of dry pits to agriculture, forestry or public amenity;
- For restoration to agriculture, soil preservation is a prime consideration and good handling techniques are necessary;
- These techniques will influence the phasing of soil stripping, handling arrangements and stockpile maintenance;
- Long term stockpiling of stripped soil is not recommended;
- Progressive rehabilitation is recommended.

6 Review of Existing Aggregate Site Best Management Practices from Ontario

6.1 Government of Ontario Aggregate Rehabilitation Publications

After the introduction of the Pits and Quarries Control Act in 1971, the Government of Ontario commissioned a number of studies on Pit and Quarry Rehabilitation. One of the first publications released was a Bibliography of Pits, Quarries, and Other Surface-Mined Lands in 1978. This publication included an extensive reference list of information available and was prepared to enable operations, professionals, and government to access information on the various rehabilitation techniques available at the time. This reference list is now 40 years old. The background research and literature review undertaken in this Report updates the information and reference list in the 1978 publication.

Subsequently, a series of practical rehabilitation guidelines which were released in the 1980’s and are identified in the Table below. These documents have guided pit and quarry rehabilitation over the past 30 years and represent the existing Best Management Practices for pit and quarry rehabilitation in Ontario.

This series of publications identify specific end-uses that pit and quarry rehabilitation can achieve, including: Forest Production, Wildlife Habitat, and Agriculture.

A review of these documents was undertaken in order to assess their applicability to current rehabilitation requirements and end-uses.

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Table 4: Review of Government of Ontario Aggregate Rehabilitation Publications from the 1980s

<table>
<thead>
<tr>
<th>MNR Rehabilitation BMP Publications</th>
<th>Summary</th>
<th>Rehabilitation End-Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rehabilitation of Pits and Quarries for Forest Production</strong> 1988</td>
<td>• Best Management Practices document to assist operators in formulation and carrying out effective rehabilitation to a Forest/Woodland after-use.</td>
<td>• Forestry / woodland</td>
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<tr>
<td></td>
<td>• Step-by-Step guide on how to complete successful Reforestation</td>
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<tr>
<td></td>
<td>• Includes species/planting lists for different forest regions in Ontario</td>
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<td></td>
<td>• Focus is on reforestation for timber production and not for natural habitat</td>
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<tr>
<td></td>
<td>• List of Tree Nurseries is likely outdated and no longer relevant</td>
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<tr>
<td></td>
<td>• Includes excellent details on the Characteristics of Tree Species Recommended for Rehabilitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• BMPs are still relevant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reference list is outdated</td>
<td></td>
</tr>
<tr>
<td><strong>Rehabilitation of Pits and Quarries for Fish and Wildlife</strong> 1987</td>
<td>• Includes a checklist of physical, operational, and economic factors for operators to use to help identify which fish and wildlife uses are appropriate for their sites</td>
<td>• Waterfowl Hunting Area</td>
</tr>
<tr>
<td></td>
<td>• Seven major fish and wildlife after uses of rehabilitation pits and quarries are addressed</td>
<td>• Waterfowl Protection Area</td>
</tr>
<tr>
<td></td>
<td>• Provides a good background review for fish and wildlife rehabilitation based on scientific literature and field investigations. This needs to be updated with new scientific literature review.</td>
<td>• Commercial game farm</td>
</tr>
<tr>
<td></td>
<td>• Provides a rehabilitation summary checklist with key physical, operational, economic factors involved in rehabilitation for wildlife habitat. Much of this information can be carried</td>
<td>• Wildlife Hunting Area</td>
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<td></td>
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<td>• Wildlife Protection Area</td>
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<tr>
<td></td>
<td></td>
<td>• Recreational Fish Pond</td>
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<td>• Commercial Fish Farm</td>
</tr>
</tbody>
</table>
| **Sand and Gravel Pit Rehabilitation in Northern Ontario** | Charactizes different northern regions  
- Outlines steps for successful rehabilitation in North  
- Provides information on rehabilitation operations for: stripping and stockpiling, grading, vegetation establishments,  
- Limited information on appropriate after-uses  
- Identifies plant hardiness zones for Northern Ontario  
- Includes suitable planting list for Northern Ontario  
- No reference list included. |
| **A Study of Pit and Quarry Rehabilitation in Southern Ontario** | Assesses the effectiveness of the Pits and Quarries Control Act, 1971 in regard to rehabilitation.  
- Various techniques, costs, and methodology are described.  
- Includes a review and evaluation of Rehabilitation that has been undertaken across Southern Ontario.  
- Includes information on rehabilitation costs, which will requiring updating  
- Reforestation  
- Conservation  
- Agriculture  
- Recreation  
- Trout Ponds  
- Residential  
- Transportation Corridors  
- Sanitary Landfill  
- Academic Research |
| **Trees & Shrubs for the Improvement and Rehabilitation of Pits and Quarries in Ontario** | Includes information on Site Planning, Site preparation, Planting Design, Sources and Type of Nursery Stock, Planting and Maintenance Techniques, Criteria for Choosing Species  
- Provides a list of recommended Trees and Shrubs.  
- Reforestation  
- Naturalized / Conservation  
- Recreation  
- Residential |
<table>
<thead>
<tr>
<th>Literature &amp; Background Review Summary Report</th>
<th>Aggregate Rehabilitation Best Management Practices</th>
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</thead>
<tbody>
<tr>
<td><strong>Selecting Native Biodiversity Habitat at Your Pit or Quarry 2013</strong></td>
<td><strong>Opportunities for Establishing Native Ecosystems and Enhancing Biodiversity at Pits and Quarries 2013</strong></td>
</tr>
</tbody>
</table>
| - Discusses planting trees for visual improvement, recreation or residential, forestry and conservation purposes.  
- Good information on tree planting techniques and maintenance  
- Provides criteria for choosing species  
- Species list includes non-native species and some that are possible invasive |  
|  
| - In the summer of 2012, field work was undertaken to investigate methods of reducing the impact of aggregate resource extraction on Bank Swallow populations |  
|  

- Marsh  
- Fen  
- Swamp  
- Meadow  
- Woodland/Forest  
- Cliff and Talus  
- Alvar  
- Rock Barrens  
- Tallgrass Prairie  

- Ponds and wetlands  
- Specialized habitat creation  

- Includes a good discussion on regional, local landscape and site considerations.  
- Identifies specific habitats that can be created through rehabilitation and specific site and climatic conditions needed for these end-uses  
- Provides a broad overview on each end-use and discusses site criteria  
- Does not include any species list  
- Provides limited information on how to create specific habitats  
- Includes a good reference list  

- Includes Best Management Practices that are designed to provide information to aggregate operators who may want to know how to incorporate increased native biological diversity into their existing and future rehabilitation plans.  
- Identifies operational techniques for the creation and restoration to promote biodiversity  
- Includes a good reference list  

|  
|  
|  

- Specialized habitat creation  

- Specialized habitat creation  

- Specialized habitat creation
• Sand and gravel pits are of great importance to the Bank Swallow in Ontario.
• Suitable Bank Swallow Habitat can be created in sand and gravel pits

Rehabilitation of Aggregate Extraction Sites: Opportunities for Establishing Native Ecosystems
Science Report OLL RT.REC 104.04
2002

• The main objective of the Report is to determine the types of natural ecosystems that are possible on extraction sites.
• The report also begins to identify critical factors for success in the establishment of these ecosystems and provides some insight into what ecosystem variables may be predictable in the naturalization process.
• Total number of plant species and the overall floristic quality of a site appear to be predictable given site age since rehabilitation or abandonment, and the landscape context for that site
• Traditional techniques of spreading overburden, then grading and seeding with an exotic species mix should be discarded.
• New techniques being developed for the restoration of damaged natural systems can certainly be applied to extraction sites.

In addition to the 1980’s BMP publications outlined in Table 4, the Province has released two “State of the Art in Ontario” Reports on Aggregate Rehabilitation:

1. **Pit & Quarry Rehabilitation - The State of the Art in Ontario (1984)**

This report described the state of pit and quarry rehabilitation in Ontario with respect to legislation, site planning, choosing an after-use and rehabilitation in urban areas. It also outlines four essential steps that all rehabilitation projects should include - a shorter and more general “Recipe”. The report described each step in further detail, with many BMPs reflected in the 1982 and 1985 MNR reports. These BMPs are as follows:
Storage of Topsoil, Subsoil and Overburden - Prior to commencing aggregate extraction, all the topsoil and sufficient amounts of subsoil and overburden material should be stockpiled for future rehabilitation needs. The topsoil should be stored separately from the subsoil and overburden.

Grading – All steep slopes of a pit or quarry should be graded to gentle slopes.

Topsoil – Topsoil that should have been stored in a separate stockpile prior to starting the excavation should be spread over the pit or quarry when grading is completed.

Vegetation – The site should be revegetated as quickly as possible to prevent erosion and to hasten the establishment of an aesthetic vegetation cover.

Topsoil should not be stockpiled any longer than necessary. After some time, stockpiled topsoil can begin to lose its structure and nutrient value. Progressive rehabilitation techniques should therefore be employed so that the time that any particular topsoil is stockpiled is kept to a minimum.

Stockpiling practices should be carefully carried out to ensure that topsoil is stripped and stored separate from the remaining subsoil or overburden. In this way topsoil can be returned to the site uncontaminated by less fertile layers of the soil.

For the first several years, crops introduced to a rehabilitated site should be of a type that are soil binding and nitrogen fixing. Legume species such as clover, alfalfa, birdsfoot trefoil and crown vetch have proven excellent in this respect. Corn is an especially undesirable initial crop species because it badly depletes nutrient content and as a row crop, it is susceptible to erosion.


SAROS Paper 6 identified strategies such as pre-planning and post-rehabilitation management as BMPs that can be successfully implemented for aggregate rehabilitation. Other rehabilitation techniques that have proven to be successful were also reviewed in the study. A brief overview of the current state of legislation related to rehabilitation was also provided. The following are some of the general recommendations described in the report:

Pre-Planning – Early compilation of baseline information should include consideration of topsoil, subsoil and overburden characteristics such as organic matter, stoniness, structure, texture, soil capability, crop yields, depth of extraction, elevation of water table, surface water drainage patterns, surface water quality
for water bodies on or adjacent to the site, geology of the site, and floral and faunal characteristics. Associated with the pre-planning stage is a need to gain an understanding of past and present land uses, including the types of crops and/or natural habitat features occurring pre-extraction, relief or topography of the area, and how the post-extraction topography will affect the end land use terrain conditions (i.e. drainage, slope, presence of exposed bedrock, prevailing micro-climatic conditions, etc).

- **Stripping and Stockpiling** – A soil strategy is highly recommended as part of the pre-planning stage in order to develop a planned program for the movement of soil materials, outlining how and where they will be stored and how, when, and where they will be replaced. Topsoil should be stripped under dry conditions to minimize compaction. It should be stored separately from the subsoil and overburden, so that it can be returned to the site uncontaminated by the less fertile layers of the soil. The topsoil should be reinstated as soon as possible to reduce the loss of structure and nutrient value and microbial activity associated with stockpiling, and also to avoid handling more than once.

- **Mulch** – The application of mulch such as straw creates a microclimate that protects the soil against both desiccation and erosive forces, and may be very useful for end land uses such as agriculture and forest. Straw mulch typically favours agricultural uses, whereas woody mulches tend to be recommended for rehabilitation to natural features end land uses.

- **Seeding** – Seeding sites is a low cost and relatively quick way to re-establish vegetation. For the first few years, it is currently recommended that crops introduced to a rehabilitated site should include the use of those that are soil binding or nitrogen fixing such as legumes (e.g. clover; alfalfa; birdsfoot trefoil; and crown vetch).

- **After-care of Rehabilitated Pit and Quarry Extraction Sites** – Stone picking since cultivation and frost action may bring stones to the surface and they may required removal. Incorporation of organic matter since the addition of green manure and/or animal manure will enhance the nutrient content of the soil and may be applicable for certain land uses such as agriculture and forest.

- **The physical conditions** – hydrology, soil/substrate and topography must be assessed and developed correctly for individual sites and after use.

- **Equipment operators need to be educated so they understand the sensitivity of soil handling and the goals for the final landscape.**
Chisel ploughing to alleviate compaction from the rehabilitation process of soil replacement is necessary, if the goal is to create a growing medium.

- Monitoring and assessment of successes, so that future rehabilitation plans can be adapted accordingly (adaptive management plan). This leads to a more successful rehabilitation process.

### 6.2 Aggregate Rehabilitation Research and BMPs from TOARC

In 1997, the mandate and responsibility to undertake research on Aggregate Rehabilitation in Ontario was transferred from the Government of Ontario to The Ontario Aggregate Resources Corporation (TOARC). TOARC serves as the trustee for the Aggregate Resources Trust which collects 3% of the fees from aggregate Licenses and Permits to undertake rehabilitation of legacy sites and research on aggregate resources management, including rehabilitation.

In partnership with academic institutions and stakeholders, TOARC has coordinated and funded a number of research projects and Reports. A review of this information is presented in Table 5.

<table>
<thead>
<tr>
<th>BMP Publication</th>
<th>Summary</th>
<th>Rehabilitation End-Use</th>
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</table>
| The Feasibility of Mitigating Hardwood Forest Removal through Afforestation of Farmland Richardson, P.J & Murphy S.D. 2015 | - Discusses the knowledge gap in how to establish a new self-sustaining forest ecosystems that will eventually provide all of the ecological “goods and services” supplied by the original forest cover.  
- Afforested Environments Study (AES) was initiated in 2011 to provide scientific information on the best approach to replacing a mature forest through afforestation  
- Many forest properties can be successfully replaced through conventional afforestation, additional management can achieve an even greater ecological condition similar to the pre-existing forest.  
- The study concluded that managers can now plan and | - Reforestation |
Implement mitigative afforestation with high confidence that the outcome of forest planting will be a nearly complete ecological replacement of the forest ecosystems undergoing removal.

<table>
<thead>
<tr>
<th><strong>Prairie Restoration in Post-Extraction Sandpits: Plant Response to Arbuscular Mycorrhizal Inoculum, Biochar, and Municipal Compost</strong></th>
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<tbody>
<tr>
<td>This research report describes the results of a multi-year, large-scale prairie restoration project established on the Norfolk Sand Plain in southern Ontario.</td>
</tr>
<tr>
<td>Depleted aggregate sites are good candidates for prairie restoration projects due to their ‘open’ nature, sandy substrata, and adaptability to management scenarios.</td>
</tr>
<tr>
<td>The research tested the effect of soil supplements (municipal compost, biochar) and plant symbionts (commercially-available arbuscular mycorrhizal fungi [AMF]) on prairie plant growth and soil rehabilitation.</td>
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<tr>
<td>The research results indicated that:</td>
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<tr>
<td>o Compared to natural site recolonization, sowing plant plugs is an effective strategy for rapid plant biomass development.</td>
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<tr>
<td>o The use of native plant material is essential when restoring grassland habitat in post-mine aggregate sites.</td>
</tr>
<tr>
<td>o The results of this study indicated that the addition of municipal compost, biochar, and mycorrhizal inoculum are simple land management tools that improve plant performance in post-extraction aggregate sites.</td>
</tr>
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<table>
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<tr>
<th><strong>Establishing Alvars Mosses on Quarry</strong></th>
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<tbody>
<tr>
<td>The objective of the research project was to determine how</td>
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<tr>
<td>Specialized habitats - Alvars</td>
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</table>

All types of terrestrial rehabilitation
| Floors: A Necessary Step in the Restoration of Quarries to Alvars | alvar moss species can be successfully established on quarry floors on the assumption that they are an important component of functional alvar plant communities. The research was intended to provide recommendations for simple and affordable methods that could be used to promote and accelerate the establishment of alvar moss species on depleted quarry floors. The research included an analysis of already existing quarry and alvar vegetation survey data and a series of field experiments on how to establish alvar mosses on limestone quarry floors. Soil depth, moisture and degree of exposure are important and potentially modifiable factors that determine the distribution of moss species in alvars and quarries. S. rivulare and T. tortuosa, for example, are the most suited for the initial stages of rehabilitating quarry floors. Potential for water movements and pooling of excess water therefore need to be taken into account in quarry restoration. |
| Best Practice Guidelines for Aggregate Rehabilitation Projects - Extracting the Benefits for Species At Risk and Rare Habitats | A series of best management practices for the restoration and rehabilitation of aggregate sites to achieve the goal of maximizing the biodiversity value while minimizing maintenance costs. Outlines the latest development in rehabilitation planning for species at risk. Provides a checklist and comprehensive information on Alvar, Cliff & Talus, Cultural Meadows and Thicket, Fen, Forest, Marshes, Open or Shallow Waters, Rock Barrens, Sand Barrens and Sand Dunes, Swamp. |
| Environmental Consulting | pre-rehabilitation site considerations  
• Identifies habitat types for potential rehabilitation for species at risk and rare habitats types | • Tallgrass Prairie, Tallgrass Savannah, and Tallgrass Woodlot |
<table>
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<tr>
<th></th>
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<tbody>
<tr>
<td>February 2008</td>
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| **Optimising Ecohydrological Protocols to Enhance Calcareous Wetland Rehabilitation in Abandoned Quarries** | • The objective of the research was to understand the ecohydrological conditions required for the establishment of a wetland type that will readily establish in shallow quarries and along deep quarry shorelines dominated by groundwater seepage: the calcareous fen.  
• The lack of knowledge regarding appropriate water depth, substrate characteristics, and vegetation type, combined with limited resources has often led to the creation of open water/marsh-type ecosystems that have limited biodiversity and habitat value  
• The calcium carbonate-rich groundwater seepages found in some quarries provide the perfect opportunity to investigate the calcareous fen wetland type as a low-cost, self-sustaining ecosystem that is more appropriate for the location, and a valuable societal and natural refuge.  
• Provided protocols for calcareous fen creation derived from scientific field research | • Wetlands  
• Specialized habitats – Calcareous Fen |
| Duval, S., Solondz, D., Waddington, M., Branfireun, B. |                                                 |                                                  |
| September 2009           |                                                 |                                                  |
| **Experimental manipulation of aquatic habitat to:** | • The purpose of the research was to explore using abandoned aggregate sites in an experimental manner to determine the role of aquatic habitat in shaping fish communities, and to identify effective options for reclaiming sites with fisheries potential. | • Aquatic rehabilitation |
| a) determine the role of habitat in shaping fish communities, and  
b) identify effective options for |                                                 |                                                  |
|                         |                                                 |                                                  |
reclaiming sites with fisheries potential

Management of Abandoned Aggregate Properties Program, Aggregate Producers’ Association of Ontario, and Fisheries and Oceans Canada 2004

- Aggregate ponds contain a minimum amount of what is traditionally considered desirable heterogeneous fish habitat
- The addition of habitat structures to aggregate ponds can have a neutral to positive impact on total fish biomass.

6.3 Industry Developed Rehabilitation BMPs and Aggregate Research

The Aggregate Producers Association of Ontario (APAO) (now Ontario Stone, Sand and Gravel Association) has undertaken a number of initiatives to develop operation and rehabilitation BMPs and undertake research. In 2003, a Rehabilitation Workbook was developed by the APAO and its members and is intended to assist operators in understanding the true costs of rehabilitation, as well as to provide technical information on specific rehabilitation techniques. It contains worksheets used to calculate the costs of rehabilitation for operators and case studies, which expressed information on certain best management practices. The workbook also outlines necessary processes for slope creation, floor preparation, overburden replacement, soil replacement and revegetation such as the following:

- To ensure an adequate rooting medium, a minimum of topsoil overlying subsoil is generally 15cm; however, a depth of 20-25 cm is preferred.
- Contour and grade overburden to a 1-2% slope to ensure proper surface drainage.
- Deep rip the pit floor in two directions to alleviate any soil compaction.
- Spread paper biosolids on the area under rehabilitation with a small dozer or manure spreader at a maximum rate of 125 tonnes per hectare and work the paper biosolids into the soil by plowing or diskng.
- Strip topsoil, subsoil and overburden in separate stages and store the materials separately.
• Generally, a minimum of 1 metre of overburden is recommended over the pit or quarry floor to ensure that there is at least one metre of material above the water table.

• Generally, 30 cm is the minimum subsoil depth recommended.

• Once the subsoil is placed at the desired depth, it should be ripped or chisel plowed to reduce soil compaction.

• Agricultural lime is used to raise soil pH where acidity is a problem and can be used to establish a cover crop or an initial planting or to correct acidity caused by organic matter.

• Adding organic matter to the soil prior to planting is helpful if it can be mixed throughout the topsoil layer and if it is not “fresh” and subject to heating up through composting actions.

• Organic matter promotes drainage, is a source of slow release nutrients and increases water holding capacity of soils – it is the most important soil additive.

• Compost is a source of slow release nutrients and is a relatively dry material.

A 2002, paper titled *An Evolution of Reclamation Approaches Through the Life of a Southern Ontario Gravel Pit* (Kevin D. Trimble, ESG International Inc., Monique Seibert, Lafarge Canada Inc.) summarizes a series of changes in both the local landscape setting as well as in the approaches to rehabilitation during the life of the pit in Uxbridge, Ontario. The paper discusses changes in rehabilitation objectives and approaches over the 30-year life space of the pit and introduces the concept of “Cumulative Rehabilitation”.

Several innovative rehabilitation approaches and techniques were utilized at the Lafarge site including:

• Experiments with transferred forest plugs
• An experimental planting program to assess seedling survival rate in drought conditions and with competing groundcover vegetation
• Grading to mimic hummocky topography, rather than slopes of 3:1
• Cumulative Rehabilitation and Ecosystem Design with adjacent extraction areas

The paper demonstrates two increasingly important practices in aggregate extraction operations:

1. The presentation of advancements in technologies for the education of agencies and public stakeholders; and,
2. The application of cumulative rehabilitation to achieve regional environmental goals by including numerous licensed operations in ecosystem based design.
The article *Quarry Rehabilitation - Cliffs, Landforms and Ecology*, by Yundt and Lowe, presented at the 26th Annual British Columbia Mine Reclamation Symposium in Dawson Creek, BC, in 2002. The paper discusses the ecological, aesthetic and social values of introducing naturalized cliff landforms as part of quarry rehabilitation with specific reference to the Milton Quarry.

A program of Biodiversity Conservation through Quarry Rehabilitation was initiated at the Milton Quarry in the mid-1980’s by Holcim. This came about as a result of Holcim’s membership in the Cement Sustainability Initiative, an association of 24 major cement producers with operations in more than 100 countries. Holcim’s program is multi-faceted, and includes assessing impacts of operations on biodiversity, addressing sustainability factors, working with local partners, resource conservation/recycling, monitoring/reporting, communications and outreach.

At Milton Quarry:

Through proper rehabilitation planning, the Milton Quarry now includes natural heritage systems that have both biodiversity and recreational value. The original quarry site has been rehabilitated to a park setting with open areas and two baseball diamonds. The goal of the rehabilitation plan is to design a naturalized landscape with ecological diversity, compatible with the Niagara Escarpment surroundings and include public and private recreational opportunities.

Through an extensive ongoing quarry rehabilitation project the restored landscape now features extensive naturalized water bodies with varying shorelines, wetlands, wooded upland margins and slopes, open space, an education center with access to the Bruce Trail network and many kilometers of cliff face. The Milton quarry was the first site in Ontario that was allowed to leave exposed cliff faces as part of the rehabilitation process. The vertical faces are designed to duplicate the naturally exposed faces of the Niagara Escarpment. The rehabilitation design promotes a diversity of habitats with many plant and animal communities.

The program has led both economic and ecological beneficial outcomes:

7 Stakeholder Identification & Outreach

Throughout the development of the Best Management Practices guidance documents, the following stakeholders will be included in the review of the BMP’s and will be asked to provide comments and feedback on the draft BMPs. The following reference information will be used to develop the BMP guidance documents.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Rehabilitation End-Use</th>
<th>Information Provided/Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallgrass Ontario</td>
<td>• Meadow and Prairie Habitat Enhancement</td>
<td>• <em>A Landowner's Guide to Tallgrass Prairie and</em></td>
</tr>
</tbody>
</table>

MHBC
Identified Rehabilitation End-Uses & Next Steps

Based on the review undertaken in this Report, Table 6 identifies the following rehabilitation end-uses appropriate for pits and quarries in Ontario.
Table 6: Identified Rehabilitation End-Uses

<table>
<thead>
<tr>
<th>Rehabilitation End-Use Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Aquaculture / Fisheries</strong></td>
<td>Rehabilitation of pits and quarries for commercial production of fish.</td>
</tr>
<tr>
<td><strong>2. Managed Forest</strong></td>
<td>Rehabilitation to forest for the purposes of the commercial production of forest products (i.e. timber, maple syrup, Christmas Trees)</td>
</tr>
<tr>
<td><strong>3. Woodlands for Conservation</strong></td>
<td>Rehabilitation to forest for conservation purposes with the primary objective of providing ecological benefits and functions, such as biodiversity, wildlife habitat, and passive recreation.</td>
</tr>
<tr>
<td><strong>4. Grasslands / Early Successional Habitat</strong></td>
<td>Rehabilitation to open communities of grasses and wildflowers with few trees that provided habitat for pollinators such as bees, butterflies, moths, and other insects</td>
</tr>
<tr>
<td><strong>5. Aquatic Rehabilitation</strong></td>
<td>Rehabilitation to an aquatic feature such as a pond, wetland, or floodplain that provides ecosystem benefits and functions such as flood attenuation, specialized wildlife habitat, improved water quality, recreation opportunities</td>
</tr>
<tr>
<td><strong>6. Rock Outcrops</strong></td>
<td>Rehabilitation to bare rock outcrops, including Cliffs &amp; Talus, Alvars, and Rock Barrens that provide specialized habitat for wildlife and plant species</td>
</tr>
</tbody>
</table>

The next phase of this project will build on the information collected and summarized in the Literature Review and Background Report and identify the **Strengths, Weaknesses, Opportunities, and Threats (SWOT/Gap Analysis)** for aggregate rehabilitation. The key findings from the Literature and Background Review will incorporated into the SWOT/Gap Analysis.

This analysis will determine which end-uses require the development of new or updated BMPs.
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King, H., 2013. *Introducing an ecosystem services approach to quarry restoration*. Cranfield University, Cranfield. Available at: [https://dspace.lib.cranfield.ac.uk/bitstream/handle/1826/8024/Ecosystem_services_quarryrestoration_report-2013.pdf?sequence=1](https://dspace.lib.cranfield.ac.uk/bitstream/handle/1826/8024/Ecosystem_services_quarryrestoration_report-2013.pdf?sequence=1)


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University of Minnesota, Wildlife Values of Gravel Pits, Miscellaneous Publication 17, 1982. Available at: [https://conservancy.umn.edu/bitstream/handle/11299/112621/1/MiscP17.pdf](https://conservancy.umn.edu/bitstream/handle/11299/112621/1/MiscP17.pdf)


Appendix A - Case Studies
Case-Study #1 – Recreation and Aquatic Habitat Enhancement, Milton Limestone Quarry (Kelson Quarry Park), Town of Milton

Location: 5529 Steeles Avenue West, Milton Ontario

ARA Licence Status: Surrendered

Size: 71 ha

Site Overview:

The Milton Limestone Quarry is a 71 hectare formerly licensed area located within the Niagara Escarpment Plan Area, in the Town of Milton. The quarry was opened in 1958 to provide materials for the construction of Highway #401. Due to the ideal location of the quarry a short distance from Toronto, this extraction operation provided millions of tonnes of high quality Amabel dolostone to Canada’s largest market. The quarry operated for over 40 years, until ceasing operations in 2001. After closing in 2001, Barrick Gold Corporation, in partnership with Conservation Halton undertook extensive rehabilitation efforts. The site also includes ecologically significant natural forest and cliffs that were protected from extraction and includes an old-growth forest of eastern white cedar.

Because of the location of the quarry adjacent to over a thousand hectares of land already in Public Ownership, a short distance from the GTA, and within the Niagara Escarpment Plan Area, the former quarry was a prime opportunity to establish a public conservation and recreation area and contribute to the natural features and recreation values of the Niagara Escarpment Plan Area.

In the mid-1990s a partnership was struck between Barrick Gold Corporation and Conservation Halton, to rehabilitate the quarry for recreational and conservation purposes. An innovative part of the agreement between Conservation Halton and
Barrick Gold was to modify the final rehabilitation plan to accommodate Conservation Halton’s wishes for a recreational lake, while still meeting the requirements in the Site Plans approved under the Aggregate Resources Act. In 2006 Barrick Gold completed their rehabilitation requirements under the Aggregate Resources Act and donated the rehabilitated quarry and adjacent 700m of natural forest and cliff habitat to Conservation Halton. Since 2006, Conservation Halton has undergone additional rehabilitation efforts including:

- The planting of 4000 native trees, shrubs and wetland plants as part of Conservation Halton’s Trees for Watershed Health Program;
- Fish and wildlife habitat enhancement funded by the Federal Department of Fisheries and Oceans Recreation Fisheries Conservation Partnership Program

Rehabilitation End-Use

Cliff faces, lake, wetland, forest habitat and public access/recreation

5-meter deep lakes with a beach areas as well as a shallow areas with shoals for fish spawning, a wetland areas with native aquatic plants which provide waterfowl and fish habitat. Lands surrounding the lake have been reforested with native trees and shrubs, which over time will spread and naturalize the slopes.

Rehabilitation Practices and Techniques

The objective of the quarry rehabilitation was to develop a naturalized landscape that is compatible with the surroundings, ecologically productive and of recreational value to present and future generations.

Quarry Rehabilitation has been undertaken in three primary phases of Ecological Restoration:

1. Landscape Structure
2. Vegetation Establishment & Reforestation
3. Fish and Wildlife habitat creation

Rehabilitation for recreational uses include, the creation of beaches along the lakeshore for swimming, trails for hiking, and the establishment of park infrastructure such as parking and washroom facilities is planned for the future.

1. Landscape Structure
• Since the 1970’s the quarry has undergone progressive rehabilitation, including the sloping of the east cliffs which were then planted with grassed and native trees.
• The early extracted quarry faces were backfilled conventionally from top to bottom using native soil and imported clean fill to create 2:1 and 3:1 slopes.
• The west quarry face, which was more recently extracted was left as a cliff rather than backfilled.
• The lakes floor was designed to include shallow areas for aquatic habitat and also areas for future public beaches and swimming.

2. Vegetation Establishment and Reforestation
• Several grass and legume mixtures were used by Barrick Gold to stabilize the slopes and quarry floor, and planted native trees on the slopes including MTO standard Roadside groundcover mix, MTO Mixture with Crown Vetch added, and an all-purpose Park Mixture.
• Since 2006, Conservation Halton has added about 5,000 native trees and shrubs, 6 kilograms of tree nuts and wetland seeds and 3500 wetland plants.

3. Fish and Wildlife Habitat Creation
• Since the transfer of lands to Conservation Habitat, additional restoration work has occurred to help establish a future recreational fishery within Kelso Quarry Lakes.
• 4,000m³ of new spawning shoals have been constructed.
• 7 large fish habitat structures have been placed in the lake.
• Large floating wildlife logs have been added; and,
• Additional native aquatic and riparian vegetation has been planted and seeded.

Next Steps and Long-Term Management

Conservation Halton will undertake trial fish stocking in the lake between 2016 and 2017, in addition to, ongoing evaluation and enhancement of fish shoals. Biological inventories have also occurred on the property since 2002. The management and control of invasive species such as Common Phragmites is also an ongoing priority. Conservation Halton is currently working to update their Park Master Plan for Kelso Conservation Area and Glen Eden which will outline strategic management direction for infrastructure operations and environmental conservation.
Innovative Rehabilitation Practices

The quarry rehabilitation was especially innovative in the approach taken to cliff and slope creation to create varied landforms and the configuration of the quarry floor to create a 5-meter deep lake that is suitable for swimming. In addition, the former quarry is surrounded by adjacent conservation lands including the Kelso-Glen Eden Conservation Areas and will provide habitat connectivity and linkages with the surrounding natural areas of the escarpment. The recreational trails running along the west edge of the property are connected to the Bruce Trail.

References:


Case-Study #2 – Floodplain and Aquatic Habitat Enhancement, Snyder’s Flats, Bloomingdale

Location: Snyder's Flats Road, west of Sawmill Road near the village of Bloomingdale in Woolwich Township.

ARA Licence Status: Surrendered

Size: 96.5ha

Site Overview:

From farmland to aggregate pit to valuable wildlife habitats, the Snyder’s Flats property has evolved into a diverse ecological landscape. Snyder’s Flats is located directly across the Grand River from the urban centres of Kitchener and Waterloo. It is a former gravel pit that has been restored to a natural area and recreation area and is now a Conservation Area owned and managed by the Grand River Conservation Authority (GRCA).

The site was originally owned by the Snyder Family who cleared and farmed the land in the late 1800’s through to the 1960’s. In 1969 the Grand River Conservation Authority purchased the Snyder Flats property as part of the K-W Lands Acquisition Program which had the objective of reducing flooding & erosion risks along the Grand River. In the late 1970’s the site was identified as a source of high quality aggregate. 1979, the GRCA entered into an agreement with Preston Sand and

Gravel to extract sand and gravel from the Snyder’s Flats property with a long-term vision for future rehabilitation of the area to a naturalized wetland and floodplain habitat. This collaborative approach was modelled as an “environmentally friendly” method of aggregate extraction. Aggregate extraction above the water table occurred on the property for about 8 years. In 1987, high quality aggregate resources were determined to be located below the water table which facilitated the advancement of the Snyder’s
Flats Rehabilitation Plan. The primary rehabilitation objective of the property was to create various aquatic and floodplain features.

The Snyder’s Flats project is an attempt to recreate lost floodplain habitat, features and functions. The Snyder’s Flats Rehabilitation Project has created more than 17ha of floodplain habitat and about 5km of shoreline.

**Rehabilitation End-Use**

Natural area with ponds habitat, reforestation, grasslands, and public access/recreation

5-meter deep lakes with a beach areas as well as a shallow areas with shoals for fish spawning, a wetland areas with native aquatic plants which provide waterfowl and fish habitat. Lands surrounding the lake have been reforested with native trees and shrubs, which over time will spread and naturalize the slopes.

The floodplain rehabilitation of the site included the construction of five main aquatic zones:

- The floodplain channel,
- The north floodplain pool,
- The south floodplain pool and wetland complex; and
- The cool water habitat and the warm water habitat.

Snyder’s Flats also includes passive recreational opportunities including 4.5 km of trail system for walking/hiking, biking, birdwatching, and fishing. The close proximity of the property to the urban centres of Kitchener and Waterloo make it a very attractive destination

**Rehabilitation Practices and Techniques**

The majority of rehabilitation activities occurred between 1991 and 1995, once extraction was completed.

1. **Landscape Structure**

   - Construction of the coolwater pond in 1989 including the installation of an inlet control structures and weirs to direct flow from the Grand River and control water elevation.
   - Construction of the floodplain channel
   - Linking of the floodplain channel to the south floodplain pool.
• To break up wind gusts that would cause thermal mixing of the pond, vegetated finger projections were constructed during extraction activities.
• Installation of soil bioengineering structures including live crib walls, live fascines, and brush layers for erosion control.
• Extraction of the warm water pond and spring inundation from the Grand River which introduced numerous fish species.

2. Vegetation Establishment and Reforestation

• In 1995, the area around the warm water pond was frost seeded with a mixture of legumes and grasses.
• Between 2009-2011, about 11,000 trees were planted with additional tree pruning and replanting occurring in 2011.

3. Fish and Wildlife Habitat Creation

• The creation of a 3.8 ha floodplain pool, with 1,620m of shoreline. Seasonal flooding from the Grand River has introduced many species of fish, including: Largemouth Bass, Smallmouth Bass, Black Crappie, Northern Pike, Yellow Perch, Pumpkinseed, suckers and many species of minnows.
• The warm water pond is 9.6ha in size with 1,640m of shoreline and has been designed to allow flooding during the spring and fall. This pond will contribute to the fishery in the Grand River, as fish return to the river when water levels rise again in the fall. Species such as Largemouth Bass, Smallmouth Bass, Northern Pike, Pumpkinseed and minnows have been recorded in the warmwater pond during fisheries inventories.
• The coldwater pond has been isolated from other aquatic features and is 3.6ha in size with 1,120m of shoreline. The original intent of the coldwater pond was to establish habitat for coolwater fish; however, the pond does not receive sufficient inputs of groundwater and is better suited for warmwater species.
• The area of the property that has been re-forested provides early-successional meadow habitat to a number of bird and wildlife species.

Next Steps and Long-Term Management

A comprehensive hydrogeology and natural heritage features plan was completed in 1988, prior to the floodplain and wetland restoration work to collect baseline data.
Rehabilitation began in 1995, once aggregate extraction was completed and has been monitored since that time to assess the establishment of the newly created aquatic habitats.

Biological inventories were completed in 2014-2018 to assess the past 15 years of rehabilitation efforts. A total of 15 distinct terrestrial ecological communities were identified, 150 bird species, 33 species of fish, four amphibian species and numerous incidental wildlife observations.

A Park Management Plan was developed in 2016 and outlines the goals, objectives, and long-term management priorities for the property. Ongoing monitoring has occurred since 1988 and ongoing monitoring is a key recommendation of the Park Management Plan. Invasive species monitoring and management is also a key priority outline in the Management Plan.

Innovative Rehabilitation Practices

Snyder’s Flats represents an example of habitat restoration techniques through an innovative approach to gravel extraction. Through the Rehabilitation Planning process, below the water table aggregate extraction was permitted with the long-term goal of creating specialized aquatic and terrestrial habitat on the property.

Through the Snyder’s Flats rehabilitation plan, gravel extraction was permitted with the vision of modeling an innovative approach that would lead to the creation of productive aquatic and terrestrial habitat.

Rehabilitation involved the partnership of numerous organization to provide rehabilitation funding, expertise, and volunteers for tree planting, trail development, and invasive species control.

References

**Case-Study #3 - Aquaculture and Aquatic Habitat Enhancement, CBM McMillian Pit, Aberfoyle**

**Location:** Concession #2, Aberfoyle, Ontario, Puslinch

**ARA Licence Status:** Active

**Size:** 24 ha

**Site Overview:**

The McMillian Pit is in the Township of Puslinch on a major outwash deposit that provides high quality aggregate products to the western GTA market. CBM/St. Mary’s, and its predecessors TCG Materials and Blue Circle Aggregates, extracted this 88 acre site between 1986 and 2006. The site yielded over 5 million tonnes of aggregate materials that were used for high strength concrete products and road building.

The rehabilitation of this site was completed in 2008 and included the creation of a 50 acre lake. The side slopes of the pit were seeded and wetland plantings occurred along the shoreline in 2008, but did not take. After 5 years, there was little riparian and wetland vegetation establishing along the shoreline of the lake. In addition, there was very little life in waters of the lake and cobbles were clearly visible in over twenty feet of water.

Due to the cold, clear, nutrient poor waters of the lake, rainbow trout were seen as a viable fish species to introduce to add some biological activity in the lake and shoreline. Rainbow trout are very adaptable fish that need cold clean water to thrive.

A local fish hatchery suggested that the high quality waters in the lake could support commercial fish production. The commercial fish production in the lake would generate revenue, but would also be a method of introducing naturally occurring nutrients into the lake water to “kick-start” the lakes biological processes.
An aquaculture License was obtained from the MNRF and a pilot project was initiated in 2014 using new aquaculture technology from the southern United States that was adapted to the CBM site. This technology allowed fish to be raised in contained, floating structures and did not require any water pumping or water discharge. This aquaculture system of “floating raceways” could be used to add nutrients to the pond from the production of fish, which in turn, would help the lake ecosystem develop. This technology also allowed for the collection of fish waste which could then be used as terrestrial fertilizer and compost on adjacent aggregate rehabilitation projects.

Three years into the project, the nutrient input from the fish production has quickly brought the portion of the pond closest to “floating raceways” to life. The aquatic vegetation around the shoreline is taking off, algae and diatoms are visible in the water, and wildlife is beginning to use the area, including migratory birds, a nesting pair of loons, and bald eagles.

Bluegills and golden shiners have been introduced to the lakes are doing well. Other minnow species are also finding the pond on their own. In the first year there were only fat head minnows stickle backs and northern red bellied dace in the pond and now there are at least three other minnow species that arrived on their own. There have also been some escaped rainbow trout in the lake and there is evidence that they have spawned successfully in the pond. It is believed they have used the springs on the bottom to successfully incubate their eggs.

**Rehabilitation End-Use**

The final rehabilitation plan for the McMillian Pit is a naturalized lake and productive wetland ecosystem. A controlled rainbow trout aquaculture system has been used in the lake to generate revenue and add nutrients into the lake water to kick start natural ecosystem processes.

**Rehabilitation Practices and Techniques**

The majority of rehabilitation activities occurred between 2006 and 2008, once extraction was completed.

1. **Landscape Structure**

A required by the rehabilitation plan, 3:1 slopes were created above the water and a 2:1 slopes below the water table.
In the south end of the property were the resources was not as deep, a shallow contoured area was established to provide the base for a wetland and shallow pond complex. There are also three areas along the west side of the pond that had limited reserves that have been contoured to create shallow water habitat. Overburden and topsoil has been spread over the dry, side-slope areas.

2. Vegetation Establishment and Reforestation

- Side slopes seeded with a grass mixture
- Wetland planting has occurred in shallow areas of the lake
- Nodal plantings of aquatic plants including water lily and elodea
- With the input of nutrients from the aquaculture aquatic vegetation including pond weed and milfoil have flourished.

3. Fish and Wildlife Habitat Creation

- In 2013, the lake was determined to be very nutrient poor, but with exceptionally cold, clean water quality (drinking water standard). Minimal “life” was establishing in the pond due to low nutrient levels. Originally, only a few minnows were observed in the lake in 2013.
- A self-contained aquaculture pilot project was started in 2014, in an effort to introduce naturally occurring nutrients into the lake in a controlled manner.
- The increased nutrient load introduced from the aquaculture system has accelerated aquatic and shoreline vegetation growth and has helped to establish a sediment and nutrient substrate to allow future development of the ponds.
- Golden shiners and bluegills have been introduced to the lake and other minnow species have arrived on their own.

Next Steps and Long-Term Management

- Routine water monitoring for phosphorus, ammonia, and oxygen levels occurs daily throughout the year to ensure that the water quality in the lake is maintained well within Provincial Water quality standards.
- Nutrient levels are monitored using secchi disc readings regularly through the ice free season. The target is to maintain readings in excess of 2m.
- Visual monitoring of vegetation occurs regularly and incidental wildlife observations are recorded.
• There are future plans to expand these types of aquaculture systems to other sites to enhance aquatic rehabilitation and support local agricultural business opportunities.

Innovative Rehabilitation Practices

A self-contained aquaculture system was used to introduce a naturally occurring source of nutrients to a sterile lake environment in order to boost ecosystem function of the lake and wetland environments.

The aquaculture system has aided the rehabilitation objective of creating naturalized aquatic and wetland habitat while also generating a source of revenue. Marketable fish are sold from the aquaculture system, which supports 2 full-time jobs and 1 part time job. In addition, the excess waste from the aquaculture system is used as a source of organic fertilizer at nearby pit rehabilitation projects.

References

Information and photos provided by:

Stephen May
Votorantim Cimentos
CBM Aggregates | Lands Manager - Western Region
St Marys Cement Inc. Canada
**Case-Study #4 - Reforestation and Woodland Enhancement, Walkers Duntroon Quarry Expansion**

**Location:** Simcoe County Rd. 91, Duntroon

**ARA Licence Status:** Active

**Size:** Quarry Expansion 65.93ha, existing quarry 57.5ha, area to be rehabilitated approximately 52.4 hectares.

**Site Overview:**

The Duntroon quarry expansion is an example of how rehabilitation can occur outside, as well as within, a Licence Boundary to off-set the ecological impacts of aggregate extraction.

The quarry expansion is located in a well forested landscape that includes a large contiguous woodland. This contiguous woodland supports interior forest habitat, species that prefer large connected forest blocks and landscape linkages. The Expansion required the removal of approximately 26.7 ha of woodland. In order to avoid reducing the ecological functions of the large contiguous woodland, approximately 52 ha of woodland will have been replanted beyond the extraction area and a further 8 ha will be established through progressive and final rehabilitation.

As part of the quarry expansion, soil is being moved from the forested expansion area to the existing quarry floor as part of rehabilitation efforts for the existing quarry. In addition, a four-year research study has been initiated to determine the best way to re-create the habitat conditions, including understory vegetation, of the natural forest.

In conjunction with the reforestation and pond enhancement plan, an Ecological Enhancement and Mitigation Monitoring (EEMM) program was developed to track the ecological progress of the reforested area and pond enhancements and to compare the ecological characteristics to established targets for ecological form and function.

The reforestation plan will replace the forest cover on pasture lands in the adjacent landscape. The reforestation and woodland enhancement includes:
• An increase the total area of woodlands cover in the landscape;
• Improvement associated with landscape functions such as vegetative linkages and interior forest areas;
• Improvement to forest ecological characteristics such as species diversity and age-class distribution;
• The incorporation of specific wildlife habitat features such as snag trees, nesting structures, bat hibernacula, and small scale vernal pools;
• The enhancement of vernal pool habitat associated with a wetland by creating depressions in the reforested area west of the wetlands that will provide areas of standing water in the spring to support amphibian breeding and larval development, and;
• The introduction of management perspectives and land ownership patterns focused on establishing and maintaining a wide range of ecological services from the forest, including public access.

The objectives of the woodland rehabilitation and enhancement are to:

• Establish a healthy woodlot with enhanced species diversity, understory and wildlife habitat;
• Use small-scale topographic variation and natural drainage patterns, combined with species selection, to encourage variable forest floor ecology;
• Create and strengthen forest linkages to enhance existing landscape functions including the Niagara Escarpment Linkages; and,
• Provide long-term gain in natural heritage functions.

Rehabilitation Practices and Techniques

The goal of the Forest Restoration Plan is to implement an ecologically sound approach to reforestation on lands adjacent to the proposed extraction area, in order to mitigate the loss of forest within the proposed extraction area. Both the existing quarry and quarry expansion will ultimately be rehabilitated to a naturalized lake within a forest complex.
The goal of the Reforestation program is not just replace the forest habitat features but to achieve a net gain in the ecological functions of the forested landscape.

1. Landscape Structure
   - The revegetated areas are to be graded with imperfect drainage depressions
   - Topsoil relocated from the forested areas that will be extracted will be placed in a 1.5-2.0 windrow.
   - Clusters of stumps, boulders, or brush piles are to be placed in the windrows.

2. Vegetation Establishment and Reforestation
   - All new plantings will consist of a broad diversity of native trees, including up to 30 softwood and hardwood species.
   - The woodland program was initiated in 2015, with the planting of 13,000 trees.
   - Reforestation will consist of seeding and planting
   - The Planting list includes 13,000 deciduous whips, 13,000 deciduous seedlings, and 15,500 coniferous seedlings for a total of 41,500 plantings.

3. Fish and Wildlife Habitat Creation
   - Specific wildlife habitat features such as snag trees, nesting structures, hibernacula, and small scale vernal pools are incorporated into the reforestation design plan;
   - Vernal pools will be creating depressions in the reforested areas to provide areas of standing water in the spring to support amphibian breeding and larval development; and
   - Kestrel boxes are placed in the reforested windrows.

Next Steps and Long-Term Management

The ecological enhancement and mitigation monitoring plan is included as part of the Adaptive Management Plan.

The purpose of the Ecological Enhancement and Mitigation Monitoring (EEMM) program is to track the ecological development of the reforested areas and pond enhancements and to compare the ecological characteristics to established targets for ecological form and function.
The objective of the EEMM Program is to properly implement mitigation measures (e.g. ensure that an appropriate number and species of trees are planted) and manage the resulting features in adaptation with changing conditions and trends (e.g. replanting for dead trees, controlling pest damage, controlling/allowing public access, etc.) for enhancements to the natural features.

**Innovative Rehabilitation Practices**

This rehabilitation project is creating new forest and woodland habitat on agricultural fields. The reforestation of the quarry expansion lands is being studied to determine how quickly and old-growth forest can be created through afforestation.

**References**


Paul Richardson, Research Associate & Adjunct Professor, School of Environment, Resources and Sustainability (SERS), Faculty of Environment, University of Waterloo,
Study #5 – Reforestation and Woodland Enhancement, Clinton Pit, Clinton, Ontario

Location: 80897 Sharpes Road Creek Line, County Road 31, Clinton

ARA Licence Status: Active

Size: 27 ha

Site Overview:

The licenced area of 22.2 ha includes a significant woodland known as Forest Patch 38, that is approximately 19.3ha in size. About 14.9 ha of the forest patch will be sequentially removed and extracted in a total of four phases. Associated with this sequential forest removal is a progressive Woodlot Rehabilitation and Restoration Plan which has been incorporated into the ARA Site Plans and Site Plan Notes.

Jennison Construction Ltd. (the Operator) is required to demonstrate that rehabilitation is being undertaken in accordance with the Restoration Plan on an ongoing basis throughout the life of the pit operation and through the post closure period. This will be accomplished through the monitoring program and annual reporting. Ministry of Natural Resources and Forestry approval is required for each phase of the extraction and is contingent upon the success of each phase of forest restoration. If the prescribed success parameters of the Woodlot Rehabilitation and Restoration Plan are not met, then extraction cannot proceed to the next extraction phase.

The existing forested area that will be removed for extraction will be totally replaced and an additional 1.8 ha to the immediate south of the proposed licenced area will also be restored with a mixture of hardwood trees.

The end result after the complete extraction of the gravel pit and the final reforestation and rehabilitation will increase the total forest cover of Forest Patch 38 of about 10.3 percent which represents an overall enhancement to the size and forest cover of the woodland.
Forest functions will be restored through implementation of the Woodlot Rehabilitation and Restoration Plan. The objectives of the Woodland Rehabilitation and Restoration Plan are:

- To establish a climax forest woodland community similar to the existing tableland woodlot (FODM5-1) throughout the JCL property through a process of forest ecological restoration.
- To maintain the interior forest habitat and diversity functions of Forest Patch #38, and minimize the loss of these functions on the JCL property, through a phased extraction and progressive forest ecological restoration approach.
- To maintain the buffer function of the existing tableland forest in order to protect the core form and function of Forest Patch #38 in the Maitland Valley.
- Accelerate the natural succession processes in the Enhancement Areas in the south portion of the property as that area converts to forested land, thereby increasing the area of forested lands in the Lower Maitland sub-watershed over the long term.
- To monitor, assess and manage the implementation of the Plan to ensure these objectives are met.

Forest ecological restoration is intended to accelerate natural succession, achieve a desirable species mix and a basal area comparable to pre-extraction conditions. Ecological Restoration combines recognized woodland restoration techniques with ecological and biodiversity targets, and accelerates natural succession through adaptive management.

**Rehabilitation End-Use**

The re-establishment and improvement of the Significant Woodland.

**Rehabilitation Practices and Techniques**

1. **Landscape Structure**

   - Forest soils will be moved as intact as possible and efforts will be made to retain soil horizons. The Woodlot Rehabilitation and Restoration Plan includes the removal, preservation and re-establishment of the forest soils, organic structures and seed bed.
Large amounts of woody debris and the upper soil horizons are used in rehabilitation. The final grading of the pit floor is to replicate undisturbed forest floor conditions reflective of diverse micro-topography which includes hummocks and depressions to encourage a variety of moisture conditions, habitats, slopes and aspects as well as enhancing infiltration.

2. Vegetation Establishment and Reforestation

- In 2014, the South West Enhancement area, the Borrow Pit and the Buffer Triangle were infilled with 2,000 bareroot seedlings. The infilling was carried out to increase stocking in scattered gaps, to improve plant richness by adding a shrub and several under-represented tree species and to continue to build canopy closure.
- Invasive species controls were also undertaken to continue the eradication of common buckthorn and the reduction of garlic mustard.
- The tree and shrub barefoot seedlings will be hand planted in a random pattern.
- Tree species include: sugar maple, red-osier dogwood, hackberry, silver maple, red oak, black cherry, white pine, and hybrid poplar.
- Randomly hand plant tree and shrub nuts
- Use of forest soils and its stored seed bed in the forest ecological restoration.

Innovative Rehabilitation Practices

The Licensed portion of Forest Patch 38 will be gradually cleared in incremental phases over the life of the Clinton Pit, so as to retain the forest interior and core functions for as long as possible.

This phased extraction approach and progressive Ecological Restoration strategy will:

- Minimize losses of forest cover over the long term;
- Maintain the main body and core functions (interior habitat and diversity) of Forest Patch #38;
- Maintain buffer; and,
- Increase the rate of recovery during restoration.

In addition, prior to extraction, the forested area within the extraction area will be actively managed during operation of the pit to reduce the presence of invasive species, improve forest growth and quality and maximize the production of high-quality timber, stimulate the regeneration on the forest floor and increase the diversity if the seed bed.
Ultimately, the phased approach and progressive forest ecological restoration strategy will ensure that temporary losses of forest cover will be offset, and the main body and ecological functions of Forest Patch #38 along the valley corridor will be maintained over the long-term.

**Next Steps and Long-Term Management**

Enhancement areas were established in the first year of the pit operation to establish test plots to allow the evaluation of forest removal, soil handling and ecosystem rehabilitation. The test plots provided preliminary results in seed bed and seed rain contributions, species adaptability, vegetative growth and will continue to further guide the planned forest ecological rehabilitation.

The Woodlot Rehabilitation and Restoration Plan requires annual, then three and five year evaluations of the success of the reforestation and the demonstration of success is a precondition to moving to the next phase of extraction.

In keeping with the adaptive management approach, recommended revisions to the rehabilitation methods will be documented in the annual reports. Monitoring and reporting must be supervised by a Registered Professional Forester or Ecologist with experience in ecological restoration. Monitoring results will be analyzed and summarized in reports that will be prepared and submitted to the Ministry of Natural Resources & Forests and other agencies as appropriate for review on an annual basis.

MNRF approval is required prior to extraction proceeding to the subsequent Phase of operations in accordance with the Site Plan. Each rehabilitation phase must successfully demonstrate specific characteristics of forest succession, before extraction in the next phase can occur.

**References**


Appendix B – Scientific Literature Review
Scientific Literature Review

1. Method of the Review

Records of recent peer-reviewed scientific studies relevant to rehabilitation of aggregate extraction sites were searched for and obtained using Web of Science. Advanced search options were used in conjunction with access to University of Waterloo library databases and holdings, and the search was constrained to journal articles published since January 1, 2007. The main search was for works containing keywords related to both opencast mining sites (e.g. “quarr*” OR “gravel pit*” OR “sand pit*” OR “surface mine” OR “opencast” OR “extraction”, etc.) and ecological restoration (e.g. “ecolog*” OR “restor*” OR “rehabilit*” OR “reclaim*” OR “reclamation”, etc.). This returned approximately 1400 records, which we reduced to 506 by limiting results to results from databases aligned with ecological, environmental, geological or engineering research. The 506 articles were sorted and ranked subjectively by perceived relevance based on the title of the article, the journal, and the content of the abstract. Iterative reassessments of each record enabled weeding-out of less-relevant studies and highlighting those likely to offer insight on forward-looking best management practices, in the spirit of the MNRF’s Request for Consulting Services. This process resulted in a compilation of 362 “relevant” articles, with a subset of 156 “highly relevant” papers which eventually became the tagged bibliography and the subject of the in-depth literature review.

Full-text versions of the articles were acquired and read as needed, and each article was classified according to the type of study (experimental, observational-comparative, modelling or review), the country the study took place in, and the type of extraction site that the work was most relevant to (either “aggregate”, i.e. mineral sand, stone or gravel extraction, or “other opencast”, e.g. surface gypsum, lignite, and coal mines). While the goal of the review is to help develop best management practices for aggregate sites, other surface mine sites can face similar constraints and opportunities, with innovative approaches that are successful at other opencast mines potentially transferrable to aggregate sites. Nevertheless, the key findings of the review presented below are largely constrained to the majority subset of study sites, which were on aggregate-extracted lands.

As the number of articles was too great to annotate each one, we determined that a “tagged” bibliography would be most useful, providing a comprehensive resource list that is easily sortable and searchable according to the major “themes” of the research, which are related to the objectives of the work that the domains in which useful lessons from the research are likely to be derived. Further iterative analyses of each paper thus provided for tagging of each entry with terms identifying greatest values of the research, eventually these were consolidated to suite of 15 themes that could apply to the studies. The bibliography presented in the appendix presents each article’s citation information;
the study location, type of extraction site and type of study; a link to access the article online; a copy of the published article abstract; and the list the list of rehabilitation themes applicable to the research.

2. Results of the Review

Geographical Scope

While the geographical scope of the literature search was global, the final list of highly relevant studies was strongly clustered into several main jurisdictions. The greatest number of articles came from the Czech Republic (N=25), followed closely by Spain (N=24), though each of these can be seen as core blocks in research endeavors dictated more by geological and climatic rather than political boundaries. The Czech research was in keeping with studies from similar ecoregions throughout central Europe, including 3 from Germany, 3 from Poland, 1 from Austria, 2 from Switzerland and 3 which crossed international borders. Likewise, the studies from Spain were consistent with a larger swathe of studies focused on the Mediterranean Basin, including 10 from Italy, 5 from Portugal, 1 from Greece and 3 from the south of France. There were 4 studies from the United Kingdom, 3 from the United States, and 13 from Canada (with N=10 from Ontario). South America was represented by 10 studies (with N=8 from Brazil), while Africa was only featured in 1 (Namibia). Asia was represented by 25 studies (with N=19 from China).

Types of Sites Studied

The types of extraction sites in which rehabilitation activities were studied were classified as either “aggregate” sites, meaning mineral sand, stone or gravel had been extracted, or as “other opencast” sites, meaning some other material had been quarried from the surface (e.g. gypsum). The majority of studies (N=106) focused on aggregate sites, and most of these had experienced some form of limestone extraction. Some of the sites had been for minerals such as marble or basalt, however, while others did not identify the nature of the material extracted. Approximately half of the aggregate studies involved sites where unconsolidated sand and/or gravel had been extracted ("pits"), and half dealt with hard rock extraction ("quarries"). The studies which investigated other opencast extraction sites (N=50), including surface gypsum, coal and lignite mines. The “site type” classification was based on how the authors described their research goals and did not necessarily correspond to a field location, as many studies designed to gain knowledge applicable to a particular field environment are actually conducted under controlled glasshouse or laboratory conditions.

Types of Studies Conducted

Coincidentally, 69 studies happened to be categorized as “experimental” and 69 studies were considered to be “comparative-observational”. For a study to be classified as experimental, it had to include controlled manipulations that were designed with hypothesis-testing in mind. In contrast, comparative-observational studies might simply
involve monitoring the outcome of rehabilitation or succession over time, or might include hypothesis-testing through “after-the-fact” comparisons, e.g. among similar sites that had been exposed to different management regimes historically. A much smaller number of studies were mainly interested in computational modelling (N=9) or reviewed previously published literature (N=10) papers.

**Research Themes**

Each study was tagged with at least one of the 15 short-listed themes that were chosen to identify the main domain, objective or insight of the research, but most studies were associated with more than one theme, with an average of 3.4 themes per scientific article. These thematic categories are as follows, with the number of papers in each group shown in parenthesis.

- **Theme 1: Ecosystem services, climate change, resilience and invasion (N=56)**

  This theme is perhaps the most important one for conceptually positioning aggregate-site rehabilitation to face the future. It corresponds the wider call for restoration ecology to redefine itself for maximum utility in the 21st century and beyond (Martin 2017), rallying behind the notion that the reasons why we might want to restore or create particular ecosystems at a particular location should be considered carefully and with priority relative to jumping directly into what ecosystem we wish to build and how we hope to do it. While the traditional restoration ethos often presumed that the target of restoration must by default be the ecosystem which had been present just prior to degradation, the more modern perspective first considers what variety of ecosystem services could conceivably be provided at a location, and assess through debate with stakeholders the suite of services which would yield the greatest net benefit when accounting for the plethora of interrelated social, economic, cultural and ecological constraints and opportunities. Choices can be difficult and trade-offs must be made, but the range of possibilities is often overlooked. Future-oriented restoration (Choi 2007) must be careful of this. The ecosystem services which are perceived to be most beneficial will change with the place and the time and the project, but at present, managers may seek to establish ecosystem which can:

  A) Adapt, bounce back, or otherwise function stably (i.e. “stay restored”) under the threat of increasing extreme environmental fluctuations (e.g. intense floods, droughts, storms, fires, cold snaps, pest and disease outbreaks);
  B) Provide refuge to biodiversity, including at-risk species and distinctive heritage communities;
  C) Reconnect fragmented remnant ecosystems, or bridge novel ones;
  D) Provide continuous forage and nesting sites that maintain healthy pollinators and wildlife;
  E) Control floods, prevent erosion, recycle nutrients and replenish groundwater;
  F) Store carbon over sufficient time scales to help mitigate global warming;
  G) Prevent or reverse species invasions;
H) Do any or all of the above while simultaneously providing people and human communities with recreational, economic, cultural and/or psycho-spiritual benefits.

There are many technical roads to achieving specific goals under specific constraints once the goals are set, but studies that acknowledge such goals are possible and encourage the debate, or better yet, propose novel ideas for organizing the debate and making decisions, were tagged with this theme. While the Ontario’s Aggregate Resource Act only makes the rather nebulous requirement that rehabilitate extraction sites are compatible with the surrounding land-uses, forward-looking restoration instead seeks to create ecosystems that provide the utmost quality and reliability of services to the surrounding landscape.

- **Theme 2: “Big-picture” planning; landscape & socio-economics (N=60)**

  In some ways this theme overlaps with the first, and indeed, many studies were associated with both. The distinguishing feature of this second theme, though, is that it tends to involve the mechanics of landscape-scale environmental planning, such as comprehensive rehabilitation planning for multiple sites in the same region, or managing credit-trading systems in biodiversity-offset or ecosystem-service markets (Weber, Hauer & Farr 2015). Studies that focus on socio-cultural or economic benefits of rehabilitation (or risks from problems with rehabilitation) were also tagged with this theme. The synergistic combination of approaches reflecting the first two themes may be particularly powerful for helping aggregate rehabilitation first define, and then achieve, the elusive goal of “net ecological gain” (Maseyk et al. 2016).

- **Theme 3: Predicting and controlling species-by-environment filtering, succession (N=70)**

  Studies corresponding to this theme (the most numerous in the collection) tend to share an intersection of the theoretical with the practical. The rehabilitation goals have generally been narrowed-down and the research is concerned with understanding how features of the living and non-living environment – including both spontaneous and manipulated conditions – interact with the functional traits of target species during spontaneous or manipulated processes in restoration or ecosystems development. The processes range from recruitment, growth, and survival of individuals, to dynamics of populations, assembly of communities and functioning of ecosystems. This theoretical domain includes classical succession models but also steps beyond these to account for more perhaps more useful concepts in uncertain times, from novel ecosystems and non-linear dynamics to alternative stable states and metacommunities.

- **Theme 4: Creating high-value conservation habitats (N=45)**

  It is often an implicit or explicit goal of rehabilitation, and a valued outcome of spontaneous succession, that aggregate extraction sites provide prime habitat to remarkable amounts and types of biodiversity. Research in this group spans the gamut
from engineering experiments attempting to build specific habitat features, to seed additions aimed at creating species-rich native plant communities, to long-term successional studies investigating the capacity for aggregate sites to support rare, threatened or specialist taxa. Focal organisms from plants to birds, herptiles, beetles, butterflies, bees, wasps and various other arthropods.

- **Theme 5: Sensing, mapping, monitoring & modelling rehabilitation (N=26)**

Many studies worked to develop, test or utilize remote-sensing technologies, computational models, and multidimensional spatial analyses in rehabilitation of aggregate sites, whether in planning rehabilitation activities, evaluating success, or monitoring difficult-to-observe ecological processes.

- **Theme 6: Creating and amending soils (N=37)**

Improving substrate capacity to support plant growth has long been a challenge in aggregate site rehabilitation. The battle continues, though now aspects of soils relevant to climate change mitigation and resilience are of keen interest, including the rates and forms of carbon storage. Most of the studies in this group are focused on optimizing performance of human-created substrates ("technosols" or "anthroposols") which are applied as functional soil replacements during rehabilitation until true soil can form. Technosols are frequently desired in arid environments, where soil resources are scarce. Researchers often experimentally combine various mineral waste products from extraction (e.g. limestone fines) with various organic wastes (e.g. dewatered, municipally-treated sewage sludge), and test additional treatments and conditions to maximize particular substrate properties of value. These include capacity to support plant growth (in general, and with influence on target species), improve hydroseeding, stabilize slopes and sequester carbon, while the minimization of ecotoxicological risks and longevity of effects pose other major concerns.

- **Theme 7: Understanding soil biology and development (N=46)**

This theme is similar to the previous one, but reflects specific interest in soil microbes, biology, and the integration of key biological, chemical and physical factors in soil development. It applies to studies where restorative soil amendments are attempted, and where various aspects of soil stability, fertility and microbial activity are predictors or indicators of rehabilitation success. Yet, research on spontaneous soil development during succession, and responses of soil functioning to aspects of climate change would also fall under this theme.

- **Theme 8: Soil relocation and storage (N=47)**

Many stages in the process of mining and rehabilitating aggregate sites requires moving and storing soil. Status-quo management practices were designed by engineers, not soil biologists, and some of the key challenges and failures in rehabilitation may come down to ecological inefficiencies in the treatment of soil (i.e. stockpiling practices that render
The material functionally “dead”). The need for more research in this field is currently pressing, but the valuable studies which have already worked to address some of the questions are in this group. Studies employing direct topsoil transfer from target ecosystems to restoration sites - one of the most successful restoration techniques globally - also relate to this theme.

- **Theme 9: Planting and seed addition (N=52)**

A staple of pit and quarry rehabilitation, research on plant additions will probably never end because there are so many conditions and factors to consider. Every species-by-site interaction is a story, not to mention impacts of planting methods, the types of propagules used, the season of planting, irrigation and water relations, interactions among target species and between target and non-target species, impacts of various restoration interventions, and interactions of all of these factors with time. In general, studies in this category manipulate plants, among other conditions, and analyze the patterns which emerge.

- **Theme 10: Afforestation (N=10)**

Similar to the previous theme, but where forests are always the goal. Creation of new forests in an important theme in restoration generally – especially in light of increased societal drive to battle climate change – but afforestation studies were not abundant in the results of the search of the aggregate rehabilitation literature. This is probably extremely wet, dry, or soilless environments do not produce good forest cover easily, and aggregate sites frequently experience one, two, or all three of these stressors. Regardless, afforestation can be a goal of rehabilitation, especially where some unconsolidated substrates remain after extraction as in dry sand-gravel pits. Research working towards such ends, or alternatively, aimed at mitigating forest loss through compensatory off-site forest creation, correspond to this theme.

- **Theme 11: Creating faunal habitat; animal indicators (N=23)**

Similar to, and generally overlapping with, the conservation habitat theme, this tag is specifically for studies dealing with animal life in one way or another. Creating refuge for various animal species may be a goal of rehabilitation; site usage by animals may contribute to succession; faunal community composition may indicate restoration success or imminent failure. Whatever the case, studies of aggregates and animals go here.

- **Theme 12: Stabilizing slopes and restoring cliff faces (N=20)**

Technical reclamation of pit and quarry sites usually strives to stabilize steep slopes created during extraction by grading to shallower slopes and revegetating, often through hydroseeding and tree planting. Substantial research has worked to optimizing such operations, though not so much has been published in the past 10 years. Recent research has focused on improving hydroseeding mixtures to function under conditions
of steep rocky slopes which cannot be graded down, and in a few cases, studies have attempted innovative techniques for promoting naturalized cliff face features and biotic communities. There has perhaps not been as much work on this front as there should be, given the well-known ecological and socio-cultural benefits of rock-outcrop ecosystems (Fitzsimons & Michael 2017).

- **Theme 13: Applying geodiversity, habitat heterogeneity (N=5)**

  This sparsely-populated category is for research that explicitly considered the potentially important relationships between diversity in the physical environment at various scales, and the ability of the environment to support biodiversity at various scales. There are good theoretical reasons to believe the high environmental heterogeneity characterizing many aggregate sites may contribute to these same sites providing refuge to high levels of biodiversity. Considerably more research is needed, however, before designing heterogeneity into restoration can be confidently used as a tool to achieve specific biodiversity goals.

- **Theme 14: Creating wetlands (N=13)**

  Wetlands provide numerous ecosystem services which are highly valued by society, and they may be particularly helpful with respect to both mitigating climate change to help landscapes respond resiliently to the impacts of climate change, such as increased flash flood events. As aggregate extraction sites often operate at or below the water table, interesting opportunities to create wetlands in the rehabilitation of flooded sites should be seized. Constructed wetlands may serve multiple ecological and even recreational and commercial functions, and may range from ponds and shorelines of small quarry lakes, to rich marshes, calcareous fens, and potentially even bogs or swamps, depending on hydrology, management and surrounding vegetation trends. Despite the enticing possibilities, we found few studies explicitly dealing with strategies for wetland creation at aggregate sites in the recent literature.

- **Theme 15: Controlling hydrology (N=14)**

  This theme overlaps with the previous one, except some studies here deal more expressly with technical aspects of hydrological control, from engineering water-retention structures to managing groundwater discharge and recharge, to manipulating site drainage for achievement or avoidance of particular effects.

3. **Key Findings of Scientific Literature Review**

3.1. “Big-Picture” Planning and Resilience to Global Change

- Researchers investigating the utility of the landscape-scale perspective for rehabilitation planning in southern Ontario modelled the costs and benefits of implementing after-uses that promote either economic activities, biodiversity, or a combination of the two. Looking at habitat patterns and resistance of the landscape
to rehabilitation interventions, the cost efficiency was greatest when the goal is biodiversity, due to lower landscape resistance to this option. Some combinations of biodiversity and economic goals may, however, be accomplished effectively together (Corry, Lafortezza & Brown 2010).

- Adopting a “bigger picture” perspective, researchers on ecological restoration of aggregate sites around the Mediterranean Basin explore how a complex suite of social, cultural, economic and political factors unavoidably interact with ecological and geographical controls of ecosystem services, impacting stages or restoration from goal-setting to success-evaluation across different scales. For restoration to be successful, they argue, it must transcend the traditional boundaries of ecological science. Only thorough, educated, fulsome debate all stakeholders will success at three key stages be possible. At the design stage, debate should inform the setting of project goals and success indicators. At the implementation stated, information technology and cognition science should be linked to restoration science to create tools adapted for engaging in and then resolving ecological debate. At the evaluation phase, success indicators should be based on consensus following debate considering potential sociocultural as well as ecological aspects of restored ecosystems (Khater et al. 2012).

- European researchers provided a conceptual framework for making decisions about optimal after-uses for aggregate extraction sites, based on valuation of the benefits or services that ecosystems provide. The biggest problem is the wide range of options that may be available for any given site, and the large amount of information about potential ecosystem services associated with each option. It can be a lot to digest even for a scientist, let alone non-scientist stakeholders and managers. Strategies for narrowing-down the information relevant to decision-making are thus crucial. By exploring three case-studies, the authors compare the benefits to both nature and society of targeting rehabilitation towards habitat that has high conservation value but which sequesters carbon only slowly, versus a faster carbon sink that provides less benefit to biodiversity. The analysis concludes that the substantial ecological and societal benefits of fostering conservation in this case significantly outweigh the minor costs of forgoing the slight amount of climate-change mitigation associated with a more productive but less diverse ecosystem (Wilker et al. 2016).

- In the same vein, one potential after-uses for a UK gravel pit is aimed at nature conservation while another is a public park. Decision-making should consider the main functions of each outcome, but also the secondary ecosystem services that would accompany these. While the park option has little natural value other than benefit of its use, a restored nature area not only provides refuge for biodiversity, it sequesters more carbon than the park and thus contributes for to climate change mitigation, and it helps connect people to elements of nature which they may otherwise have difficult accessing, such as wildlife. Thus the collective and cumulative
benefits arising from the naturalized area after-use indicates it is the more valuable investment for both nature and society (Blaen, MacDonald & Bradbury 2016).

- “Next-level” aggregate rehabilitation practices will require planning for management of multiple sites simultaneously, such that recovery processes occurring at one location can complement those occurring at other, potentially interacting (e.g. through species migrations) locations in the region. Chinese researchers designed a comprehensive multi-site rehabilitation plan for a collection of small deserted extraction pits throughout the Beijing Plain. They used remote sensing technologies and on-site surveys to characterize numerous sites with respect to location, extraction depths, areas and volumes, soil composition, and current status. These properties were then used to classify sites into rehabilitation planning categories, with different sites requiring different approaches depending on conditions, from soil modification and slope engineering to vegetation establishment and landscaping. Rehabilitation actions were designed to meet a wide variety of ecosystem service goals and to provide benefits including flood water retention, rainwater utilization, groundwater replenishment, reduction of dust pollution, natural recovery and public green space. The comprehensive plan has been adopted by the Chinese government and will be employed in ongoing rehabilitation efforts (Tang et al. 2011).

- Efforts to rehabilitate extraction sites can be significantly hampered by establishment of undesirable invasive species, such as aggressive and opportunistic ruderal plants. Researchers in Italy tested whether an invasion by Ambrosia artemisifolia (common ragweed) at a limestone quarry could be suppressed by inducing competition with other herb species. Both hay from local sources and a commercial seed mix were attempted as propagule sources for Ambrosia competitors. The commercial seed mix was more effective than the hay, but the hay application preserved local biodiversity and still had a dampening effect on the invader population (Gentili et al. 2015). A longer-term follow-up on this study found that after two years, the commercial seed mix had completely suppressed the invasive ragweed, while after three years, the hayseed mix had accomplished this as well (Gentili et al. 2017). When goals other than ragweed suppression were accounted for in a comprehensive cost-benefit analysis, using the local native hayseed was clearly the best approach. It was more expensive in terms of time and finances, but it was far more effective in promoting target biodiversity establishment. Application of the commercial seeds actually inhibited establishment of target trees and shrubs due to interference by one of the sown species, Lolium perenne which forms dense vegetation patches (Gilardelli et al. 2016).

- Portuguese researchers sought to understand why the common recommendation that native plant species be incorporated into hydroseeding mixtures for Mediterranean quarry revegetation has not yet found practical application in the industry. Field and greenhouse hydroseeding trials were conducted using target specialist natives, generalist species which are also native, and commercially-
available exotic species traditionally used in rehabilitation. Species were grown alone and in combination, tested for germination and growth under various controlled and field conditions, and assessed under numerous treatments ranging from seeding rate variation to irrigation to fertilizer applications. Results allowed the researchers to attribute some of the poor performance of native specialists which had been observed in previous field trials to species-specific germination requirements that set the specialists apart from the generalist and exotic species (longer germination times; seasonal (fall); conditions needed to break seed dormancy) (Oliveira et al. 2012). The primary cause of native specialist failure when included in the hydroseeding mix, however, turned out to the inexpensive native generalist species that are typically including to help “fill out” the seed mix (Oliveira et al. 2013). These generalists were grasses that germinate and grow large leaves quickly, and it is likely that this blocked the native specialists’ access to resources. (Oliveira et al. 2014). Fortunately, the problem may be relatively easy to solve, by simply reducing the proportion of generalist natives in the seed mix and being more rigorous in species selection considerations.

- In contrast, follow-up work on an older quarry restoration experiment by the same researchers suggests rehabilitation success may be simpler to achieve than previously thought. Short-term results from an experimental out-planting of drought-tolerant native sclerophyllous shrubs on limestone quarry terraces had previously suggested that potentially expensive and complex combinations of planting, irrigating, fertilizing, and inoculating with mycorrhizae were required to maximize success. Results after 8 years, however, indicated that none of the treatments offered any significant advantage over simply planting the shrubs and letting nature take its course. This simple intervention led to significant and long-lasting effects on the quarry restoration (Oliveira et al. 2011). Efforts to stimulate soil development and revegetation in abandoned clay quarries in northern Italy supported a similar, though more negative, result. Whereas short-term patterns had indicated that complex combinations of interventions, including topsoil relocation, addition of slow-release nitrogen fertilizer, phosphate fertilizer, and organic amendments had some stimulating effects on soil development, after 11 years none of the treatments had statistically appreciable effects on soil or vegetation (Muzzi & Mongardi 2016).

- Research at a rehabilitated Niagara Region quarry investigated the role that the site’s after-use – first as a landfill, and later as a capped and rehabilitated landfill converted to a naturalized hilly park – played in supporting local wild bee communities. Conversion of the landfilled quarry to potential bee nesting and forage habitat (achieved by seeding and planting) produced rapid and persistent occupation of the site by bees. This suggested creation of bee habitat was sufficient to establish bee communities when there are naturally occurring colonies of bees nearby. Although bees declined on site after an initial peak four years after restoration, similar patterns were observed in undisturbed control sites, suggesting the decline is due to broader
factors such as intensified drought regionally. The potential to use aggregate-site rehabilitation as a vehicle to enhance the health of pollinator populations should not be ignored (Onuferko et al. 2018). The best management practices to achieve this will likely involve taking steps to ensure constant nectar sources (i.e. flower blooms) throughout the entire growing season, and maintaining open habitat for nesting. This may entail planting a high diversity of tree, shrub and grassland/meadow species, and a trade-off may be required whereby non-native species are valued for their availability, reliability, low cost and resource-provision to pollinators, and thus utilized in rehabilitation despite their exotic status.

- Potential suppression of ecosystem services by competition among restored species was investigated in an older afforested Mediterranean quarry. As in Ontario, establishing low-diversity pine plantations was a traditional approach to controlling soil erosion. In the Mediterranean basin, this provokes concerns that the resulting ecosystems are poorly equipped to be resilient and adaptive in the face of climate change (i.e. at increased risk of fire, drought, nutrient limitations). An experimental 35% pine thinning was applied, and responses with respect to the functional traits of organisms were monitored for two years. Reduced pine cover led to increased density of groups with nitrogen-fixing ability, semi-deciduous drought strategy, therophytic growth habits (i.e. annuals that emerge and complete their life cycle quickly when conditions are good), and seed dispersal by wind and gravity. Such functional shifts generally correspond to increased ecosystem resilience in the face of climatic disturbances (Nunes et al. 2014).

- Researchers studying abandoned limestone quarries in southern Ontario proposed a general conceptual approach for the restoration of severely degraded environments: perhaps the optimal target ecosystem that should be strived for is not what occurred at the location prior to disturbance, but rather a point further along the successional trajectory upon which the degraded site is already progressing. The difference between pre-disturbance and post-rehabilitation ecosystem types may be negligible when the disturbance is reversible, but in some cases it is clearly not, such as when surface mining operations convert terrestrial environments into aquatic ones. In such situations it may be better to adopt a future-looking restoration paradigm, and ask whether the degraded ecosystem which stubbornly resists restoration ecologically resembles any other type of naturally-occurring ecosystem in the region, which may be different from the pre-disturbance ecosystem but which nevertheless provides ecosystem services of natural and/or societal value. If so, such a natural analog of the degraded state may be a target that can be achieved with high efficiency, to the benefit of the region.

The conceptual approach was tested empirically by analyzing biophysical features of dry limestone quarry floors and comparing them to naturally-occurring limestone pavement ecosystems called alvars. Alvars can support very high levels of floral and faunal species richness (including many at-risk and outcrop-specialist
species; they can provide heterogeneous habitat conditions which grade from wetlands to pavement, to scrubland, to tallgrass, to savanna; they contribute importantly to flooding control and groundwater recharge; and they can host integrated biotic communities that are resilient in the face of intense drought, flooding, grazing, fire, and sudden cold. Such features make alvars a very attractive target ecosystem for restoration of quarry floors, especially given that comprehensive biophysical evaluations indicated that old dry limestone quarries are approximately 50% complete along a successional course toward alvars (Tomlinson et al. 2008).

However, for alvars to be considered a reasonable “degraded-state analogue” for limestone quarry restoration, the chief constraint on establishment of alvar species not already occupying quarry floors should be factors that are relatively easy for managers to overcome, such as the physical distance between natural alvar seed sources and suitable quarry sites. Experimental seed-additions and substrate amendments were conducted on four replicate quarry floors to test which factors limited establishment of 18 target alvar wildflowers and grasses. Outcomes indicated that chemical and biological differences between quarry and alvar substrates did not inhibit establishment by target species, while the abundance of quarry fins in the substrate imposed a minor constraint. The primary limitation was thus indeed the immigration barrier, and overcoming this through simple seed addition resulted in increased species diversity and compositional similarity of quarry to alvar communities (Richardson, Lundholm & Larson 2010).

Further analyses and experiments suggested that alvar plant communities could be established with high diversity thanks in part to the strong degree of habitat heterogeneity characterizing quarry floors, and that interactions between heterogeneity and species diversity enhanced the productivity and resilience of resultant plant communities when disturbed by extreme drought (Richardson, Horrocks & Larson 2010; Richardson, MacDougall & Larson 2012).

3.2. Species-Sorting, Environmental Filtering and Succession

- Analysis of successional patterns in disused and rehabilitated aggregate sites has long been a cornerstone of the restoration literature, but increasingly, perspectives have shifted from classical succession models to the dynamic interplay between environmental gradients and species functional traits – including both how species respond to different conditions, and the alterations that species make to their environments. Concepts of potential immigrant species being “sorted” or “filtered” by the environment become relevant here, as well as the function of environmental diversity in influencing the coexistence of different species at different scales. Such perspectives are not contrary to classical succession theory, but are perhaps better suited to predict outcomes of restoration efforts and novel combinations of species and environmental conditions brought about by drivers of global change (e.g. climate change, species invasions, habitat fragmentation, biodiversity loss).
• An analysis of 50 years of vegetation change following abandonment of sand-mining in Poland revealed a number of complex relationships among wet versus dry hydrological conditions, the passage of time, and the responses of species expressing different traits related to life form, methods of reproduction, overwintering, pollination, seed dispersal, light requirements, stress tolerance, nitrogen requirements, and competitive ability. While the overall map of relationships is complicated, accurate knowledge of ecological processes, environmental conditions and the traits of species in local and regional pools can help managers predict and drive succession towards desired outcomes (Kompala-Baba & Baba 2013).

• Similar complex patterns were observed in Czech sand-gravel pits, where the life history traits and habitat preferences of colonizing species were assessed for a sequence of sites representing a 75 year time-series (“chronosequence”), (Rehounkova & Prach 2010). Investigation of plant communities and environmental features spanning a 100 year chronosequence of heavily-disturbed “man-made habitat” sites across central Europe revealed the controlling importance of factors such as climate and soil pH (Prach, Pyšek & Jarosik 2007), as well as the colonization abilities of potential site occupants (Prach et al. 2017). Despite these effects, the authors inferred that the single most important factor dictating the outcome of succession is the nature of the surrounding vegetation (Prach et al. 2011; Prach et al. 2013; Prach et al. 2014; Prach et al. 2015).

The authors further concluded that although the endpoint of succession may be set by the surroundings, the pacing of the process depends somewhat on the nature of land disturbance. Perhaps counter-intuitively, the successional models generated by the collected data predicted it will take longer to recover from a disturbance necessitating secondary succession (250 years) than from one triggering primary succession (200 years) (Prach et al. 2016). While succession is ongoing, the species diversity and conservation value of such “man-made” habitats may considerably higher than the surrounding land-uses and can serve as local hotspots for biodiversity, and as remnant habitats for endemic and specialist early-successional species. The importance of such features can be disproportionately large relative to the area considered. It has thus been argued that preserving such habitats where possible should be a conservation priority, while technically reclaiming them or converting them for economic or recreational uses could be detrimental to conservation (Poschlod & Braun-Reichert 2017) (Sebelíková, Rehounkova & Prach 2016).

• Studies of succession in rehabilitated Chinese quarries planted with exotic woody species over 214 years indicated that although the non-native canopy cover had a prolonged impact, a high diversity of native woody species established in the understorey quickly, within about 10 years. This indicated that the exotic trees served as an effective “nurse” crop (Zhang, Zhuang & Chu 2013). Other research investigated in-depth the dynamics of microbial community development in
rehabilitated quarry soils (Zhang & Chu 2013b) as well as the contribution of soil seed banks to revegetation processes (Zhang & Chu 2013a), knowledge of which can help predict and control restoration outcomes.

- Other research on the wide variety of successional stages found at post-industrial sites in the Czech Republic (including abandoned and rehabilitated aggregate pits and quarries) found that the success of different plant species in different environments could be predicted from particular seed traits, especially seed mass, longevity, and method of dispersal. The strong correlations observed may be useful in rehabilitation planning, as trait-based screening applied to the local and regional species pools may predict likely outcomes of succession under different management scenarios (Horackova, Rehounkova & Prach 2016).

3.3. Conservation Value of Aggregate Sites

- Czech researchers explored the unintended consequences of land management policy changes that are meant to protect the environment, and of extractive industries that are assumed to be harmful. Application of the EU’s Environmental Impact Assessment Directive is forcing closure and technical reclamation of the majority of the Czech Republic’s small and medium-sized sand and sand-gravel pits (but having little impact on the larger industrial operations). Biophysical sampling of these environments and their surroundings, however, showed that active sand pits and recently disused sites provide essential habitat to an incredible diversity of animal species, especially insects and other arthropods. For example, 221 bee and wasp species (53 red-listed, 2 thought to be regionally extinct) occupied the aggregate pits (Heneberg, Bogusch & Rehounek 2013); 401 beetle species and 41 orthopteroid species (e.g. crickets, grasshoppers) were found, including 63 red-listed species (Heneberg, Hesoun & Skuhrovec 2016); and 383 spider and 8 harvestmen species occupied the sites, including 81 at-risk species (Heneberg & Rezac 2014).

A large proportion of all of these groups occupied active and recently disused sand pits, but apparently nowhere else in the surrounding natural and post-industrial sites. Surprisingly, the presence of common phragmites, largely viewed as a problematic invasive species, had a positive habitat-creation effect for at least 183 bee and wasp species, thanks to particular habitat conditions of reed beds rooted on sandy loose bedrock, and to reed galls created by Liparia flies, which can create serve as prime habitats for specific suites of insect species (Heneberg, Bogusch & Astapenkova 2014).

While historically the Czech landscape would have been a heterogeneous patchwork of ecosystems at varying states of succession, including mature forests but also sandy, naturally disturbed open areas and river banks. Urban, agricultural and industrial development removed nearly all such early-successional habitats, while rehabilitation policy promotes afforestation to the exclusion of these. This is
detrimental of the sand martin, an endangered (and protected) bird species that depends on soft (not crusted-over) sandbanks to burrow and create nests in (Heneberg 2013). The types of habitat conditions found in active and recent small-medium sized aggregate pits are vital to highly diverse arthropod communities that are valuable in their own right, valuable as pollinators, and valuable as indicators of biodiversity at other scales. The value of these habitats should be prized in aggregate rehabilitation planning as well as in trading within ecosystem service markets.

In cases where extraction must cease but the ecosystem benefits of maintaining a regularly disturbed early successional habitat are desired, a policy tool to achieve this may be to plan for a recreational/economic after-use that can achieve this incidentally, such as creation of off-road motorcycle circuits (Heneberg, Bogusch & Rezac 2016). Rehabilitation through natural succession combined with additional experimental disturbances from recreational activities was found to be more successful than succession alone or technical reclamation, with respect to maximizing diversity of rare open-habitat and sand-specialist species of plants, spiders, beetles, flies, bees, wasps, and orthopterans (Rehounkova et al. 2016).

- Limestone quarries (as opposed to sand-gravel pits) undergoing spontaneous succession in this region have been found to host a tremendous diversity of spider species (Tropek & Konvicka 2008) as well as numerous other arthropods and plants, including many red-listed and dryland specialist species (Tropek et al. 2010). These species-rich environments were additionally employed as the setting for experimental evaluation of different butterfly-survey techniques, to determine which was most efficient for inclusion in monitoring programs. More butterfly individuals and species were recorded using the “timed survey” method than standard linear transects, while the ability of both methods to detect mobile and imperceptible species was the same. The timed survey method involves zigzagging study sites and flexibly checking transient butterfly resources, while limiting the amount of time that sampling is permitted. Linear transects may still be preferred where an army of moderately experienced surveyors is employed, but the timed survey method is likely more efficient when the number of potential species and the experience of the surveyor are high, but the number of surveyors and amount of time available are low (Kadlec, Tropek & Konvicka 2012).

3.4. Technosols, Amendments, Planting & Seeding

- In a 4-year, multi-factor planting experiment at a reclaimed limestone quarry in the Rocky Mountains of Alberta, establishment of woody biodiversity was attempted using different propagule sources, planting times and soil amendments. The diversity of native trees and shrubs was improved most by transplanting nursery-grown stock in fall, leading to establishment of 5 of 7 species, and good survival by 3 of these. Spring plantings were less successful due in part to grazing and trampling by herbivores during the sensitive early growth period, and application of seeds, topsoil seed banks
from nearby forest floors, and transplantation of wildling plants from local surroundings were largely unsuccessful. Amending the reclaimed quarry substrate (mineral substrates leftover from extraction) with wood shavings or clean fill had no impact on planting success (Cohen-Fernandez & Naeth 2013b).

A related study looking at the success of sown native grasses on quarry slopes in the same system found similar minimal impacts of soil amendments, but a strong positive effect of erosion control blankets on seeding success (i.e. increased cover by sown species, reduced cover by non-sown species, no changes to soil properties) (Cohen-Fernandez & Naeth 2013a). Interestingly, greenhouse trials of the soil amendments indicated their high potential to improve quarry revegetation (Cohen-Fernandez, Naeth & Wilkinson 2013), suggesting the reality of harsh and variable quarry field conditions overwhelmed the benefits of treatments found to be effective in a controlled environment.

- In an experimental sowing of hardy grasses and legumes on limestone quarry terraces in Greece, germination, density and cover of vegetation was increased by 65% when mulching with wheat straw was applied. As straw mulch is light and needs to be weighted down, mineral spoils from quarrying were used in small quantities (30 g bentonite powder / m²) to accomplish this. The beneficial impact of the mulch was not hampered by the mineral application (Abraham, Kostopoulou & Koukoura 2009).

- Recent efforts to incorporate native plants when hydroseeding Mediterranean quarry slopes have met with failure, and Portuguese researchers hypothesized components of the hydroseeding slurry may not be optimal for use with the native seed mix. Experimental sowing using slurries varying in the presence of bacterial-based fertilizer, biostimulant, dye and surfactant revealed relatively minor impacts of the hydroseeding components, with only 4 of the 12 species tested showing any response in germination time to any component. Thus the hydroseeding mixture is unlikely to be preventing the success of the native seed mix overall, though the performance of the mix may be improved somewhat by adjusting species selection and seeding levels to fit the hydroseeding conditions (Clemente et al. 2016).

- Restoration experiments carried out in aggregate-extracted areas of the Campos Rupestre – species-rich tropical mountain grasslands in Brazil – revealed that hay transfer from the target grasslands was largely ineffective for establishing vegetation, despite multiple application strategies and recipient substrates tested, and despite the high abundance and diversity of native seeds in the hay. The few seedlings that did emerge tended to be the less-desirable, ruderal species, and the authors attribute the failure to germination issues with the target species rather than unsuitable soil conditions (Le Stradic, Buisson & Fernandes 2014). Direct planting of target native trees and shrubs was considerably more successful, with more than half of the 14 added species exhibiting > 78% survival 4.5 years after transplantation. These, and even some of the less successful species, were able to improve shade and soil conditions in their
vicinity and support establishment of a herbaceous layer which in turn further improved ground-layer litter conditions. Success in such a harsh environment is best measured by transplant survival rather than growth, as the two responses were barely correlated in this study (Le Stradic et al. 2014).

- Research and development of “technosols” or “anthroposols” for use in aggregate site rehabilitation has been most intense in the Mediterranean region, where the need for replacement soil can be great. The focus of such research has been combining different waste products in novel ways, such that the basic functions of soil are achieved while potential ecotoxicological risks are minimized. Spanish researchers investigating microbial activity in technosols found that addition of dewatered sewage sludge to substrates collected from working limestone quarries increased the level of microbial biomass and respiration as well as soil carbohydrate content when applied, with significant effects maintained after 9 months of laboratory incubation. The stimulating effect of the sewage sludge was proportional to the amount added, but greater when the sludge was thermally dried prior to application, probably because this created more readily-available carbohydrates for microbial breakdown. While composting the sewage sludge prior to application was expected to achieve a similar effect, it did not, with the non-composted sludge providing stronger microbial stimulation than the composted material (Jimenez et al. 2007).

    Nearby studies on other technosols found that sewage applications were of some environmental health concern, especially the risk of sulfate and nitrate contamination, but proper engineering of technosol construction, treatment and monitoring can reduce the need for alarm (Jordan et al. 2017). Impacts on soil chemistry including elevated nitrate levels must be managed carefully (Jordan et al. 2008). There is less need for concern over impacts on soil physical properties, as sewage sludge applications were found to reduce bulk density and increase aggregate stability, thereby improving the structure of substrates used in reclamation (Jordan et al. 2014). Fortunately, potential leaching of heavy metals from these substrates was assayed and found to be well below standard safety limits (Jordan et al. 2012) and numerous other physiochemical properties of sewage-treated substrate have been found to be generally acceptable for use in rehabilitation (Marando et al. 2011). However, some contrary evidence has been published for saline leachates from technosols, with potential impacts including heavy metal contamination (Perez-Gimeno et al. 2016).

    Assays of other organic materials arising from municipal sources (e.g. composted municipal waste) as well as agriculture (a mixture of compost, poultry manure and wheat husk) were applied to revegetation of Mediterranean quarries using sclerophyllous shrubs. These both produced similar positive results, though the agricultural organic source created more favorable growth conditions for plants as well as soil microbes (Maisto et al. 2010).
• An experimental study in Spain, which involved manipulating irrigation levels and sowing fast-growing but not drought-tolerant herbaceous species typically used to control bank erosion, found that it is not advisable to depend on a dense, continuous cover of such vegetation to maintain the stability of stony spoil slopes where drought risk is high. Periods of no rain unsurprisingly reduced soil moisture availability, but this effect was exacerbated where the sown vegetation achieved dense cover, as the vegetation transpired virtually all soil water and then died, producing drier, less-stable banks than if less-dense, slower-growing but drought-tolerant plants had been established (Josa, Jorba & Vallejo 2012).

• A field experiment at a dry Spanish quarry where establishment of woody species was the goal found that increasing water availability could benefit target species by overcoming a resource limitation, but it could also indirectly harm target species by stimulating growth of herbaceous species which compete with the targets for multiple resources. Importantly, the net effect of irrigating was positive for later-successional woody species but negative for pioneer woody species, suggesting that restoration planting efforts should target the former vegetation type to habitat patches of expected high water and nutrient availability, but rely on a mixture of planted pioneer species to fill-in the intervening more drought-prone areas (Soliveres, Monerris & Cortina 2012).

• Experimental rehabilitation of the largest slate quarry in Europe (in Wales, UK) investigated potential constraints on native woody species establishment imposed by nutrient and water limitations, alone and in combination. While treatments designed to overcome either limitation alone did not improve plant establishment, two different treatments designed to overcome both limitations simultaneously (addition of organic waste, and addition of boulder clay) both strongly enhanced growth. The organic waste addition had the greater impact in stimulating soil microbial activity, while treatments that increased soil nitrogen were preferred by native trees that did not fix nitrogen, and trees that did fix nitrogen responded best to treatments that did not increase soil N content (Williamson et al. 2011).

• Italian researchers trying to engineer replacement soils for use in aggregate sites and related reclamation activities crossed two possible mineral components (limestone gravel and zeolitized tuff) with two possible organic components (commercial compost and phosphorite-poultry manure) and monitored the short-term development of soil properties when pasture grasses were grown on the substrates under controlled conditions. Soil formation — especially development of organic matter — was greatest when the softer, volcanically-derived tuff (with rich micropore structures) was combined with the phosphorite-poultry manure, and was insufficient for sustained plant growth wherever the limestone gravel was used as the mineral component of the technosol (Buondonno et al. 2013). In Ontario, we have had less need to rely on technosols than in the Mediterranean region, but in cases where they
are needed, it would be best to know how to create substrates that can rapidly develop plant-relevant properties of natural soils, including organic carbon storage.

- Italian researchers, seeking to learn if fine-particle waste from stone cutting can be effectively disposed of by incorporating it into quarry rehabilitation, mixed different waste sources (gangue saw with abrasive shot; diamond frame saw; mixed sludge from both) with different organic components (compost, green manure, soil) and distributed the mixtures on quarry floors. Mixing-in organics improved the fertility and quality of the stone wastes, reducing hydrocarbons and metal content and producing technosols that demonstrated no phytotoxicity after 8 years on the quarry floor (Dino, Passarella & Ajmone-Marsan 2015).

- The role of water limitation in constraining native tree restoration in sand extraction pits was investigated in a dry tropical ecoregion of Venezuela. A series of increasingly costly interventions to increase water and/or nutrient availability to greenhouse-reared tree seedlings planted in the sand pit was tested, featuring 8 possible combinations of irrigation, fertilizer addition, and application of a water-retaining polymer gel. After 8 months, the trees which showed the greatest levels of survival and growth were those treated with the hydrogel only – which was incidentally the most cost-effective intervention (Fajardo et al. 2013).

3.5. Soil Relocation, Storage and Development

- Borrow-pits on quartzite soils in the Succulent Karoo Biome – one of the world’s most species-rich arid ecosystems – were experimentally rehabilitated by methods including dozing and grading subsoils, contour-ripping subsoils, adding wild-collected native seeds, and redistributing stockpiled topsoil (from 4 year-old, 3-4 m high piles). While shallow extraction pits showed relatively rapid recolonization by plants even in the absence of soil preparation and seed addition, the more deeply-extracted pits showed complete failure in revegetation except where topsoil was applied. In this latter case, plant cover and richness were lower in the rehabilitated pits than in a nearby undisturbed control area, and plant species composition was only partially overlapping (Burke 2008).

- Soil development after 30-40 years was investigated in dry alluvial quarries of southern France, which has been extracted in the 1970s and then abandoned or rehabilitated to varying standards. The depth of extraction and the method of rehabilitation had distinctive impacts on soil fertility in the upper layer and on the vertical soil profile, and only rehabilitation employing topsoil relocation under good conditions resulted in soils that were similar to the reference steppe ecosystem soils. Soil development was otherwise slowed or stalled by extraction and rehabilitation activities, especially the biological components (Chenot et al. 2018).

- Establishment of tropical dry forest in a limestone quarry using direct translocation of topsoil propagule banks (i.e. seeds and resprouting root fragments) was tested
experimentally in Brazil. Topsoil transfer was highly effective regardless of whether watered or not, and whether tall mounds were created and left alone, a 40 cm layer or topsoil was deposited, or a 20 cm layer of topsoil was deposited. Tree and vine establishment primarily occurred from resprouting while herbaceous vegetation mainly came from seed banks. Topsoil deposition increased species richness nine-fold and tree density five-fold (Ferreira & Vieira 2017).

• While sewage sludge applications in quarry rehabilitation are carried out with the short term goal of stimulating soil development and plant establishment for more successful, given the growing global interest in maximizing carbon storage to mitigate climate change, it would be advantageous if ecosystem developments “kick-started” by sewage application produced long-term carbon sinks. While more research is needed, re-sampling of quarry substrates previously treated with municipal sewage sludge suggested this may indeed be the case. The initial increase in soil organic carbon stimulated by the addition was still detectable 18 years later, the form of this carbon had shifted towards slow rather than rapid turnover channels, and the aggregate stability of the soil had increased. These effects were most pronounced at the higher rate of sewage application tested, 400 tonnes per hectare (Ojeda et al. 2015).

• A similar increase in soil organic carbon was observed when a sewage sludge was applied to a limestone quarry afforested with pines, with the additional benefits of a remarkable surge in tree growth. After 12 years, treated pines were twice as tall, larger in diameter, and produced five times as many cones with twice as many seeds each compared to untreated pines, and these began reproducing in almost half the time needed by untreated pines. All of these effects suggest sewage sludge applications in afforestation and quarry rehabilitation may be a powerful tool to enhance carbon sequestration above and below ground and mitigate climate change (Ortiz et al. 2012).

• Application of municipal sewage sludge (at 100 tonnes / ha) to dry barren gravel pit floors in Brazil not only resulted in establishment of diverse herbaceous plant communities within 3-6 years, it also led to unprecedented levels of carbon sequestration that were much higher than observed in surrounding undisturbed ecosystems, as determined by isotopic analysis of plants and soil (Silva et al. 2013). Interestingly, the rate of carbon accumulated peaked when the diversity of the plant community peaked; as native diversity dropped in response to increasing dominance by exotic invasive species, so too did the rate of soil carbon, nitrogen and phosphorus sequestration.

• The particularly high rate of carbon sequestration seems to be the result of complex, synergistic interactions among geological properties of the gravel pit substrate, chemical properties of the sewage sludge (especially iron content), and biological processes of the colonizing plants. Combined, these produced particularly stable
organic carbon that is protected by strong soil aggregates (Silva et al. 2015). Application of sewage sludge to moderate Mediterranean slopes increased cover and biomass production of spontaneous native vegetation for at least 5 years, with no indication of heavy metal contamination. The maximum biomass production (550 g/m²) was achieved when 80 tonnes of sludge per hectare of land was applied, and higher application rates was correlated to a reduction in the diversity native plants as well as biomass production (Walter & Calvo 2009).

- Comprehensive bioassays, including microbial biomass, respiration, and enzymatic activities, collembolan (springtail) abundance, plant emergence and growth and the Microtox assay, were used by Spanish researchers to determine potential ecotoxicological risks of applying mixtures of sewage sludge and quarry mineral wastes in rehabilitation of extraction sites. Trials were carried out in the lab and field, on substrates and leachates from substrates. While a number of mining waste and sludge sources were combined in various ways, overall the study revealed that combing mineral wastes and organics produced soil-like substrates that were functional in supporting vegetation cover without producing ecotoxicological impacts on soils or groundwater (Domene et al. 2010).

3.6. Slope Stabilization

- Gabions were experimentally installed and planted with tree saplings as an alternative method to steep slope stabilization in a dry Austrian quarry. Gabions were mechanically stable enough but highly drought-prone. Trees planted on the gabions survived better when relatively drought-tolerant species were chosen (e.g. conifers), and when less-tolerant species (e.g. angiosperms) were first pre-conditioned to drought (i.e. exposed to dry enough conditions as a sapling that embolisms formed) (Beikircher, Florineth & Mayr 2010).

- Researchers in Italy, concerned with predicting how native calcareous grassland herbs may be deployed to stabilize topsoil on quarry slopes, modelled the effects of planting three different species, based on root characteristics such as mechanical properties and diameter distributions. It was determined that for two of the species, establishing 100 individuals per square metre would guarantee a more stable soil surface (Federica et al. 2017).

- Despite occasional calls to the contrary, there seems to be a bias in the quarry rehabilitation literature favoring grading slopes to avoid steep vertical faces, and thus climbing, rock-loving vegetation is rarely targeted in restoration. Innovative Chinese research on quarry slope stabilization tested the potential for using highly stress-tolerant rock-climbing plant species as pioneer vegetation in areas that are too steep to support soil, such as cliff-faces. Two of the three species tested showed little need for soil, as they could cling to rock surfaces using tendrils or air roots, and survival success was high when seedlings were transplanted to holes which were artificially
drilled into the steep rocky slopes (Wang et al. 2009; Wang, Wu & Liu 2009). This has some parallels to research on revegetation of Niagara Escarpment cliff faces in Ontario using Eastern White Cedar, a rock-loving, highly stress-hardy tree and shrub species capable of reaching extreme longevity. Some guidelines for establishing such vegetation cover on steep rocky slopes may be drawn from this research (Matthes & Larson 2006). An alternative approach to stabilizing slopes that was likewise tested in Chinese quarries involved adding soil cover and attempting to block its erosion using bamboo fences and eco-bags. Both methods were effective, with the fences better at intercepting water while the bags were better at preventing soil movement (Zhang et al. 2015).

• Much of the research on aggregate site rehabilitation is devoted to technical aspects of slope stabilization, but this is where a divide seems to form between environmental scientists and civil engineers. Research from South Korea recognized that the number of potential factors needed to appease all sides is unmanageably large, and employed a consensus-based approach utilizing expert opinions from different disciplines (the Analytic Hierarchy Process) to select a manageable number of factors to include in analysis and planning efforts that satisfies both engineering and ecological perspectives. From an initial list of 65 potential factors to consider, a “top 5” list that strategically addresses the vast majority of concerns on all sides was derived: rain intensity, seepage water, slope angle, drainage condition, and ground-layer vegetation (Kim et al. 2016).

• Application of sewage sludge in hydroseeding to revegetate and stabilize quarry slopes in China was studied via factorial experiments by researchers trying to optimize the hydroseeding media “recipe”. Integrating the results of dozens of different trials, a protocol was derived that will maximize benefits to soil nutrients, bulk density, porosity and plant growth while minimizing soil runoff and loss. Soil should be mixed with sewage sludge at a 6:4 (v/v) ratio, fiber content should be adjusted to 15% (v/v), and the concentration of the tackifying soil additive should be 0.6 kg/m³. A bioorganic fertilizer that was tested was found to have no appreciable effect and so is not recommended for inclusion in the hydroseeding mix. Further technical research from China found that the stability and fertility of soils existing along the ecotone between terrestrial and aquatic environments (such as the shorelines of quarry ponds and lakes) can be improved by deploying a mixture of straw mulch and water-absorbing polyacrylamide gel (at a 3:1 ratio by weight) (Lu et al. 2016).

3.7. Wetland Creation

• Aggregate extraction sites operating in lowland areas of England were studied for their potential to provide habitat to wading birds through pond creation. Water quality, sediments, occupation by wading birds, and abundance of potential prey sources for the birds were compared between rehabilitated ponds and silt lagoons created during active quarrying for fines deposition. Wading birds made use of both
types but favored the rehabilitated ponds, possibly because of greater invertebrate prey resources; water quality was otherwise similar, though sediments were courser in the rehabilitated ponds. Increasing the substrate heterogeneity of silt lagoons and creating temporary ponds may increase invertebrate abundance and diversity, thereby providing more attractive habitats for target birds (Day et al. 2017).

- **Calcaceous fens** are highly desirable ecosystems when it comes to both mitigating and adapting to climate change. As wetlands in general, they filter water and control flooding and erosion, while as peatlands they store carbon efficiently. As the less-acidic, more nutrient-rich variant of peat bogs, calcaceous fens can harbor a high level of biodiversity at multiple trophic levels. Ontario researchers investigated the potential to promote calcaceous fen development at a disused limestone quarry by creating multiple connected shallow pools with a groundwater source. They experimentally transplanted a dominant sedge, *Carex aquatilis*, from a nearby natural fen, using cages submerged to different depths and containing various growth substrates. Regardless of growth substrate, sedge survival was 100% over three years; however, growth of new shoots from the transplanted material was much greater when fine screenings and topsoil were included in the cages than when fines or rocks alone were used. The topsoil treatment was even more successful than the much more costly addition of a fully intact peat ball with vegetation from the donor fen. While it was expected that seasonally fluctuating water table depth may constrain the success of transplanted *Carex*, this turned out not to be a problem, as transplants performed equally whether installed above, at, or below the spring water table level (i.e. +/- 15 cm) (Duval, Waddington & Branfireun 2010).

- Aggregate extraction and rehabilitation in riparian or lowland areas has potential to create ponds or other wetlands with high value as songbird habitat, but the role of climatic variability (e.g. rainfall, spring flooding) in providing this service is not well known. British researchers monitoring bird productivity (ratio of young to old birds captured) in a rehabilitated gravel pit over 18 years found that year-to-year climatic variation played as strong a role as local land management in shaping the productivity of both resident and migrant birds (16 species in total). Community composition most strongly shaped by the amount of winter flooding, rather than the amount of precipitation overall or seasonally. Surprisingly, year-to-year climatic variability played a stronger role than the passage of time and cumulative process of vegetation succession over the 18 years (Harrison & Whitehouse 2012).
References


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