Peatland Restoration Guide
Planning Restoration Projects

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INTRODUCTION

This booklet in the *Peatland Restoration Guide* series has been prepared to make available the new approaches to planning restoration projects developed since the 2003 publication of the *Peatland Restoration Guide, Second Edition*.[1] It is intended mainly for the horticultural peat industry, but may also be useful for those interested in restoring peatlands that have been drained and where the surface is largely bare peat. It is an update of the 2003 guide section covering the planning of restoration projects (pp. 13 to 24 of the English version).

This booklet begins with a brief review of the Moss Layer Transfer Technique and then gives details on the steps involved in planning restoration projects. The time and resources required for each step are also described.

MOSS LAYER TRANSFER TECHNIQUE

The Moss Layer Transfer Technique (MLTT) developed by the Peatland Ecology Research Group (PERG, Université Laval) for the restoration of peatlands (bogs, poor fens and moderate-rich fens) is based on active reintroduction of peatland plant species combined with rewetting through hydrological management. This technique has been used in over one hundred restoration projects in Canada as well as in many other countries. It makes it possible to bring back to the restored site over 80% of the species present in the plant material collected from a donor site, and it limits non-peatland plant species to only 3 to 6%. In addition, long-term monitoring of the vegetation (more than 10 years) shows a progressive decrease in these atypical species as the moss carpet develops. A study by PERG in collaboration with researchers at McGill University demonstrated beyond all doubt that a peatland was once again able to capture and sequester carbon 15 years after restoration.[2]

The success of the Moss Layer Transfer Technique is largely related to how well the restoration work is done, as well as the meteorological and hydrological conditions prevailing while the work is carried out. The MLTT involves the following steps:

- Planning;
- Preparing the sector to be restored;
- Collecting plant material from a donor site;
- Spreading the plant material;
- Spreading mulch;
- Fertilizing;
- Rewetting by blocking the drainage system; and
- Monitoring the restored sectors.

[1] Quinty, F. and L. Rochefort. 2003. Peatland Restoration Guide, 2nd edition. Canadian Sphagnum Peat Moss Association and New Brunswick Department of Natural Resources and Energy. Québec, Québec.

[2] Nugent, K., I.B. Strachan, M. Strack, N.T. Roulet and L. Rochefort. 2018. Multi-year net ecosystem carbon balance of a restored peatland reveals a return to carbon sink. Global Change Biology 24(12): 5751-5768.

This booklet focuses primarily on planning the restoration of *Sphagnum*-dominated peatlands. The distinction between reclamation, ecological restoration and rehabilitation[3] is further described in the following box.

RECLAMATION, ECOLOGICAL RESTORATION AND REHABILITATION

Reclamation is a general term that includes all work aimed at reclaiming a site after it has been altered. Ecological restoration and rehabilitation are both considered types of reclamation.

According to the Society for Ecological Restoration (SER), **ecological restoration** is the process of assisting the recovery of an ecosystem that has been damaged, degraded or destroyed. The goal of restoration is the return of the biological components and characteristics of a given reference ecosystem, a peatland in this case. Considering that peatlands are ecosystems that evolve over time, their restoration can aim at establishing conditions that differ from those present when the peatland was disturbed. For example, a *Sphagnum*-dominated peatland used for peat extraction could be restored as a poor fen dominated by sedges, knowing that the site will evolve over time toward the return of *Sphagnum* mosses that were present before peat extraction began.

In contrast, the goal of **rehabilitation** is to restore a disturbed or contaminated site to an acceptable and safe condition that includes minimal natural characteristics, regardless of the original ecosystem, such as planting trees in post-extracted peatlands or establishing vegetation cover on mining waste sites.

INTERNATIONAL STANDARDS FOR ECOLOGICAL RESTORATION

The restoration approach described in this guide is the result of many years of collaboration between Canada's horticultural peat industry and the scientific community, particularly the Peatland Ecological Research Group. It has been developed in response to the need to find ways of decreasing the environmental impact of human activities and is based on numerous trials and research projects aimed at developing and refining peatland restoration methods. This approach is also consistent with the *International Principles and Standards for the Practice of Ecological Restoration*[4] established by the Society for Ecological Restoration (SER). The SER is an international nonprofit organization that promotes the science and best practices of ecological restoration to benefit humans, biodiversity, ecosystems and the climate. The Society develops tools, publishes reference documents, disseminates information and establishes standards in order to define and share excellence in the field of ecological restoration.

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[3] Underlined words refer the reader to the boxes.

[4] Gann, G.D., T. McDonald, B. Walder, J. Aronson, C.R. Nelson, J. Jonson, J.G. Hallett, C. Eisenberg, M.R. Guariguata, J. Liu, F. Hua, C. Echeverría, E. Gonzales, N. Shaw, K. Decleer and K.W. Dixon. 2019. International Principles and Standards for the Practice of Ecological Restoration. 2nd edition. Restoration Ecology 27(S1): S1–S46. https://onlinelibrary.wiley.com/doi/10.1111/rec.13035

The International Principles and Standards apply to all types of ecological restoration. The approach described in this guide follows and is inspired by the eight fundamental principles of ecological restoration set out by the SER:

1. Ecological restoration engages stakeholders.
2. Ecological restoration draws on many types of knowledge.
3. Ecological restoration practice is informed by native reference ecosystems, while considering environmental change.
4. Ecological restoration supports ecosystem recovery processes.
5. Ecosystem recovery is assessed against clear goals and objectives, using measurable indicators.
6. Ecological restoration seeks the highest level of ecosystem recovery possible.
7. Ecological restoration gains cumulative value when applied at large scales.
8. Ecological restoration is part of a continuum of restorative activities.

More specifically, the *International Principles and Standards* provide guidelines for planning, implementing, monitoring and maintaining ecological restoration projects that are applicable and pertinent in the peatland context.

PLANNING PROCESS

The planning process should begin before extraction operations cease in a peatland sector,[5] in order to reduce the period during which the sector is drained and devoid of vegetation. Postponing the restoration results in additional procedures and cost increases, and reduces the chances of success. Over time, the environmental conditions and the characteristics of the remaining peat deteriorate, which can lead to decreased water-holding capacity due to oxidation and decomposition, surface disruption due to frost heaving, formation of a surface crust and so on. Longer delays before beginning restoration work also increase the risk of undesirable plant species colonizing the sector.

In the context of fighting climate change, rapid restoration after peat extraction also helps avoid releasing of large amounts of greenhouse gases (GHG). Such emissions are greatly increased when the peatland surface is dry and devoid of vegetation. According to a study on GHGs, immediate restoration offsets the impact of extraction activities 155 years faster than if a site's restoration is delayed 20 years. If a sector cannot be restored quickly, it is better to block the drainage ditches to raise the water level until the work can be done.

As a rule, it is easier to properly manage the blockage of drainage ditches when adjacent sectors are restored simultaneously. It is therefore worthwhile to coordinate sector closures and the ensuing restoration work to encompass larger areas.

[5] The term "site" refers to a peat extraction site, i.e. a peat bog. The term "sector" describes a homogeneous area affected by the same drainage network, and is the scale at which restoration must be planned. A sector includes a number of peat fields, which are separated by secondary drainage ditches. However, for ease of reading, the terms "site" and "sector" are both used in this document to designate areas undergoing restoration.

For all these reasons, it is recommended that, from the outset, a site development plan includes each sector's anticipated production end date to facilitate the eventual restoration of the entire site. Therefore, restoration planning should begin well before a sector is closed. All restoration and rehabilitation projects should begin with the preparation of a detailed plan in order to make sure that suitable options for a given sector are identified and to estimate the time and resources needed to implement them. There are two main steps in planning a restoration project:

1. Defining the project; and
2. Planning the work.

In the project definition step, the options most likely to be successful are selected according to the characteristics of each sector. The goal and objectives the project is intended to accomplish are also clearly defined. **The goal of peatland restoration is to re-establish the ecosystem and its functions, including peat accumulation and biodiversity**. The project should also include specific objectives leading to specific actions with measurable results, so that the success of the project can be monitored and evaluated.

The purpose of the planning step is to precisely describe the procedures to be used to reach the objectives, including the methods, resources and schedule, as well as an estimation of the costs.

DEFINING THE RESTORATION PROJECT

Defining a restoration project involves analyzing the factors that influence the required restoration work, particularly with respect to site preparation. This analysis might also lead to choosing to restore the site to a state other than a *Sphagnum*-dominated peatland; for example, establishing a fen or other type of wetland. When the conditions are not conducive to these alternatives, other reclamation options such as planting trees can be considered. To ensure that the best option is chosen, the factors specific to each sector should be analyzed in depth at the beginning of the planning process.

Characterizing the Sector

Despite the similarity of the peat extraction methods used across the industry, site conditions can differ significantly from one peatland to the next once extraction activities cease. The thickness of the peat deposit, the type of peat, the nature of the underlying mineral substrate and the topography all contribute to these differences. A precise characterization of the sectors to be restored is therefore needed to ensure the most suitable restoration options and methods are selected.

The purpose of the characterization is to collect information on the conditions of the sector to be restored:

A. Characteristics of the ecosystem before disturbance
B. Characteristics of the sector to restore
   i. Hydrological conditions
   ii. Topography
   iii. Peat characteristics
   iv. Chemical aspects
   v. Existing vegetation
C. Characteristics of the surrounding environment
D. Source of plant material

A. Characteristics of the Ecosystem before Disturbance

In its natural state, each peatland will have its own set of characteristics and conditions (e.g., open or forested terrain, presence or absence of bog pools, specific plant communities). It may also have been affected by other activities that modified those conditions even before peat extraction began. Identifying the elements previously present in the sector can help guide the selection of elements to be re-established or to be considered during restoration work (e.g., bog pools). Knowledge of the original conditions also helps interpret the results of the restoration project during monitoring. For example, we can expect trees to establish if the peatland was forested in its original state.

Information about the pre-disturbance conditions of the peatland can be gathered from various sources:

- Geological reports, ecological descriptions, maps, environmental impact studies, vegetation surveys;
- Old and more recent photographs, both aerial and taken at ground level;
- Testimonials from peatland workers and people from the area;
- Paleoecological evidence and dendrochronology; and
- Similar nearby natural peatlands or natural sectors within the same peatland used for peat extraction.

The pre-disturbance characteristics of the ecosystem influence:

- The type of elements that can be included in the restoration plan; and
- The interpretation of the monitoring results.

B. Characteristics of the Sector to Restore

i. Hydrological conditions

The potential for rewetting is an essential consideration for the restoration of peatlands because of the key role water plays for all wetlands. However, the capacity of natural peatlands to store water and regulate water table level fluctuations is diminished when they are drained. The hydrological conditions of the sector post-extraction should be examined to evaluate the potential for rewetting and to prepare water management strategies that will ensure a sufficient water supply for *Sphagnum* mosses and other plants to establish.

Potential water losses should be identified as well as any constraints to blocking ditches and raising the water table. Such constraints could include the size of the sector to be restored, adjacent sectors that are still in production, drainage ditches bordering the sector to be restored that must remain open or the partial loss of the impermeable layer at the bottom of the ditches.

SIZE OF THE SECTOR TO BE RESTORED

As restoration operations require the use of machinery, these projects are usually carried out on an area at least 1 hectare (ha) in size. It is easier to raise the water table and create hydrological conditions appropriate for the establishment of peatland plants on one large sector than on several smaller peat fields adjacent to areas still in use for peat extraction. Keep in mind that drainage ditches affect the water level approximately 15 m on each side: the water table in restored sectors near active ditches will thus be lower, which will have repercussions on the establishment of plants.

Restoration should be done in sectors where the ditches can be blocked, which is generally the case when large areas are closed. In addition, when restoration work is carried out on larger areas, this facilitates the movement of machinery, increasing the efficiency of all operations. It also generally decreases the costs, due to economies of scale and time. Clearly, if the sectors are too small or located too close to sectors still in production, it may be preferable to postpone their restoration.

For smaller areas, as may be the case in protected areas or locations where vegetation has been removed for the construction of oil drilling structures, it may be possible to use smaller machinery, such as all-terrain vehicles (ATVs) or amphibious ATVs (e.g., Argo®), and equipment adapted to them. Nonetheless, experience suggests that restoration on large areas yields better results, especially regarding hydrological conditions.

While preparing the restoration plan, natural areas adjacent to the restoration sector should be taken into consideration because they are the main source of water supply for the restoration sector, other than precipitation, helping to maintain favourable hydrological conditions. On the other hand, water coming from environments other than peatlands could negatively affect the vegetation if the water chemistry is not appropriate.

The hydrological conditions determine the following:

- The potential for rewetting and restoring hydrological conditions suitable for peatland plants; and
- The strategy for preparing the sector for rewetting.

Action items:

- Identify potential water sources and determine their chemical characteristics (see also point iv. on chemical aspects);
- Identify possible water losses;
- Determine the constraints to raising the water table;
- Examine the surrounding drainage network.

ii. Topography

Topography directly affects water distribution and movement, two factors that in turn directly impact the conditions for plant establishment. It is important to distribute water as evenly as possible over the restoration site and avoid creating spots that remain flooded or dry for long periods. Water runoff on the peat surface can wash away or redistribute the reintroduced plant material and the protective layer of straw, as well as erode the peat layer on the surface or around water-retention earthworks. In sloped sectors, peat dikes should be built to distribute the water as evenly as possible and to control its movements. In certain cases, the higher elevation or peat mounds at the ends of former peat fields may prevent adequate rewetting; in such situations, another restoration option must be chosen. Similarly, sharp elevation differences between the sector being restored and the adjacent natural environment can make restoration ineffective in that transition zone. These areas should be carefully characterized in order to plan the most appropriate reclamation operations.

On a smaller scale, the topography within each peat field to be restored must be taken into consideration. Most fields have a convex profile to ensure rapid water drainage during peat extraction. Their surface needs to be flattened so that water can be more evenly distributed on the entire surface. In addition, all topographical features (mounds, outcrops, road edges, wet depressions) should be noted in order to properly plan the reprofiling operations. Profile modification of each peat field should be included in the restoration plan.

A field survey should be conducted to create a topographical map that will help plan the preparation of the sector. Topographical measurements should be taken at numerous points on each peat field, wherever an elevation change is suspected, as well as along transect lines across the sectors to be restored—up to the surrounding natural environments when possible. This can be done relatively easily using surveyors' instruments or through the services of a surveyor. Recording LiDAR elevation data on a map makes it easy to visualize the preparation needed to reprofile the terrain so that only gradual slopes remain (Figure 1). Drones and lidar data are now available free of charge in certain regions, making it possible to prepare a digital elevation model that provides high-resolution imaging of the topography. These data open up the possibility of determining the area affected by blocking a certain drainage ditch or to identify the number and location of dikes to be built. Although a simple visual assessment of the slopes can also help determine the places where dikes are needed, this method is not recommended.

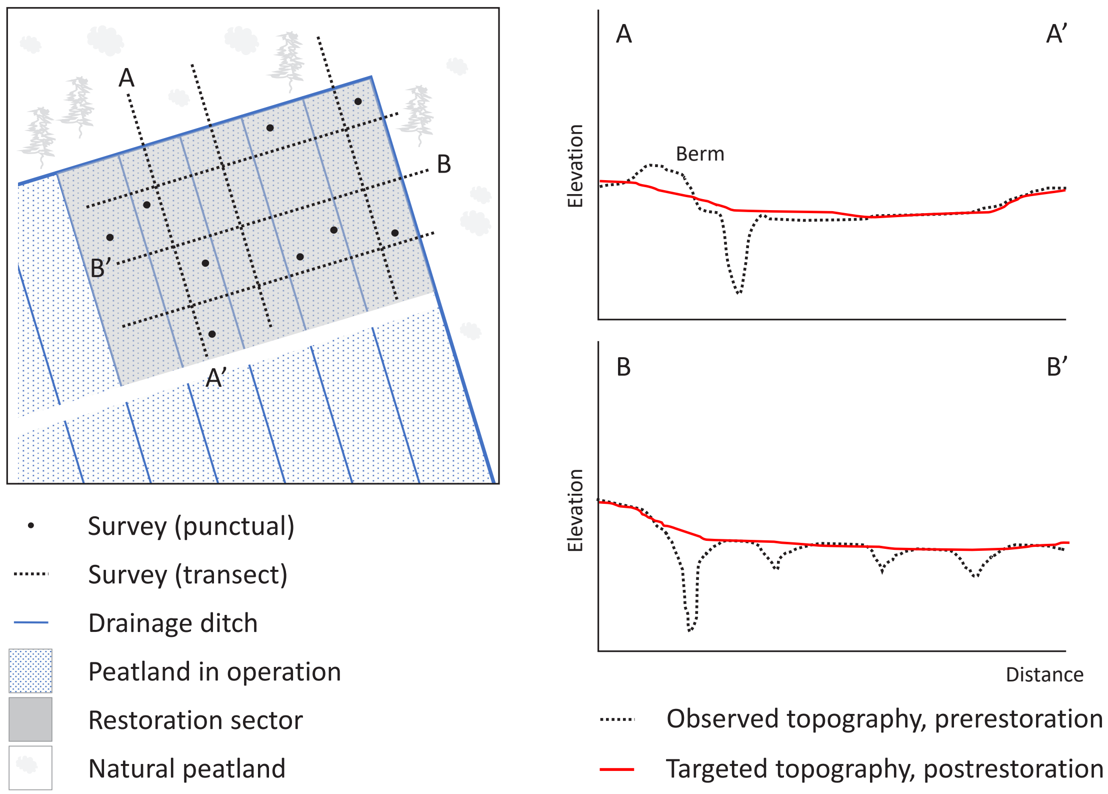

Figure 1. Example of location of topographic surveys (left) and profiles along two transects (right; A and B) of a sector to be restored.

Topography determines the following:

- The procedures needed to prepare the sector;
- The location of dikes;
- The area affected by blocking ditches;
- The local potential for rewetting; and
- The possibility of creating pools in naturally wetter areas.

Action items:

- Conduct a topographic survey or create a digital elevation model of the sector;
- Identify peat fields that are convex;
- Identify areas where the topography should be reprofiled.

iii. Peat characteristics

Good restoration plans should include information about the characteristics of the residual peat, such as its thickness, dominant plant composition (*Sphagnum* mosses, sedges, etc.) and the degree of decomposition on the von Post scale. This information is essential to choosing the most appropriate option for reclamation. When the remaining peat layer is thin, the roots of plants can easily reach the underlying mineral substrate. In addition, the surface water may be enriched with nutrients, favouring the establishment of undesirable species and possibly hampering the growth of peatland species. The presence of mineral material (e.g., clay, sand, gravel) on the remaining peat surface—as may result from cleaning drainage ditches—should also be taken into consideration when planning the work. In addition, the water-retention capacity of highly decomposed peat is poor, creating variable moisture conditions that are not conducive to establishing *Sphagnum* mosses.

It is difficult to determine the minimal peat thickness necessary to support the restoration of *Sphagnum*-dominated peatlands. Following the precautionary principle, a peat layer at least 50 cm thick should be left in place, although favourable ombrotrophic (bog) conditions can sometimes be present in areas with thinner layers of peat. Thin sedge peat layers are often found at the end of peat fields located at the peatland margin. In these cases, reclamation should be chosen over restoration. In all cases, it is preferable to rely on peat chemistry and botanical composition instead of its thickness solely.

The characteristics of the surface peat should also be examined before undertaking preparation of the sector. There is often a loose layer of peat remaining from the last harrowing of the peat fields. This loose peat layer is unstable and very susceptible to erosion and frost heaving. Peat fields that have been out of production for some time may develop a fine "biological crust" composed of a mixture of cyanobacteria, lichens, algae, mosses and liverworts. Loose peat or a biological crust can prevent the plant material fragments from accessing the moisture of the underlying peat deposit that would otherwise reach the surface through capillary action. It is thus essential to refresh the surface of the peat before spreading the plant fragments. This topic is addressed in the booklet on **Site Preparation and Rewetting**, part of the *Peatland Restoration Guide* series.

The following are determined from the peat characteristics:

- The choice between restoration as a *Sphagnum*-dominated peatland or as a fen, or other reclamation options; and
- The site preparation procedures.

Action items:

- Measure the thickness of the remaining peat;
- Determine the type of peat (i.e., *Sphagnum* peat, sedge peat, etc.);
- Determine the degree of decomposition using the von Post scale;
- Identify the type of mineral substrate (e.g., clay, sand, gravel) underlying the peat deposit and any areas where mineral material is present on the surface;
- Make note of any loose peat, frost heaving or biological crust on the surface of the peat fields.

FROST HEAVING

Frost heaving occurs when the temperature fluctuates around the freezing point (freeze-thaw cycles) and when the ground is very wet (Figures 2 and 3). When frost penetrates the surface of the peat, the water in the soil is drawn toward the surface where it freezes, forming ice needles and crystals. The peat and any plant fragments on the surface are lifted by the ice. When the ice thaws, generally in the hours following an overnight frost, the peat particles and plant fragments settle onto the surface. When this cycle is repeated, it loosens the peat, mixes the plant fragments with the peat and impedes root development. It can even break up *Sphagnum* carpets and uproot newly established seedlings. Frost heaving creates a distinctive microtopography which is very prone to erosion and often stays devoid of vegetation.

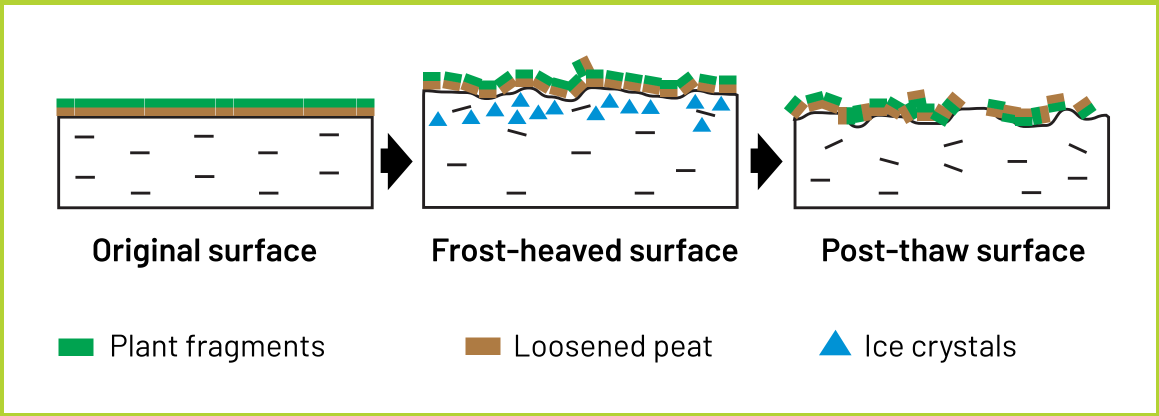

Figure 2. Disturbance of the peat surface and plant fragments caused by frost heaving.

Figure 3. Typical microtopography that forms at the peat surface following frost heaving (on the left).

iv. Chemical aspects

A chemical analysis of water and remnant peat should be conducted to make sure the conditions are appropriate for the establishment of plants typical of *Sphagnum*-dominated peatlands. For most sites, pH and electrical conductivity tests are sufficient to determine what type of peatland (ombrotrophic or minerotrophic) the remnant peat conditions are more similar to. As a general rule, **the maximum recommended thresholds for the restoration of *Sphagnum*-dominated peatlands are 5.5 to 5.8 for pH and 100 to 140 μS/cm for electrical conductivity.** Measurement of the concentration of minerals such as calcium (Ca), magnesium (Mg) and potassium (K) in the residual peat can provide complementary data that may be helpful in decision-making. To restore a *Sphagnum*-dominated peatland, the concentration of these cations should not exceed 5 to 9 mg/L for Ca, 4 to 8 mg/L for Mg, and 0.5 to 2 mg/L for K. Note that coastal peatlands will have higher electrical conductivity if the concentration of sodium (Na) from sea salts is high. When the testing results show higher mineral content, it is appropriate to consider restoring the site as a minerotrophic peatland (fen). When the environment is considered rich in nutrients (i.e., nitrogen and phosphorus), restoration as a marsh, swamp or tree plantation may be viable options. Relatively high levels of Ca are detrimental for *Sphagnum* mosses, and higher levels of nutrients, particularly nitrogen and phosphorus, can favour the establishment of undesirable species.

The chemical aspects determine the following:

- Which reclamation option to consider, whether to restore the site as a peatland (either *Sphagnum*-dominated peatland or fen) or rehabilitate it as another type of wetland; and
- The probability of invasion by undesirable species.

Action items:

- Measure the pH and electrical conductivity of the water and the peat;
- Analyze the calcium, magnesium, potassium and sodium levels, as well as the nutrient levels (nitrogen and phosphorus).

v. Existing vegetation

After peat extraction activities are discontinued on a site, it may be colonized by diverse plant communities if no interventions are made for several years. Vegetation generally begins growing near ditches, where the conditions are wetter and sometimes more nutrient rich. Vegetation must be removed when the sector is prepared, with two exceptions:

1) In very wet areas where it would be very difficult to bring in machinery in any case; and
2) In areas where graminoid species are densely established, which may be an indicator of minerotrophic conditions that would dictate restoration as a fen.

In all cases, the plant species present should be identified, because they are a useful source of information about the site's chemical and hydrological characteristics.

Experience from restoration projects has shown that invasive species such as the common reed (*Phragmites australis*) or birch (*Betula* spp.) can rapidly colonize sectors that are to be restored. These very competitive species can limit access to resources by other peatland plants, compromising their establishment and growth. The presence of these species in or near the sector to be restored must be taken into consideration when planning the restoration project and when deciding whether to restore or rehabilitate the site.

The restoration procedures can then be adapted depending on the propagation methods of the invasive species. For example, restoration work can be carried out outside the seed dispersal period of these species, or effort can be made to avoid the introduction of diaspores (rhizomes, roots, etc.) into adjacent areas where these species are not established.

The existing vegetation determines the following:

- The choice between restoration as a *Sphagnum*-dominated peatland or as a fen, or rehabilitation; and
- The site preparation procedures.

Action items:

- Identify the dominant species (peatland, non-peatland or invasive species) and species that serve as indicators of mineral enrichment;
- Determine the extent of plant cover (dense, dispersed, etc.);
- Identify the species growing within or near the restoration site that could become invasive.

C. Characteristics of the Surrounding Environment

Many peatlands used for peat extraction are located within large wetland complexes. A careful study of the hydrogeomorphological situation of the peatland can reveal indicators of the evolution of the sector to be restored. For example, in Manitoba, many *Sphagnum*-dominated peatlands are in fact ombrotrophic islands inserted into vast fens. It would therefore not be surprising for a restored sector to be influenced by the nutrient-rich water from the surrounding landscape.

The surrounding environment and human activities also impact the potential for rewetting. For example, it is difficult to restore peatlands surrounded by agricultural fields, because agricultural drainage can lower the water table over an entire region.

Action items:

- Identify the nature of the adjacent land (natural peatland, agriculture, forestry operations, urban development, industrial park, etc.);
- Determine the regional direction of water drainage for the larger area in which the ecosystem is found.

D. Source of Plant Material

Because the Moss Layer Transfer Technique is based on an active introduction of typical peatland vegetation, a large enough source of good-quality plant material is critical to the success of any restoration project. During the planning stage, it is important to make sure that sufficient plant material is available and that it is composed of the species targeted for the restoration of *Sphagnum*-dominated peatlands (see the booklet **Plant Material Collecting and Donor Site Management**, part of the *Peatland Restoration Guide* series).

The source of plant material determines the following:

- The choice between restoration and rehabilitation; and
- The plant collection procedures.

Action items:

- Assess the abundance of *Sphagnum* mosses present on the donor site and the species composition of the plant cover.
- Determine the size of the donor site pending on the size of the sector to be restored.
- Evaluate access to the donor site.

Choosing the Reclamation Option

Based on the information collected during the characterization of the sector and on the prevailing conditions, the most appropriate reclamation option can be selected: restoration as a *Sphagnum*-dominated peatland, a fen or other type of rehabilitation.

The restoration of a *Sphagnum*-dominated peatland using the Moss Layer Transfer Technique requires two essential conditions:

- The possibility to create hydrological conditions ensuring enough water is available to the plant material spread on the surface. The potential for rewetting should therefore be determined for the sector to be restored.
- The appropriate chemical conditions for *Sphagnum*-dominated peatlands must be present, because *Sphagnum* species are intolerant of high-pH conditions and environments rich in calcium, nitrogen or phosphorus. The type of peat, its degree of decomposition, the presence of invasive species, and the chemical analyses of the water and peat can all be used as indicators of good or poor conditions for restoration. Conditions can vary within a given peat field, so the entire sector to be restored should be surveyed.

These two factors should be considered jointly, and their influence on the chances of a successful restoration must be assessed. Another reclamation option should be chosen if there is little probability of the restoration succeeding.

PLANNING THE WORK

Once the conditions of the sector have been analyzed to select the type of restoration to perform (i.e., the project goal), the next step is to prepare the restoration plan. In this critical step, each of the operations is set out and described in some detail. Planning the operations is a very important factor in the success of the restoration for many reasons:

1. **Planning allows the restoration work to be integrated into the normal flow of peat extraction operations.** For example, with coordination, plant material can be collected from the areas being opened for extraction and then be used for restoration.
2. **Planning ensures that the most appropriate operations are carried out in the right place, at the right time and in the right way.** The Moss Layer Transfer Technique is based on introducing plants whose successful establishment depends on a series of factors associated with each restoration operation. The fact that living plant material requires special precautions and care should be kept in mind at all times.
3. **Planning ensures that the required equipment, materials and staff are available when they are needed.** Unforeseen delays between the restoration steps can significantly impact the success of the project. For example, if too much time passes between spreading the plant material and spreading the straw mulch, the survival of the mosses can decrease because they are very susceptible to desiccation. Early snowfalls can also impede restoration work.
4. **Planning allows data to be collected on the work progress** and helps refine peatland restoration methods. All the information about the work should be documented, including characterization of peat fields before peat extraction, the donor site vegetation, the time needed to carry out each task and details on the progress of the operations. Analysis of this information, combined with the data collected on plant establishment and on the hydrological regime of the restored sectors, will help identify the factors responsible for the success or failure of the restoration. Having all this data from diverse restoration projects leads to developing and improving peatland restoration methods.
5. **Planning reduces restoration costs.** If all the above recommendations are put into practice, the planning process will definitely reduce the cost of the restoration through efficient management of time, staff and materials.

PREPARING THE RESTORATION PLAN

The preparation of a restoration plan provides an invaluable tool for managing the restoration project, helping to ensure that the operations are carried out smoothly and providing an estimate of the costs.

RESTORATION PLANS

There are two types of restoration plans:

Conceptual plan: A conceptual restoration plan can be prepared to comply with regulatory requirements or in the early stages of a project. It is commonly required to obtain authorizations before carrying out activities that will affect a peatland. It is called a conceptual plan because, in general, it is not based on the observed conditions of the sector, but rather on the expected conditions when extraction operations end. It includes the following: a general description of the sector; the goals and objectives based on the options approved by legislation (peatland restoration, forest habitat, creation of pools, etc.) and their chances of success; a summary of the methods that will be used; and a map indicating the sectors of the peatland where the restoration work will be carried out. It also includes a monitoring program. The conceptual plan is not covered by this restoration guide because each institution has its own requirements and guidelines.

Operational plan: An operational plan is what is meant by a "restoration plan" in the context of this guide. It is the road map used by the point person for the restoration project. It is based on the conditions observed in the sector to be restored once extraction operations are ended.

A restoration plan should include the following:

- A **map of the sector** to be restored indicating:
  - the restoration area and its dimensions;
  - the donor site and its dimensions (on another map if necessary);
  - the access roads and traffic areas;
  - the storage areas for plant material;
  - the drainage network and places to be blocked or modified;
  - the topographical data, including areas where the topography must be modified;
  - the planned location of dikes; and
  - the planned location of pools or other elements to be put in place.
- **A detailed description of each of the operations** including:
  - the type of work;
  - the timeframe for completion;
  - the required machinery and equipment;
  - the required input materials; and
  - the required staff.

While some restoration steps consist of relatively simple tasks (i.e., spreading the plant material and straw), the work associated with preparing the sector must be well planned out in advance to ensure it is properly carried out and goals are achieved. For example, the placement of the surface peat collected when levelling peat fields; the width and height of the dikes; and the location, size and depth of pools should all be determined in advance.

The **timeframe for completion of each operation** is one of the most important elements of the plan, because the purpose of planning is to anticipate future activities. The activities can be listed in chronological order with deadlines, even if these are approximate dates. Some operations can be carried out at any time of the year, while others require specific weather conditions. The schedule helps ensure that the required staff is available at the right time and place.

It is important that the **appropriate machinery and equipment** be available and in good working condition. Machinery and equipment not normally used for peat extraction, such as spreaders for plant material, straw and fertilizer, may have to be leased. An equipment rental service should be selected in advance, and the availability of machinery in good working order and appropriate to peatland conditions should be verified. The ground pressure of the machinery (the weight vs. the number and type of tires) is particularly important, and it may be necessary to modify the machinery to avoid getting bogged down (e.g., by doubling the wheels). That is also true for machinery that peat producers may already own but that is normally at a different production site, such as a levelling auger or a rototiller that must be brought in to the restoration site.

The **restoration supply material** is generally limited to straw and fertilizer (see the booklet on **Spreading Plant Material, Straw and Fertilizer**, part of the *Peatland Restoration Guide* series). Straw must be located and purchased in advance, at the right time of the year (i.e., before the harvest), and brought into the restoration site. If straw is not procured ahead of time, it will have to be purchased from a reseller at a higher cost and possibly from farther away. Fertilizer should also be ordered in advance to avoid back orders and delays.

Planning helps ensure the availability of the **required staff** for each operation. This is very important, as restoration work often takes place outside the normal period for extraction operations (sometimes in winter), when some seasonal workers may not be available.

PLANNING FOR MONITORING

Restoration monitoring is not limited to collecting data on plant establishment. It begins at the planning stage by recording the characteristics of the sector to be restored and the donor site, as well as all the details on how the restoration work will be carried out. This information can help in planning the needed monitoring tasks and in identifying the factors that contribute to the eventual success of the restoration or any sector-specific problems.

Monitoring should include regular visits to the restored sector, especially during the spring thaw and intermittently during the first year following completion of the restoration work, so that any problem can be detected and corrected quickly. Special attention should be paid to structures blocking the drainage ditches and to dikes, which could fail during the first spring freshet or possibly lead to flooding of a sector.

All the previously mentioned elements and observations can be compiled into a single document that will serve as the logbook for the restoration work. Any change made to the established restoration plan can also be noted in this document, in order to keep a record of the operations for future reference and later follow-up.

RESOURCES, TIME AND COSTS

According to a 2011 estimate based on data from the Canadian horticultural peat industry and consultants, restoration planning requires on average one hour per hectare, and an additional hour per hectare for technical support. These numbers should be interpreted with care, because many factors have a bearing on the time needed for this stage.

Planning includes collecting and analyzing data before the start of the project as well as preparing the operational plan (tasks, resources, staff, schedule, etc.). It also includes the administrative management of the restoration project. Technical support covers those tasks that need to be completed by specialized staff, such as chemical analyses, mapping and topographical surveys. Some tasks may be considered fixed costs because they require a similar amount of effort regardless of the size of the sector to be restored. Purchasing inputs, coordinating the availability of equipment and machinery, and administrative management are among these. On the other hand, data collection and analysis can require a considerable amount of time. For this step, the manager's experience and the project's complexity have a major impact on the number of hours devoted to the restoration project. In addition, some or all the technical support may have to be provided by outside consultants, increasing the costs.

SUMMARY

- Coordinate the activities for opening and closing sectors within a peatland in order to restore areas as large as possible and as soon as possible after peat extraction ceases.
- Precisely determine the conditions of the sector to be restored, because they will dictate how best to proceed. These elements should be evaluated:
  - Hydrological conditions: potential sources and losses of water.
  - Topography: elevation data within and around the sector.
  - Peat characteristics: thickness of the residual deposit, type of underlying material.
  - Chemical aspects: especially pH and electrical conductivity.
  - Existing vegetation: plant cover, invasive plants.
- Use the Moss Layer Transfer Technique to evaluate the two critical factors for restoration: the potential for rewetting and the chemical aspects appropriate for *Sphagnum*-dominated peatlands.
- Prepare a restoration plan including a map of the sector to be restored indicating the earthworks and structures to put in place (e.g., donor site, dikes, ditch blockage, etc.), as well as a list of all the operations to be carried out.
- Establish a detailed schedule for the project to ensure that each step of the work goes smoothly and that all the necessary equipment, materials and staff are available when needed.

Appendix A – Example of a map presenting the characterization of a peatland sector before restoration (restoration project in Saint-Fabien-sur-Mer, Québec)

Appendix B – Example of a restoration plan (restoration project in Saint-Fabien-sur-Mer, Québec)

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