Guide for In Situ Reclamation in the Oil Sands Region of Alberta

Reclaiming In Situ Pads and Roads to Peatlands

April 30, 2017

Prepared by:

This page was intentionally left blank.

Contents

Figures:

Tables:

Acknowledgements

Sincere thanks are given to all individuals who have participated in the production of this report. A total of 30 pages of comments were received from 7 COSIA members and third-party reviewers. Third party reviewers included Susan McGillivray (Alberta Environment and Parks), Margaret Magai (Alberta Energy Regulator), and Amanda Schoonmaker and Bin Xu (NAIT Boreal Research Institute). We particularly thank the NAIT Boreal Research Institute for meeting with us and providing their insights on peatland reclamation. We also particularly appreciate the leadership provided by Judy Smith (Shell) and Jeremy Reid, who co-chaired the COSIA – EPA Led Study Steering Committee, and Jack O'Neill (COSIA) who ensured that everything ran smoothly.

Foreword

The Guide for In Situ Wetland Reclamation in the Oil Sands Region of Alberta – Reclaiming In Situ Pads and Roads to Peatlands document (the Guide) was prepared for Canada's Oil Sands Innovation Alliance (COSIA) to document, in one place, pilot projects conducted in Alberta for the reclamation of In Situ facilities placed in peatlands. These pilot studies were carried out by various parties and efforts in order to evaluate the feasibility, cost, and future performance of the reclamation techniques employed. We hope that this guide can be used as a starting point in future reclamation projects. As more projects are completed, new knowledge should be incorporated into future editions of this document. Eventually, the state of practice will reach the point where the reclamation of pad and road sites to peatland will be ready for large-scale implementation.

1.0 Introduction and Background

1.1 Introduction

The intended audiences for the Guide are those who are involved in wetland reclamation planning, design, and operations. The Guide is designed to be used as a workbook - walking through the milestones and steps involved with planning for, designing, and constructing a peatland in a peatland environment. It can also be used as a reference for In Situ company managers, regulators, stakeholders and consultants.

The objectives of the Guide are as follows:

1. Aid in the preparation of detailed wetland reclamation plans.
2. Provide practical operational guidance for wetland reclamation activities.
3. Provide a framework and structure that enables effective documentation of a wetland reclamation project from start to finish.
4. Provide guidance towards attaining healthy aquatic ecosystems, self-sustaining wetlands, and land function and operability that are a close approximation of natural regional conditions.
5. Support successful reclamation.

1.2 Regulatory Background

REGULATIONS, APPROVALS, AND COMMITMENTS

Where an Environmental Protection and Enhancement Act (EPEA) Approval has been issued for oil production sites, operators are to utilize Specified Enactment Direction 001 (AER, 2016) to guide preparation of applicable planning documents such as pre-disturbance assessments (PDA) and project-level conservation, reclamation, and closure plans (PLCRCP). When an area is ready for reclamation (from SED 001), the closure plan previously submitted (PLCRCP) should be reviewed and discussions should occur with the appropriate regulator to discuss the development of a detailed (site-specific) reclamation plan. The detailed reclamation plan should be aligned with the PLCRCP.

The Guide assumes that the EPEA Approval, regulatory conditions listed for the lease agreement, and any other provincial/local commitments are followed.

The Alberta Water Act (Government of Alberta, 2000) dictates that regulatory Approval is needed where activities affect a water body, which is defined as “any location where water flows or is present, whether or not the flow or the presence of water is continuous, intermittent or occurs only during a flood, and includes but is not limited to wetlands and aquifers”. Thus, with respect to wetland reclamation, a Water Act Approval and/or License may be required prior to development if excavating into the water table or for approval of the reclamation design if there is water impoundment (Table 1).

The Alberta Wetland Policy (Government of Alberta, 2013), which is enabled by the Water Act and Public Lands Act, was developed to minimize the loss of wetlands; to conserve, restore, protect and manage Alberta's wetlands in order to sustain the benefits they provide to the environment, society and economy. It applies to activities that directly or indirectly affect wetlands. All users of The Guide should be familiar with the Alberta Wetland Policy and consult the appropriate regulator to understand how the Policy may apply to individual wetland reclamation projects.

Under the Forests Act (Alberta Queen's Printer, 2000) and Timber Management Regulation (Alberta Queen's Printer, 1973), reclamation planners must follow the Alberta Forest Genetic resource Management and Conservation Standards if they decide to collect native seeds or plants for reclamation purposes (GOA, 2016b). Under the regulation, operators who want to collect seeds or plants will need to apply for Temporary Field Authorization (TFA).

The Guide assumes necessary regulatory Approvals have been obtained prior to commencing wetland reclamation activities. Consultation with regulators is critical to ensure compliance with regulations and identify expectations for the project.

THE IMPORTANCE OF DOCUMENTATION

Documentation of reclamation activities is a regulatory requirement for a Reclamation Certificate application. It is imperative to document and keep records of project activities as they occur.

Through the use of forms, checklists, and decision flow-charts, this document has been built to assist the user with project documentation.

Table 1: Legislation that may apply to peatland reclamation.

Legislation	Jurisdiction	Description
Fisheries Act	Federal	The federal fisheries act protects fish and fish habitat under Section 35, which is administered by the Department of Fisheries and Oceans (DFO). Given that peatlands typically do not contain fish habitat, it is unlikely that the Fisheries Act applies.
Migratory Birds Convention Act	Federal	Provides best management practices to preserve and protect habitat necessary for the conservation of migratory birds, including their nest within Canada. Timing restrictions for vegetation clearing are in place based on general nesting periods of migratory birds in Canada.
Species at Risk Act	Federal	SARA helps to prevent Canadian indigenous species from becoming extirpated or extinct. It also aids in the recovery of threatened and endangered species through species lists. Activities may be restricted if Species at Risk inhabit or breed in the project area.
Forest Act / Timber Management Regulation	Provincial	Reclamation planners must follow the Alberta Forest Genetic Resource Management and Conservation Standards (GOA, 2016b) if they decide to collect native seeds or plants for reclamation purposes. Under the regulation, operators who want to collect seeds or plants will need to apply for Temporary Field Authorization (TFA).

Legislation	Jurisdiction	Description
Water Act	Provincial	A Water Act Approval is required where activities alter or may alter flow, level, or location of water by collecting runoff or groundwater. A Water Act Licence is required for impoundment, consumption, taking, or removal of water by collecting runoff, groundwater, or precipitation
Weed Control Act	Provincial	Weeds refer to plants identified in *Part 2, Section 8* of the *Weed Control Regulation.* The holder of this area is legally responsible to control noxious weeds and destroy prohibited noxious weeds if found within the project area.
Wetland Policy	Provincial	As per the Water Act (see above), the Wetland Policy requires Approval for activities that directly or indirectly affect wetlands. Wetland replacement is required when wetland impacts that cannot be avoided or minimized will result in permanent loss of wetland area. The Wetland Policy typically applies for new activities planned after the Policy came into force in the Green Zone on July 4th, 2016. As per the *Wetland Mitigation Directive*, wetlands constructed in advance of, or soon after, permanent wetland losses have been incurred may be used to fulfill replacement obligations (permittee-responsible replacement).
Wildlife Act and Wildlife Regulations	Provincial	The *Wildlife Act* prohibits the disturbance of houses, nests, or dens for certain species at certain times of the year, except where done under specific license or authorization. Wildlife types and classifications, regions, and timings are identified within the *Wildlife Regulations*.

1.3 How to Use the Guide

This document is intended to be used as a workbook to develop and implement the site reclamation plan. The task list form in Appendix 1 is meant to assist the user in tracking progress towards achieving wetland reclamation tasks and milestones. The front end of The Guide (Milestone 1) will be most useful in detailed reclamation planning. Subsequent sections (Milestone 2-4) will guide reclamation activities and construction.

The following symbology has been used in the document to assist the reader in sifting through the material.

- ▽ Critical project consideration. Failure to consider the topic may significantly affect the outcomes of the project.
- ! Particular attention should be paid to this topic to ensure successful outcomes.
- ✓ Good practice that should be followed.
- • Important factual information.

Assumptions made in the production of this document include:

1. It is assumed best management practices have already been conducted meeting the regulatory requirements for soil conservation.
2. Any contamination issues have been addressed.

3. The vegetation acquisition processes addressed in this document assume the reclamation plans have accounted for the timing involved regarding seed collection and appropriate permits, seedling propagation, and/or nursery procurement.
4. Suitable hydrological and geochemical conditions for peatland development (which may not be the case for all sites) have been accounted for and appropriate revegetation techniques selected.
5. Most importantly: **The Guide does not supersede EPEA conditions, or any other permits or commitments.**

1.4 Reclamation Goals & Objectives

Wetlands will be reclaimed to either upland and/or wetland ecosites, depending on site conditions and operational considerations. This document presents guidance with the goal of re-establishing one or more wetland site-types that resemble pre-disturbance wetlands of the local area and have hydrological connectivity with the surrounding wetlands and/or uplands. These reclamation procedures are based on natural wetland initiation processes that have occurred in Alberta during the last 12,000 years.

Natural pathways of wetland initiation in Alberta include terrestrialization (in-filling of water-bodies), paludification (swamping of previously vegetated upland areas), and primary peat formation (organic matter accumulation in pristine unvegetated substrates). In Alberta, most peatlands (bogs and fens) initiated by paludification in the mid-Holocene Kuhry & Turunen 2006, Bloise 2007). Some peatlands, especially bogs initiated on bare clayey surfaces of dry lake basins, as these shallow lakes dried in the early Holocene after retreat of glaciers. Non-peat forming wetlands (marshes) initiated by in-filling of small water-filled basins directly after retreat of glaciers; and some of these later developed into fens or bogs. Terrestrialization was more common in the southern boreal zone, while the other two processes have been more common in the mid- and northern boreal zones.

In order to emulate these natural pathways of wetland initiation, two fundamental approaches have been attempted for pads and roads situated on deep peat (> 40 cm) deposits, with some minor variations, as follows.

Mineral Approach (M-Pad) (Figure 1): The M-Pad approach was designed as an alternative to the North American Peatland Restoration Approach (Rochefort et al., 2013) to specifically reclaim In Situ mineral pads in Alberta. It involved lowering the mineral fill to an elevation comparable to the surrounding peatlands, but without complete removal of clay and geotextile. Instead, the mineral substrate was left to saturate and re-vegetated by active planting of various stock plants to initiate wetland development. These Shell Peace River pads were built in the early 2000s in a bog near the central processing facility of Shell. On each pad, a 25m by 120m portion of the pad bordering nearby peatlands was reclaimed by removing most of the overburden clay. Trenches were created to connect the pads with the surrounding peatlands and to promote seasonal water connectivity. The lowered soil surface was either rototilled or left alone, then amended with various materials including woodchips and stockpiled peat, followed by planting of various wetland species including willow cuttings, sedge transplants, and stock larch trees. Now, the site is dominated by sedges, both planted and those from natural ingress, and willows, resembling an early successional fen community growing on wet mineral substrate. In 2013, a similar approach was initiated using a roadbed at the JACOS site near Cold Lake AB and a complete pad (CNRL) was lowered to surrounding water level. Most of the fill was removed in November of 2010 and returned to the original borrow site. After allowing the excavated site to freeze enough to support large equipment, the site was mounded to bring some organic material to the surface and to introduce microtopography onto the site. The study site was divided into 4 blocks, each 40m by 40m in size. Blocks were separated by working alleys up to 10m in width. Within each block, four plots were established, with two of the four macroplots mechanically smoothed with a dozer, track-hoe, or combination to reduce the original microrelief from approximately 1 m in elevation variation to about 0.25m in variation (Shunina, 2014).

Inversion Approach (I-Pad) (Figures 2a and 2b): The original inversion Pad trial is located 50km northeast of the Town of Peace River. Prior to disturbance, the site was a poor fen complex. Shell Canada built the 1.27 ha site in 2006 with borrow clay material. Civil reclamation earth-work started in November 2011 with the removal of the clay overburden using a combination of six different removal and peat inversion techniques, completed in 4m wide strips moving from one end of the pad to the other. One technique involved clay fill and geotextile removed (partially or completely) and buried peat fluffed and compressed lightly to achieve the appropriate elevation and to ensure good hydrological connection between the restored pad and the surrounding areas. The mineral fill was transported to the nearby borrow pit from which it originated. Another technique, where underlying peat was shallow, involved some mineral fill buried and at least 40cm of peat placed on top to achieve the target elevation. A third technique was tested where most of the mineral fill was removed and the remaining mineral fill, geotextile and the underlying peat was lifted with the bucket of an excavator and inverted in one step, resulting in some mixing of the mineral soil with peat. The result of site adjustment is the removal of mineral fill with at least 40cm of peat on top and a flat, contoured surface no more than 10cm below the elevation of the surrounding peatlands. After the site adjustment, donor materials (mostly moss fragments, seeds, rhizomes) were collected from adjacent peatlands and spread across site, followed by spreading straw mulch on top to preserve moisture. Vegetation communities with different dominant bryophytes were targeted along several cutlines and the top 10cm of the peat surface was harvested according to the North American Peatland Restoration Approach (Rochefort et al., 2003).

Other Approach: An additional method that has been most recently tried involved the complete removal of the material and leaving the site the rebound on its own - Suncor's Firebag SAGD project Pad 106, this time on a road removal project (Osko et al. 2016). Civil reclamation earth-work for this latter project started in June of 2013 with the removal of the road gravel cap and 1.5 m deep clay fill. The road was relatively young (6 years) and it was set within a poor fen complex on top of 60 to 140 cm of compressed peat. The technique involves the complete removal of clay fill, fabric liner, and geogrid. In the case of Pad 106, the buried peat was not "fluffed". Rather, it was allowed to naturally decompress. Also, for Pad 106, vegetation communities were allowed to naturally re-colonize from the compressed peat and surrounding natural propagules. Short-term (1 year after road removal) assessment of the site has revealed mixed success. Although the newly re-exposed peat demonstrate a viable source of latent plant propagules, the plant species richness was relatively low and included a plant community much different and much less rich than adjacent natural communities. Most importantly, large portions of the site sustained prolonged flooding for much of the 2014 growing season, a condition that limited the development of *Sphagnum* species. It is unclear if deeper peat deposits (those in peatlands with > 40 cm of peat) will rebound sufficiently to create appropriate hydrological conditions for plant establishment. At the current time, there is insufficient data for us to recommend this approach. **Additional feasibility assessments are required to determine if this technique can produce a peatland site type.**

In summary, trials for three methods of site preparation for well sites and roads have been carried out in the Province – **I-Pad** for the peat inversion methods and **M-Pad** for the lowering of clay material to surrounding water level elevation. A component of the **I-Pad** approach also included the complete removal of introduced material. Additionally, M-pads can be vegetated on the lowered bare mineral surface (roughened or not -- M-m pad technique) or modified with a variety of organic treatments (M-o pad technique). Providing varied micro-topography increases options for both planting site and species selection, thereby increasing site resiliency to seasonal or year-to-year moisture variations. The same concept applies to improving diversity of naturally colonizing species.

Under the overall goal listed above, the objectives of reclamation to peatland should be to: 1) create a stable saturated – but not inundated – surface for the establishment of vegetation; and 2) establish vegetation that is highly productive and resistant to decomposition, enabling the site to accumulate organic matter from plant biomass and litter, thereby sequestering carbon from the atmosphere.

All wetlands share several common attributes – they are wet and have water at or near the soil/vegetation surface for most of the year and they have an abundance of organic matter, either in living plant material (marshes) or as a deposit of peat (fens and bogs). Peat forms when hydrogeological conditions limit microbial activity due to acidity, anaerobic water column, and/or plant chemistry. The design should provide appropriate conditions for wetland or peat-forming plants to establish and grow that in turn will provide suitable conditions for decreased microbial activity.

2.0 Guidance

Planning for wetland reclamation of In Situ facilities in the OSR under an EPEA Approval begins when it is written in the conceptual plans, such as the C&R Plan and/or the PLCRCP. Detailed wetland reclamation planning begins once a project area has been approved by Operations for final reclamation and land is ready for reclamation. The following reclamation milestones structure the wetland reclamation project. Detailed wetland reclamation planning begins with Milestone 1.

Milestone 1: Creation of Detailed Peatland Reclamation Plan – Hydrology has been confirmed. The surrounding wetlands have been characterized. Quality of the substrate fill material has been surveyed. Contour maps and cross-sections are created to guide construction activities. A revegetation approach is selected.

Milestone 2: Construction & Reclamation Material Placement – Grading and contouring is conducted, using onsite reclamation material, to achieve the desired topography.

Milestone 3: Vegetation Establishment – The revegetation plan is initiated, as per Milestone 1.

Milestone 4: Monitoring – Survey the site to determine vegetation establishment and any issues that may arise.

This document presents tasks which fall under each of these reclamation milestones. The form in Appendix 1 can be used to track and document wetland reclamation progress through the milestones to assist with project documentation.

Reclamation Milestone 1: Creation of Detailed Wetland Reclamation Plan

This chapter includes the steps and tasks leading up to, and including, creation of the final wetland design. In support of reaching "equivalent land capability", the reclamation plan should address the physical, chemical, and biological characteristics of the land, including (Government of Alberta, 1993):

1. topography,
2. drainage,
3. hydrology,
4. soils, and
5. vegetation.

This Milestone addresses all of these components. The final landform will largely be dictated by site topography, hydrology, chemistry, and the surrounding wetland site-types. This chapter includes the steps and tasks leading to choosing a peatland restoration technique, suitable species, and final design.

Milestone 1

Step 1.1: Confirm Reclamation Approach and End Land Use	Select the reclamation approach	Determine fill removal option
	Select peatland site-type	Review reclamtion plan commitments Characterize available material Characterize the reference site
Step 1.2: Information Gathering	Elevation data	
	Water table information	
	Soil sampling (if necessary)	
Step 1.3: Design	Develop final design	
	Develop topography map and wetland cross-section	
Step 1.4: Revegetation Planning	Plants species selection	Determine vegetation layers Select species based on site-type
	Determine plant collection and establishment methods	Select establishment method
	Scheduling revegetation	Schedule according to Table 9, 10, 11

Step 1.1. Confirm the Reclamation Approach and End Land Use

Purpose: Design should address the "physical, chemical, and biological characteristics of the land, including topography, drainage, hydrology, soils and vegetation", as well as reflect the targeted wetland site-type. This will support reaching "equivalent land capability" (Government of Alberta, 1993).

Guidance:

1.1.1 Select the Reclamation Approach

▽ The reclamation approach (structural design) and the wetland site type to be chosen are inextricably tied. In the M-Pad approach (Figure 1), since vegetation is established directly on mineral (i.e., alkaline) substrate, the water chemistry will be alkaline. Thus, it is most appropriate for circumneutral/alkaline/saline fen site-types, but not acidic site types (poor fens or bogs). The I-Pad approach (Figures 2a & 2b) is appropriate for acidic site-types, but can also be used for other site-types, depending on the surrounding wetland site types and the porewater chemistry of the compressed peat underneath the pad or road. Thus, **selection of the reclamation approach should be made in concert with a decision on the desired reclaimed wetland site-type**.

Table 2 provides some considerations to assist with the selection of a reclamation approach.

Reclamation Approach Options:

- Option A: M-Pad (see Figure 1)
- Option B: I-Pad (see Figures 2a and 2b)

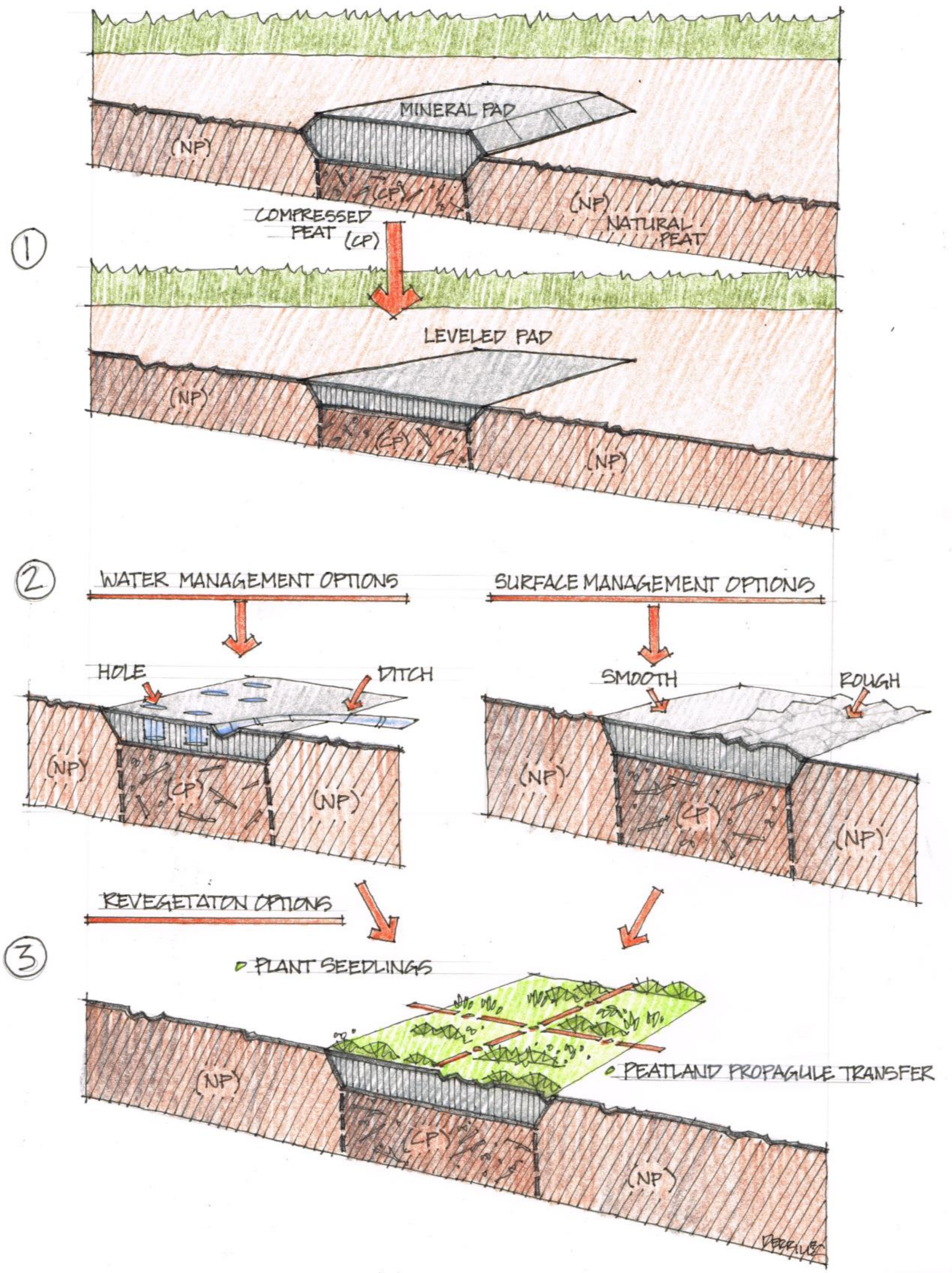


Figure 1: M-Pad Approach.

M-Pad Approach Description: Fill is removed to an elevation approximating the surrounding wetland site-types. Revegetation for M-m (m=mineral) pad occurs on the wet mineral soil surface that can be sandy, silty, or clayey, while revegetation for M-o (o=organic) occurs from a shallow organic layer spread from surrounding peatland.

STEP 1: Fill is removed to an elevation approximating the surrounding wetland site-types, i.e., down to the spring water table elevation. Material (e.g., gravel and clay) is transported offsite for storage (e.g., back in borrow pit) or re-use if viable.

STEP 2: Substrates that are either submerged or too dry will not provide proper substrate for peat-forming plants. Thus, management options may be required such as water and/or surface management. Drainage may be put in place to either remove or add water to the site – water table elevation should be consistent with surrounding peatland and substrate should be saturated, but NOT inundated. “Rough and loose” soil treatment will add topographic diversity and micro-habitat.

STEP 3: Once desired hydrology is in place, re-vegetation can occur. If placement of 5-10 cm of living organic material is the preferred revegetation approach, we recommend lowering the pad to accommodate this organic material and ensure wetness. See re-vegetation options as per Section Step 1.4 (p. 23).

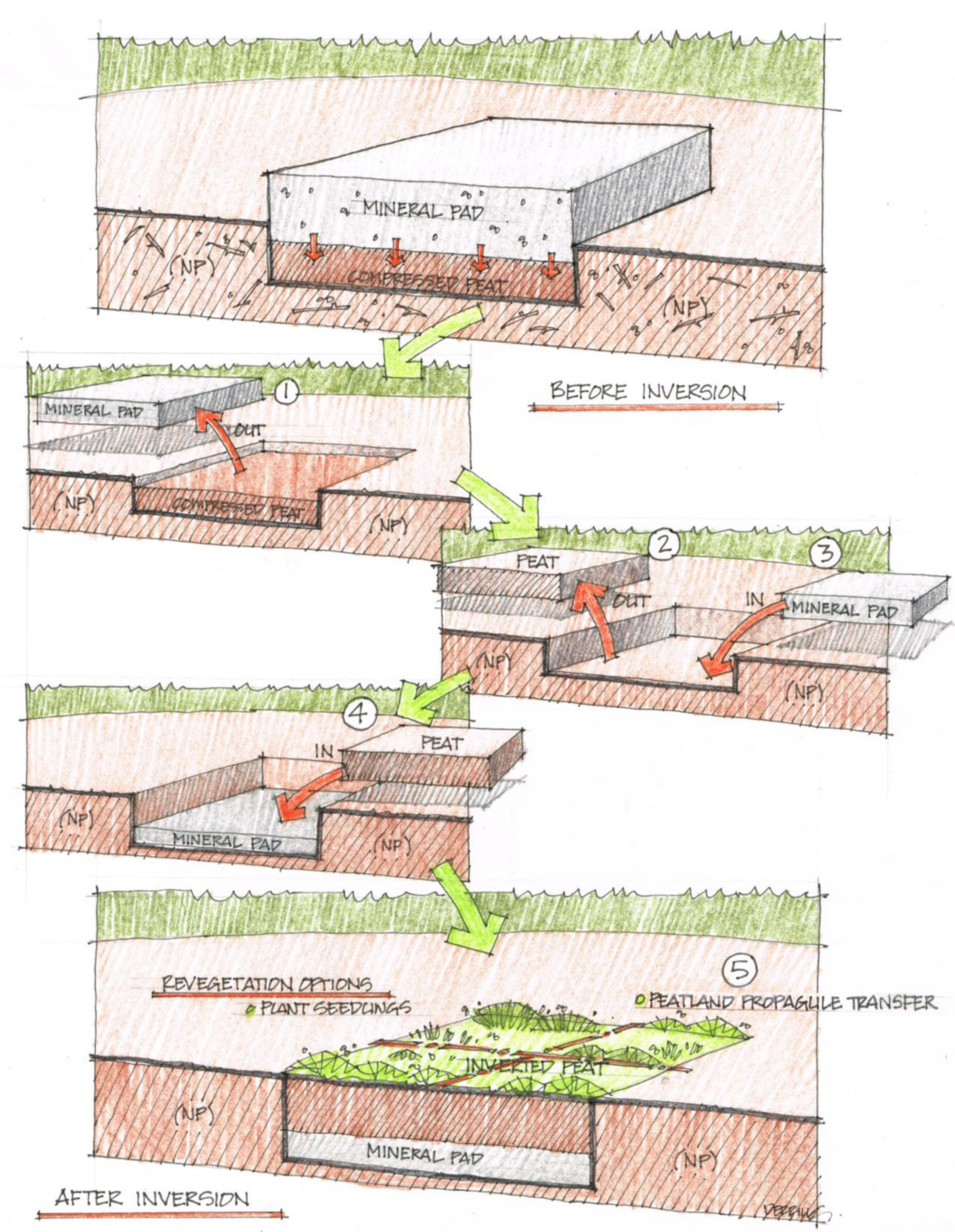
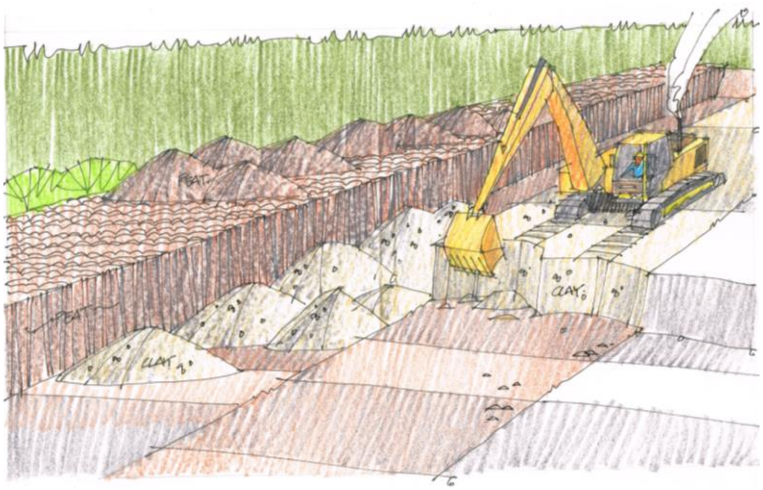


Figure 2a: I-Pad Approach - Inversion (Sobze & Rochefort, 2012).

I-Pad – Inversion Approach Description: Removal of fill and geotextile, then removal of underlying peat, then re-place mineral fill and cover with 'fluffed' underlying peat sufficient to achieve 40cm of peat at an elevation near that of surrounding peatland site-types. Earthworks are completed sequentially in 4m wide strips, as follows.

STEP 1: Removal of clay pad and geotextile. For the first 4m wide strip, the clay pad and geotextile are completely removed and the underlying compressed peat is fluffed using an excavator to "work-up" the surface of peat and add volume so that the desired elevation is achieved. The first strip is then used as a clean surface for storage of compressed peat located under the second strip. For the second strip, the clay pad and geotextile are also completely removed and hauled offsite for storage (e.g., back in borrow pit) or re-use if viable. For the third and subsequent strips, clay is removed and backfilled into the previous strip (i.e., clay from strip 3 is backfilled into strip 2, etc.).



Detail of I-Pad approach. Earthworks are completed along 4m wide strips. This illustration shows excavator working on strip #3.

STEP 2: Peat removal. Peat from the second strip is removed and placed on the first strip. This procedure is repeated for subsequent strips. Peat from the first strip is not removed, but rather "fluffed" to achieve the desired elevation (see Step 1).

STEP 3: Clay placement. Clay from the third strip is removed and backfilled into the bottom of strip 2. Note that not all the clay will be used (some will be hauled offsite) since the site will be lower in elevation. The amount of clay placed will depend on the quantity of available peat and the design's final elevation (10cm below the surrounding peatland). It is important that a minimum layer of 40cm of peat be placed on top of the clay (no clay should be within 40cm of the peat surface).

STEP 4: Peat placement. Peat piled on top of the first strip is pushed on top of the second strip. This procedure is repeated for other strips. The final elevation should be 10cm below the surrounding peatland to account for any rebound of the compressed peat or clay. The peat surface is lightly compressed to increase hydraulic connectivity through the peat.

STEP 5: Revegetation. See re-vegetation options as per Section Step 1.4 (p. 23).

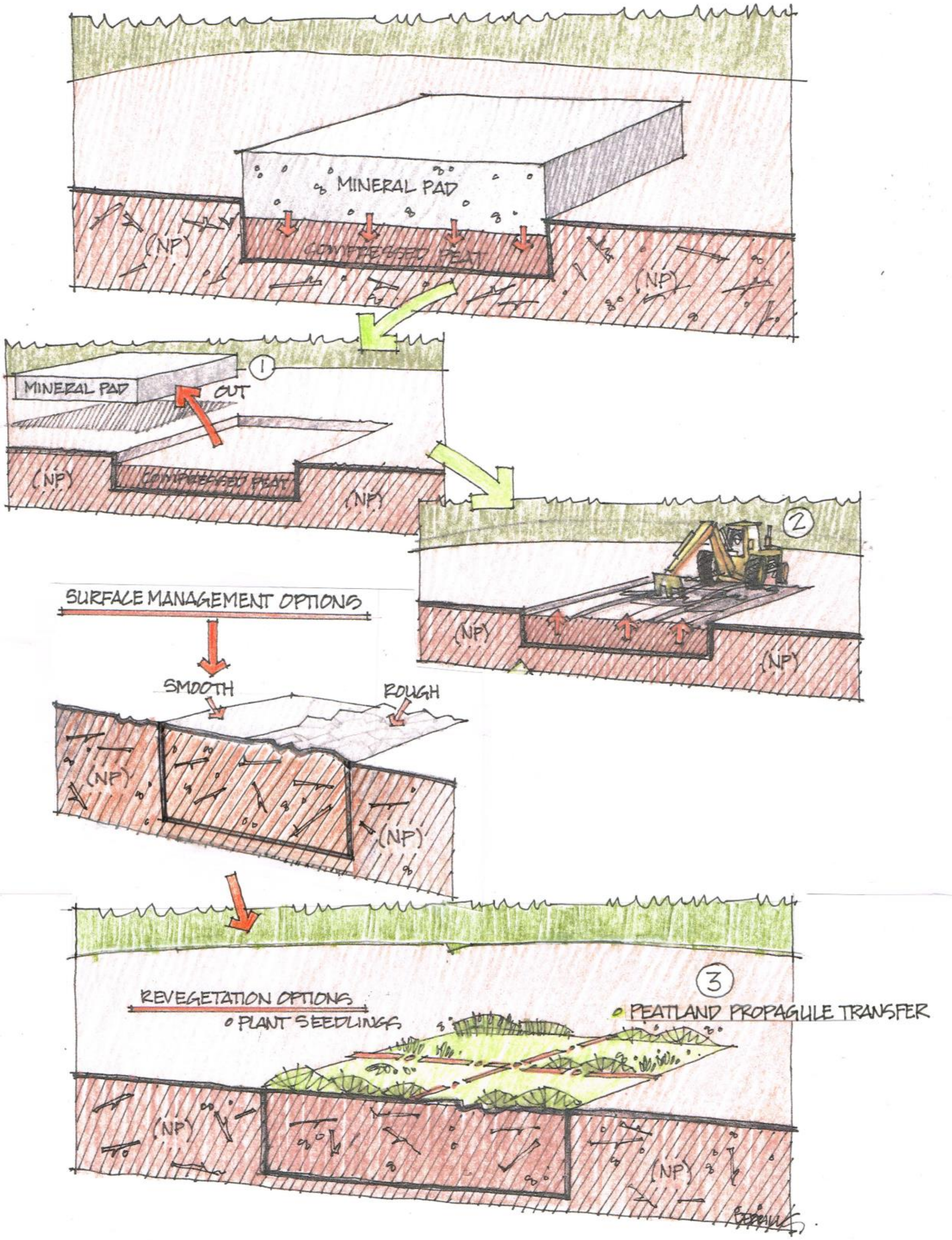


Figure 3b: I-Pad Approach - Complete Pad Removal (Sobze & Rochefort, 2012). This technique is used in Strip 1 of the I-Pad – Inversion Approach (See Figure 2a).

I-Pad – Complete Pad Removal Approach Description: Removal of fill and geotextile, then fluffing of underlying peat sufficient to achieve an elevation near that of surrounding peatland site-types.

STEP 1: Clay pad and geotextile are removed completely. Material (e.g., gravel and clay) is transported offsite for storage (e.g., back in borrow pit) or re-use if viable.

STEP 2: The underlying compressed peat is fluffed using an excavator to “work-up” the surface of peat and add volume so that the desired elevation is achieved. “Rough and loose” soil treatment will add topographic diversity and micro-habitat.

STEP 3: Revegetation. See re-vegetation options as per Section Step 1.4 (p. 23).

Table 2: Considerations for selecting fill removal option.

Consideration	Option A (M-Pad)	Option B (I-Pad)
Site type suitability	Circumneutral/alkaline/saline site-types. Will not work for acidic site-types.	Acidic site-types (bogs and poor fens) specifically. Can work for other site types.
Timing	Summer/fall/winter	Early winter
Preferred revegetation technique	Seedlings or local living peat	Local living peat. Seedlings may be used to add species (e.g., black spruce).
Return of ground layer	Sooner (~3 yr) (M-o pad); Later (~5 yr) (M-m pad)	Sooner (~3 yr)
Risk of not achieving desired outcome	Low[1]	Low[1,2]
Fabric liner/geogrid	No need to remove[3]	Removed
Cost	Relatively low	Relatively high[4]

[1] Risk is based on current results of both I-pad and M-pad experimental treatment, wherein after 4-8 years, pads have established abundant peatland vegetation.
[2] If using the Complete Pad Removal option (Figure 2b), the user should ensure that the fluffed up peat will have sufficient volume to raise the surface of the peat to approximate that of the surrounding natural peatland. Inundation can occur if the elevation is too low.
[3] Although there is no technical need to remove the geotextile, the regulator may require it.
[4] If the Complete Pad Removal option (Figure 2b) is used, the cost will be relatively low.

1.1.2 Selection of Peatland Site-Type

The specific peatland site-type may be chosen based on a combination of these factors:

- preferred reclamation approach, as described above,
- commitments from the conceptual reclamation plan (C&R Plan or PLCRCP),
- characteristics of available reclamation material, and/or
- the reference site-type - i.e., the pre-disturbance site-type or an adjacent site-type.

Conceptual reclamation plan commitments

▽ The detailed reclamation plan should be aligned with the approved end land use in the conceptual reclamation plan (C&R Plan or CLCRCP). However, this may not always be possible based on changing circumstances such as new site-specific information, logistics, cost, new technology, and selection of a preferred reclamation approach (I-Pad vs M-Pad). For example, only an alkaline fen site-type can be selected using the M-Pad technique (see Section 1.1.1). If the end land use is to be different than the conceptual plan, this must be approved by the regulator as part of the approval of the detailed reclamation plan.

Characteristics of available material

- ▽ Since peatland vegetation establishment is strongly tied to water chemistry, the porewater chemistry of the reclamation material is important. If the M-Pad approach was selected, the porewater chemistry of the pad/road at the depth of excavation (in the pad material but below the water table) should be determined. Pad/road material is predominantly clay sourced from a surface borrow excavation. When in contact with water, this material will produce alkaline water, which is not suitable for bog or acid fen peatland types (Table 3). Circumneutral and alkaline fens can develop in alkaline conditions such as over clay. There is a chance that the clay material (and thus its porewater) has moderate to high salinity. Since vegetation establishment is strongly tied to salinity, determining the salinity of the substrate is critical to the project. Measuring electrical conductivity will determine if the site is likely to be saline, which will inform plant selection.
- ! If the I-Pad approach was selected, the porewater chemistry of the peat under the pad/road should be determined, since this will be the material in contact with the vegetation.
- ! If the M-Pad approach was selected, the porewater chemistry of the clay material within the water table should be determined.
- ✓ Use Table 3 to select the wetland site-type that best suits the properties of the reclamation material.

Table 3: Generalized peatland site type characteristics (AEP, 2015).

Classic Name	**Bog**	**Poor Fen**	**Rich Fen**	
Site-type (name used in this document)	Bog	Acid Fen	Circumneutral Fen	Alkaline Fen
Alberta Wetland Classification System Name (AWCS)	Bog	Poor Fen	Moderate-rich Fen	Extreme-rich Fen
Porewater chemistry				
pH	3.0-4.2	4.0-5.5	5.5-7.0	7.0-8.5
Electrical conductivity used in AWCS (µS/cm)	< 100	< 100	100-250	250-2000 (includes saline fens)

Classic Name	**Bog**	**Poor Fen**	**Rich Fen**	
Reduced electrical conductivity used here (µS/cm)*	< 40	< 60	50-150	150-600
Calcium (mg/L)	0-3	3-10	10-40	30-100
Alkalinity (mequ/L)	0	0-350	350-800	(800) 1000-2000
Ground layer vegetation	*Sphagnum* and/or Feather mosses	*Sphagnum*	True Mosses with some *Sphagnum*	True Mosses
Water source	Ombrogenous (precipitation)	Minerogenous (surface and/or groundwater)		

*Note: *Traditionally in peatland literature electrical conductivity is a measure of salinity (base cation and their associated anions) and conductivity resulting from H+ ion is reduced ('corrected') using a formula presented by Sjörs (1952). Here we use reduced EC whereas AWCS uses EC that includes H^+, thus it is not a measure of salinity at pH's less than 5.5.*

Reference Site Characterization

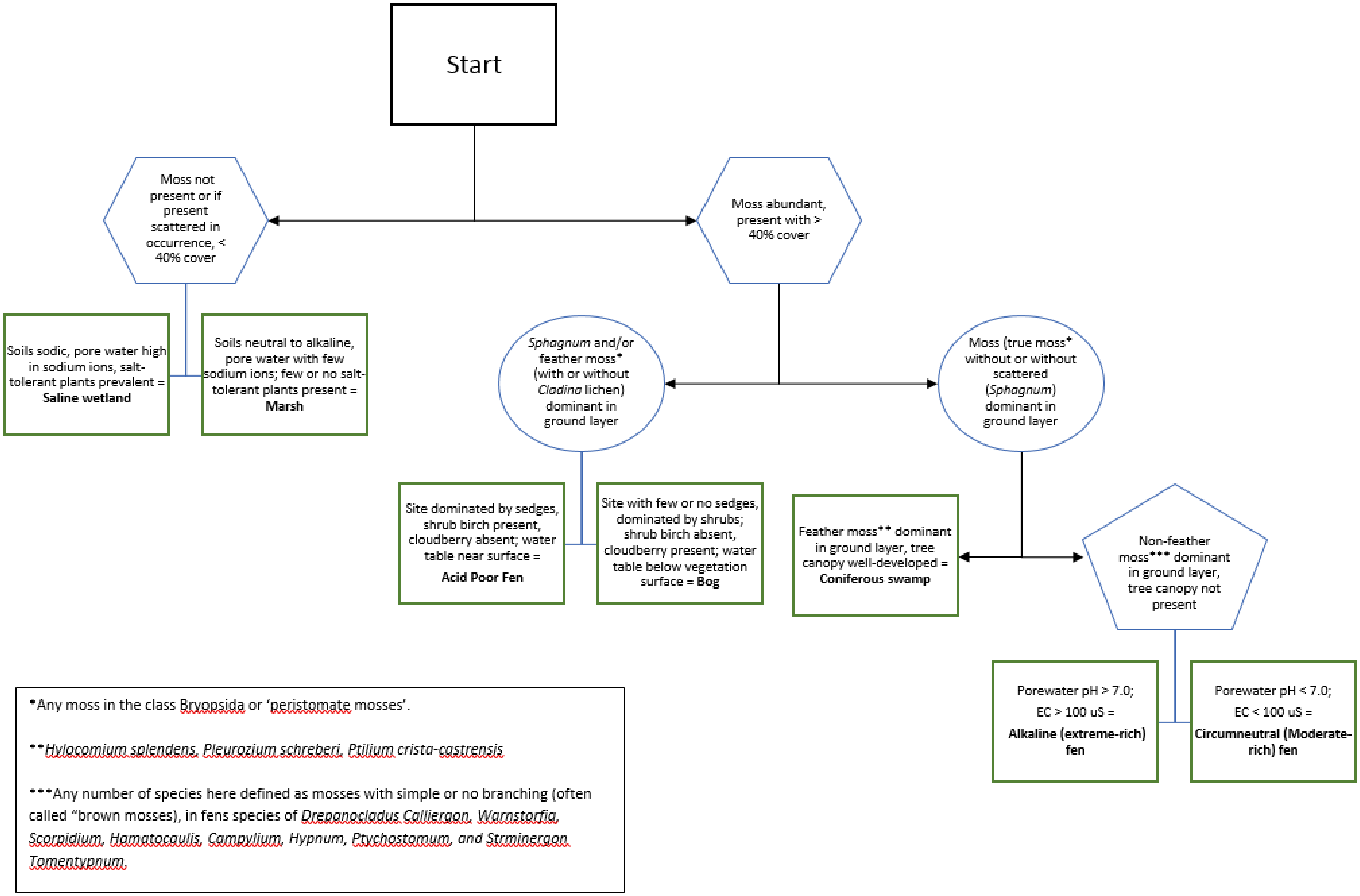
If you have decided to emulate the vegetation community of a reference site, an inventory of an off-site reference peatland is necessary to inform the revegetation plan. Collection of the following information will allow selection of the appropriate wetland site-type for the reclamation project.

- ✓ Use Figure 3 to characterize the reference wetland site-type.
- ✓ Determine the number of vegetation layers (Table 4). Knowing which vegetation layers are present will inform what species can be targeted for design. For instance, if the adjacent site-type is a treed fen, where all four layers are present, the revegetation plan may include species that are representative of all four layers.
- ✓ Determine the dominant tree species (if any). Dominant tree species in peatlands are Black Spruce (*Picea mariana*) **or** Tamarack (*Larix laricina*). This will inform tree species selection.

Table 4: Vegetation layers.

Layer	**Description**
Layer 1	Ground (moss) layer
Layer 2	Herbaceous layer
Layer 3	Shrub layer
Layer 4	Tree layer

Figure 4: A Decision-tree to classify the reference wetland site-type.



Step 1.2: Information Gathering

Purpose: Gather basic information required for the project.

Guidance:

The more information available at the front end of the design process, the better the design. The following basic pieces of information are recommended:

- ▽ The design should restore surface peat hydrologic connectivity with the surrounding peatland and create a saturated – but not inundated – surface for deployment of the moss, vascular plant, shrub, and tree species. Thus, water table information adjacent to the reclamation project is critical to determine elevations for the design (Figure 4). We recommend the installation of long-term water table monitoring wells to track changes in the water table as the project develops. Multiple wells should be installed to obtain good spatial resolution allowing precise water table contours. Once the materials have been removed from the site, wells can be installed within the reclamation area to track hydrological conditions.
- ! A detailed survey in and around the site should be conducted to obtain detailed elevation data. This information will be critical to determine water flow patterns (if any) and to integrate the detailed design to the surrounding landscape.
- ! If you have decided to re-create the same wetland site-type as a reference site, a suite of information should be collected to align the revegetation plan with the vegetation of the reference site. See Step 1.1.2 to determine what information should be collected.
- ! If pad/road material will be removed and re-used, samples can be taken from the material to determine if it is suitable for re-use. This material may be preferably re-used at another site rather than developing a new borrow resource.

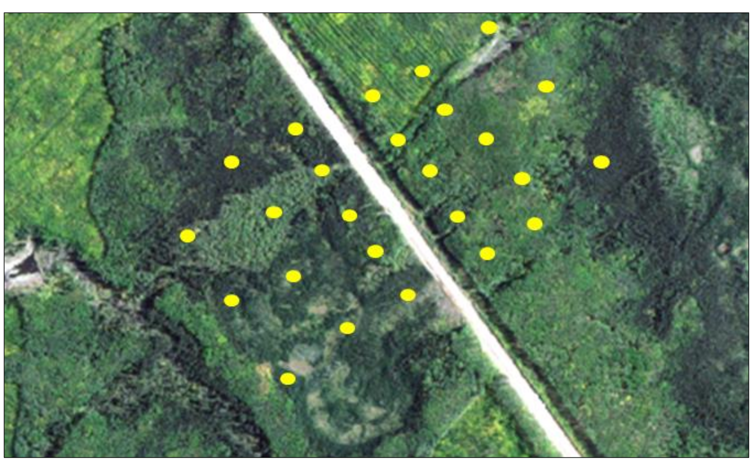


Figure 5: Example of piezometer/well transects to collect water table elevation data near a future road restoration site.

Step 1.3: Design

Purpose: Create preliminary design topography (structural design) to create the proper hydrology and as a basis for calculating reclamation material and vegetation placement needs.

Guidance:

- ▽ Detailed survey data and water table information is used to create the reclamation design. **The elevation of the design should be precisely level or leveled to match surrounding site-type elevations** (see Figures 1 and 2). This will allow a water table elevation consistent with adjacent peatland site-types. The ground surface should be just below spring water elevations for all revegetation, no matter how many vegetation layers are planned for. Site hydrology (water level, flow) should integrate with surrounding wetland site-types. Contours should be integrated with the adjacent landscape. If pad/road is in contact with uplands, riparian transitions should be established. For guidance on reclaiming riparian zones, see *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region (2010*) and *Riparian Classification and Reclamation Guide – Revised Edition (2012).*
- ✓ A reclamation topography map and wetland cross-sections can be produced.
- ✓ A geotechnical engineer may review the design to review earthworks designs, evaluate the stability of slopes, and assess risks posed by site conditions.

Step 1.4: Revegetation Planning

1.4.1 Plant Species Selection

Purpose: Wetland species chosen are appropriate for water depths expected, consistent with growing conditions on the reclaimed site, and coherent with the adjacent landscape (Boreal Research Institute, 2011). Both selection of the number of vegetation layers and appropriate species are critical for successful revegetation.

Guidance:

- ▽ Propagation of boreal wetland plant species is an emerging and continuously evolving field of study – it is in an active research phase. We recommend that the list of species and techniques presented in this document be updated regularly to reflect the evolving nature of boreal wetland plant revegetation.
- ✓ Based on selected peatland site-type (see Step 1.1.2), determine the number of vegetation layers, as per Table 5. Knowing which vegetation layers are present will inform what species can be targeted for design. For instance, if the adjacent site-type is a treed fen, where all four layers are present, the revegetation plan may include species that are representative of all four layers. See Appendices 2 to 8 for appropriate species.
    - Revegetating to bog, treed fen, or shrubby fen needs well-developed ground, shrub, and/or tree layers.

- Revegetating to wet fen needs well-developed ground and field (herbaceous) layers.
- Revegetating to marsh and saline wetland needs only a well-developed herbaceous layer

▽ *Typha* must never be considered for a revegetation plan. It may quickly dominate the vegetative community due to its aggressive growth, thus affecting plant diversity.

✓ Table 6 presents species that are common in Boreal Alberta for the different possible wetland site-types. Using this table, select species based on the peatland site-type selected (see Step 1.1.2), which is a reflection of the preferred reclamation approach, commitments from the conceptual reclamation plan (C&R Plan or PLCRCP), characteristics of available reclamation material, and the reference site-type - i.e., the pre-disturbance site-type or an adjacent site-type.

- It is possible that some sites will have slightly acidic waters and soils and in these cases species selection could include species inhabiting bog and acid fen site-types (see Appendices 2 and 3).
- If the site chemistry resembles that of saline wetlands, then the preferred species list is in Appendix 6.

✓ Appendix 7 lists species that have been successfully used in fen reclamation trials in Alberta. These species are recommended for use in Circumneutral Fen (Appendix 4) and Alkaline Fen (Appendix 5) site-types, which will often be associated with the M-Pad technique (see Step 1.1.2).

Table 5: Selection of number of vegetation layers for reclaiming individual wetland site-types.

Wetness	Bog	Acid Fen	CnFen/AlkFen	Marsh	Saline Wetland
Wet	—	F/G	F/G	F	F
Moist	—	T/F/G	T/F/G	—	—
Dry	T/S/G	—	—	—	—

Note: *Wet=water table above soil surface, Moist= water table near or at soil surface, Dry= water table below soil surface. T=Tree layer, S=Shrub layer, F=Field layer, G=Ground layer; CnFen=Circumneutral Fen, AlkFen=Alkaline Fen.*

Table 6: Species List and Characteristics of Different Wetland Site-Types.

Characteristic	Wetland Site-Type				
	Bog	**Acid Fen**	**Circumneutral Fen**	**Alkaline Fen**	**Saline Wetland**
pH of site water	3.0-4.2	4.0-5.5	5.5-7.0	7.0-8.5	8.0-9.0
Dominant pore water ion	H^+	H^+	Ca^{++}	Ca^{++}	Na^+
Ground layer at certification	*Sphagnum*		True moss		None/few
Recommended Substrate	Peat		Mineral or peat		Mineral
REC	< 40	< 60	50-150	150-600	> 600
Species list	App. 2	App. 3	App. 4	App. 5	App. 6

Notes: REC=reduced electrical conductivity.

1.4.2 Determine Plant Collection and Establishment Methods

Purpose: Choosing a technique will assist in establishing a schedule and planning for on-site revegetation. It may also preclude some species from being chosen as desired vegetation.

Guidance:

- Table 7 lists all possible wetland plant propagation techniques, as well as considerations for their use. If peatland propagule placement is chosen as a revegetation method, no species selection needs to take place.
- ▽ Seedlings and/or peatland propagule placement are the preferred approaches for revegetation. Although we include information on seeding, this method is not recommended to be used on its own due to very low germination rates as compared to the effort involved in seed collection. Scheduling is of paramount importance and options are shown in Section 1.4.3.
- ▽ Introduction of single-species (such as mono-specific populations of *Carex aquatilis*) may result in over-aggressive species colonization creating situations that impede ground layer development owing to excessive litter. Consider introducing vegetation that contains a mixture of 2-4 species. *This mixture should include some Carex aquatilis*.
- ✓ See Section 3.1 Site Revegetation for planting densities.

  Seed/Seedling Collection:

  - ✓ Follow *Native Plant Revegetation Guidelines for Alberta* (Native Plant Working Group, 2001). Additional plant material collection techniques can be found in *Seeds Collection,* *Processing and Storage* (Smreciu & Sobze, 2011) and *Native Boreal Shrub Seed Collection and Cleaning* (Schoonmaker, Marenholtz, & Sobze, 2014).

- All trees and shrubs collected from the Green Zone is governed through *Alberta Forest Genetic Resource Management and Conservation Standards* (FGRMS) and standards for collection, handling, registration and storage is found in this document and should be reviewed prior to collection activity (GOA, 2016b). Seeds collected from tree and shrubs need to be from within applicable Seed Zone of the areas to be revegetated. Although aquatic and riparian material is not required to follow FGRMS, it is good practice to collect this material locally.
- Plants harvested from public lands or destined for placement on public lands must be registered with Alberta Tree Improvement and Seed Centre. Review *Alberta Native Plants and Seeds: Wild Harvest, Registration and Deployment. A Guide for Technicians and Practitioners* (Smreciu A. , 2011). See Appendix 9: Approved Commercial Seed Processing and Testing Facilities.
- On public land, a Temporary Letter Authority for seed/seedling collection is required (i.e., a TFA). Consult the local AEP office for requirements. Generally, a plan is submitted to the appropriate agency detailing the area to be harvested, method of harvesting, timing of harvesting, and the target species. After harvesting, the proponent submits a report to the appropriate field office identifying the actual areas harvested (on a map) and the approximate yield/volume of seed/plant parts.

Table 7: Considerations when choosing an establishment technique.

Technique	Considerations
Planting: greenhouse-supplied seedlings	• Cost: High. Labor needed to plant. May include seed collection to be completed the fall before; seeds may have very low germination rates that need to be accounted for, seeds should be stratified for 30 or more days during late fall, depending on greenhouse plant availability. Plant shipping costs are to be considered. • Mortality: low • Practicality: Needs coordination with one or more greenhouse(s), depending on available greenhouse space. Plant care (watering) is needed up to planting. • Site prep needs: Works well where water levels/availability in the spring may be unreliable. • Scheduling: Transportation and planting can be completed in one to two months in the spring/early summer. Seedlings that are less than one-year old are small and easily handled. • Availability: Nursery grown stock is of consistent quality though not all species are available. Seed collection and delivery to greenhouse may be needed, depending on desired species. Check greenhouses for availability.
Planting: Transplanting plants collected	• Cost: Moderate to High. Labor needed to both collect and transplant. Site access and plant transportation costs are to be considered.

Technique	Considerations
from a donor site	• Mortality: low • Practicality: Plant care (watering) may be needed up to planting. • Site prep needs: Works well where water levels/availability in the spring may be unreliable. • Scheduling: Window of transplant is one to two months in the spring/early summer, plant collection should be scheduled within days of transplanting. • Availability: Site-specific - depends of availability of nearby donor sites. Field reconnaissance may be needed prior to plant collection.
Placement of peatland propagules from donor site	• Cost: High, Equipment costs for stripping, moving, and placing soils. • Mortality: Moderate but at this stage in the research seemingly successful with relatively high species diversity. • Practicality: Access to donor site may be challenging. May need Water Act and Public Lands Act (TFA) approvals if going offsite. This can take roughly 6 months. To preserve propagules, should be directly placed or stored less than 1 month (it is not known if material can be over-wintered). • Site prep needs: Water levels should be maintained near surrounding area level. • Scheduling: Donor sites should be harvested after freeze-up in early winter and spread as soon as possible on the frozen pad or road substrate. Straw mulch has been used to preserve moisture (Rochefort et al. 2003), however it may not be beneficial in all cases (Martin, 2017). • Availability: Depends on appropriate site-types in proximity of donor site.

Although we include information on seeding, this method is not recommended to be used on its own due to very low germination rates as compared to the effort involved in seed collection.

Technique	Considerations
Seeding: greenhouse stratification	• Cost: Least costly. Can use summer interns to collect seed. Doesn't require any heavy equipment. • Mortality: Predictability of results is low – low germination rate (5% or less). Currently only *C. aquatilis* has been shown to germinate under field conditions, so the risk is high, but the cost low. • Practicality: Straightforward - requires no specialized equipment. • Site prep needs: Water levels should be managed. Site should be wet during germination, but not flooded (water levels should be no greater 2-4 cm above soil surface). • Scheduling: Can be completed within 4-5 months – start to finish, but seeds spread before spring. Seeds collected in August-September, stratified for 30 days- and spread in early winter when site is frozen. NOTE: Seed stratification is species specific and little is known about needs of many boreal wetland species; however, wet stratification at 2C for 30 days is a conservative estimate for most species. • Availability: Site-specific - depends of availability in nearby donor sites, but species are common and abundant in most areas. Field reconnaissance should occur prior to plant

Technique	Considerations
	collection to locate donor sites.
Seeding: natural stratification	• Cost: Least costly. Can use summer (Aug-Sept) interns to collect seed. • Mortality: Predictability of results is low and germination rates are low (5% or less). Seeds may take more than one year to germinate. • Practicality: needs coordination. • Site prep needs: Water levels should be managed. Site should be wet during germination, but not flooded. • Scheduling: Least time-consuming from seed collection in Aug-Sept to seed spreading in Oct after which the seeds naturally stratify. NOTE: Sites designed to have moving water will promote movement of seeds, which may not provide an even establishment regime. • Availability: Site-specific - depends of availability in nearby donor sites. Field reconnaissance may be needed prior to plant collection.

1.4.3: Scheduling Revegetation

Purpose: Successful revegetation involves the identification, sourcing, and collection/ordering of seeds, seedlings, and propagules so that they can be available when it is time to revegetate the wetland. Almost all elements of revegetation are seasonal and need greater than six months of planning before on-site operations. Some areas may be constructed or perform differently than intended and not all the seeds, seedlings, and propagules will be available on demand (CEMA, 2014). Identifying seed-producing populations is a key ingredient to this process.

Guidance:

- ✓ Lead time of approximately one year should be planned for the production of most forbs. Lead time for shrubs and trees is longer (Native Plant Working Group, 2001).
- ✓ It is very important to schedule backwards from revegetation activities - timing will be determined by revegetation procedures (for example – revegetation from seeds, greenhouse seedlings, and native-collected seedlings will each need different scheduling).
- ✓ Revegetation scheduling, based on establishment technique, is presented in Tables 8, 9, and 10.
- ✓ Potential seed collecting stands should be field-scouted prior to actual seed collection, approximately 3-4 weeks before the fruits are ripe (Schoonmaker A. , Marenholtz, Sobze, & Smreciu, 2014).
- ✓ Fill removal and site prep should be done in the same growing season or the fall/winter season before spring planting as when the vegetation diaspores are placed in-order to decrease the establishment of undesirable species.
- ✓ Site prep is best carried out in early winter just after freeze-up.

Table 8: Revegetation using seeds.

Seeding – greenhouse stratification		**Seeding – natural stratification**	
Late Summer/Fall (Yr 1)	Collect seeds	**Late Summer/Fall (Yr 1)**	Collect seeds
Winter (Yr 1)/Spring (Yr 2)	Stratify (30-60 days)	**Fall/Early Winter (Yr 1)**	Site preparation
Late Fall (Yr 2)	Site preparation	**Fall/Early Winter (Yr 1)**	Spread seeds
Late Fall (Yr 2)	Spread seeds		

Table 9: Revegetation using seedlings.

Seedlings – Nursery / greenhouse stock		**Transplanting from Donor Site**	
Late Summer/Fall (Yr 1)	Collect seeds	**Fall/Winter (Yr 1)**	Site preparation
Fall (Yr 1)	Provide seeds to supplier of seedlings	**Early spring (Yr 2)**	Collect native seedlings
Fall/Winter (Yr 1)	Site preparation	**Late spring (Yr 2)**	Seedling planting
Winter (Yr 1)	Stratification/germination		
Spring (Yr 2)	Seedlings delivered to site		
Late spring (Yr 2)	Seedling planting		

Table 10: Revegetation using peatland propagules from donor site.

Donor Propagule Placement	
Spring/Early Summer (Yr 1)	Select donor site
Fall/Winter (Yr 1)	Acquire donor material (living plants plus top 10 cm of peat) from donor location
Fall/Winter (Yr 1)	Immediate placement (manure spreader) upon removal

Reclamation Milestone 2: Construction & Reclamation Material Placement

Upon completion of the final design, development of final drawings/maps, and species selection, landform construction can begin. This chapter includes the tasks involved in construction such as surveying, grading, managing water, erosion controls and materials movement and placement.

Milestone 2	Step 2.1: Preparation	Develop drawings	
		Develop construction package	
		Water management	
	Step 2.2: Materials Removal & Placement	Communicate construction drawings to construction crew(s)	
		Install mitigation controls	
		Site grading & re-contouring	
		Decompaction/roughing (if necessary)	
		2.2.1 M-Pad Approach	Partial fill removal Management options Revegetation
		2.2.2 I-Pad Technique	Pad inversion Revegetation

Step 2.1: Preparation

Purpose: To prepare for earthworks and compile the final wetland design, soil prescription, and any safety related plans for the formal Reclamation Construction Package to be communicated with the construction crews.

Guidance:

Drawings

✓ Upon completion of the final design, the soil prescription, and planning for revegetation, drawings to guide construction should be developed. Drawings may include:

- Grading areas
- Fill placement and excavation areas

- Topography of wetland and surrounding areas
- Reclamation material placement sequence
- Water management

Construction Package

! The construction package is critical to provide direction to the construction team, minimize disturbance, and conserve the site during construction.

▽ The Construction Package must be retained for the life of the overall project and must be available upon request by the Regulator (AER, 2016).

✓ The construction package should include, at a minimum:

- Final drawings (see above)
- Construction techniques
- Identification of environmentally sensitive areas within or beside the planned area of disturbance
- Mitigation measures to protect environmentally sensitive areas. For example:
  - Buffers and setbacks along sensitive areas
  - Refueling setbacks from watercourses and waterbodies
  - Spill detection and response
  - Erosion/sedimentation control measures
- Roles and responsibilities, chain of command, and contact information

- See Step 2.2 for methods of removal and placement of material, which can be included in the Construction Package.

Water Management

! Temporary ditching and/or pumping may be necessary in some cases to remove water from the worksite and allow construction activities.

▽ If pit dewatering is necessary, the proponent should review the Water Ministerial Regulation (Government of Alberta, 2000) and consult with the responsible regulatory agency to determine whether an approval and/or license under the Water Act are required.

Step 2.2: Materials Removal and Placement

Purpose: Implementation of the construction package and place the landform slopes and contours before soil placement.

Guidance:

- ✓ Communicate the final drawings and construction package to the construction crews to address remaining questions and ensure there are no outstanding issues.
- ✓ Layout and staking as per Final Drawings, which will guide equipment operators
- ✓ Install any mitigation controls identified in the construction package.
- Soft ground can preclude the use of large equipment. Typical equipment includes tracked dozers, excavators, trucks and graders (CEMA, 2014).
- Rough and loose surface treatments can provide an effective way to control erosion, create conditions that promote the revegetation of the site, increase biodiversity and improve ecological resilience (Polster, 2013).
- If de-compaction of pad material is necessary (M-Pad only), consider ripping the substrate where compaction is an issue to a depth of 30cm with a cultivator, discs or ripper teeth attached to a grader or bulldozer.

Photo courtesy of T. Osko

Figure 6: Example of road removal, also showing water management.

2.2.1 (A) M-Pad Approach (including both M-m and M-o pads).

- See Step 1.1 for a description of the M-Pad approach.
- See Figure 2 for a visual representation of fill removal and reclamation materials placement.

Fill Removal

- Fill removal is best done after freeze-up in the winter. Fill is removed to an elevation approximating the surrounding wetland site-type and/or surrounding water level.

Final Elevation

- ✓ Final elevation (and hence wetness of the site) should be based on number of vegetation layers desired and fit with surrounding site-types. Water levels should be just below spring water elevations for all revegetation, no matter how many vegetation layers are planned for.
- ✓ Ensure elevation will support connectivity to the surrounding wetland.
- ✓ Some micro-relief such as small hummocks (<0.25m in variation) can be included in the final grade. Providing a varied micro-topography increases options for both planting site and species selection, thereby increasing site resiliency to seasonal or year-to-year moisture variations and improves microhabitat diversity for naturally colonizing species. This can achieve through rototilling or mounding (bring some organic material to the surface and smooth to small hummocks by dozer or track-hoe) (Osko 2012).

Water Management

- After final elevation is achieved, ditches/trenches for water entry to middle of the pad or road can be inserted to connect the area with the surrounding peatlands and to promote seasonal water connectivity. Ditches/trenches can be plugged until revegetation is completed.
- In situations where the fill has a high clay content, conductivity to the center of the site may be impeded – provide either (or both) several shallow ditches from the edge to the center or remove fill in several small areas (no larger than 0.5m in diameter) to access the peat beneath.

Substrate Placement

- The M-Pad approach provides a wet mineral soil surface that can be sandy, silty, or clayey.
    - **M-m Technique:** No amendment necessary. Site is ready for revegetation
    - **M-o Technique:** Amended surface with a shallow layer (1-3cm) of freshly harvested peat. This living layer of peat (to 10cm depth) should also include the living plant layers (minus trees).
    - ! We recommend caution in using stock-piled peat due to the potential for high amounts of undesirable species. Weed infestations can be highly detrimental to revegetation efforts.

2.2.2 (B) I-Pad Approach

Guidance:

- See Step 1.1 for a description of the I-Pad Approach.
- See Figure 3 for a visual representation of fill removal and reclamation materials placement.

Fill Removal

- ✓ Remove mineral fill and geotextile. Use removal strips of approximately 3-4 m wide (Sobze & Rochefort, 2012) or use any method preferred by the operator. Remove layers slowly to avoid mixing the peat and the clay.
- ✓ Remove underlying peat.
- ✓ Ensure reclamation elevation will support hydraulic connectivity with the surrounding site-type.

Water Management

- Ditches may or may not be needed to temporarily divert water.

Substrate Placement

- ✓ Replace mineral fill and cover with 'fluffed' underlying peat sufficient to achieve an elevation of no more than 10cm below surrounding peatland site-types.
    - Fluffing is done with an excavator or rake attachment to work up the surface of the peat, to expose the peat layer and de-compact it.
    - Can compress the peat lightly to achieve the appropriate elevation and to ensure good hydrological connectivity between the restored pad/road and the surrounding areas (if necessary).
- ✓ Achieve a layer of peat at least 40cm deep, as it provides a rooting zone within organic material for plant establishment on the restored surface (Sobze & Rochefort, 2012).
- ! No clay should be left on the site within 40 cm of the peat surface, since the clay will affect the chemistry of the site (Sobze & Rochefort, 2012).

Reclamation Milestone 3: Vegetation Establishment

The goal of native revegetation is to establish a self-sustaining plant community that is compatible with the surrounding land use and includes plants that are native to the area (Alberta Environment, 2003). Wildlife habitat and ecosystem functions are dependent on appropriate site structure (vegetation) and desirable wetland species. Undesirable species (upland species, weeds, and non-peat-forming species in peatland site-types) are limited by the establishment of desirable wetland (or peatland) species. Peatland site-types store carbon as organic matter. Much of this organic matter is eventually derived from mosses that dominate the ground layer. For peatland site-types, reconstruction of the ground layer is important. This chapter includes the steps and tasks leading up to successful plant establishment, establishment of the vegetation, and vegetation management.

Milestone 3		
	Step 3.1: Revegetation	Implement revegetation plan and follow Table 12
	Step 3.2: Develop Establishment Controls/Vegetation Management	Manage for weeds
		Manage for wildlife

Step 3.1: Revegetation

Purpose: Implement the revegetation plan (see Step 1.4) and establish plants in the reclamation area.

Guidance:

- ✓ Follow the revegetation plan (Step 1.4) and guidance from Table 11. Table 11 includes planting strategies for seeding. However, seeding is not a recommended technique due to poor germination results. Plant distribution should simulate off-site occurrence of the species as much as possible (Native Plant Working Group, 2001).
- Little information is available on seeding rates or seedling planting spacing. Professional judgement suggests the following:
    - For seeds (e.g., for *Carex aquatilis/C. utriculata* mix), the germination rate is ca. 5%. Thus, seeding density should be high - suggest a rate of 200 seeds/m^2. Do not seed on areas that have the potential to flood.
    - Planting density for sedge species: 5,000 stems/ha.
    - Planting density for forbs: 2,000 stems/ha mixed with 3,000 sedge stems/ha.

- Planting density for shrubs (willow [for alkaline fens], birch [for acid and circumneutral fens]): 2,000 stems/ha.
- Planting density for trees (black spruce, tamarack): 100-200 stems/ha.
- If a nearby donor site is available, then the peatland propagule transfer method has the potential to distribute appropriate bryophyte and vascular plant diaspores. A 10:1 donor locality to pad/road ratio is recommended. A 10cm harvest depth at the donor site will allow recovery of the ground layer and associated vascular plants.
    - After the site adjustment, collect donor materials (mostly moss fragments, seeds, rhizomes) from adjacent peatlands. Target different dominant bryophytes and harvest the top 10cm of the peat surface according to the North American Peatland Restoration Approach described in (Rochefort, Quinty, & et. al, 2003). Spread across site using manure spreader, followed by spreading straw mulch on top to preserve moisture. Mulch may not be beneficial in all cases (Martin, 2017).

- Specific bryophyte species can be distributed by collecting local populations and dispersing fragments.
- If using whole plants/seedlings, they should have a portion of their leaves or stems above the water surface or they will drown (Clarkson & Peters, 2012).

Table 11: Vegetation establishment guidance.

Note that seeding is not recommended in most cases due to the low germination rate relative to the effort involved in collecting seed.

<table>
<tr><th>Technique</th><th>Establishment Guidance</th></tr>
<tr><td>Planting: greenhouse-supplied seedlings</td><td>• See recommended planting densities above.
• Seedlings are best planted in late spring after frost has disappeared.
• Willow whips can be gathered in early spring and stored in water-filled buckets on site until roots have developed (about 2 weeks) or planted immediately.</td></tr>
<tr><td>Planting: transplanting plants from a donor site</td><td>• See recommended planting densities above.
• Cores with a diameter of about 0.1m are recommended.
• Plants should have 0.2^{+}m long stems.
• Mulch may be used but not needed by whole plants.</td></tr>
<tr><td>Seeding: greenhouse stratification</td><td rowspan="2">• See recommended seeding rates above.
• Seeding has been done with hand-held seed spreaders and ATVs. In this case, seeds were mixed with bulgur wheat to gain the proper seeding rate. Other seed dispersal agents are also available.
• Seeding is best done in late fall after frost has formed in the site substrate.</td></tr>
<tr><td>Seeding: natural</td></tr>
</table>

Technique	Establishment Guidance
stratification	• Follow up spring soils should be wet, but not flooding, to ensure germination. Seeds of most species will not germinate underwater.
Donor peat propagule placement	• Should be placed immediately, however, overwinter storage is possible.

Step 3.2: Establishment Controls

Purpose: Active management of weed species and damage due to wildlife during reclamation will reduce the risk of impacts to native revegetation establishment.

Guidance:

Weeds

✓ An active monitoring program to control and destroy prohibited noxious and noxious weed species in accordance to the Weed Control Act is necessary for reclamation certification. The timing and approaches used to control noxious and prohibited noxious weeds depends on the species present, the development stage of the plant, and acceptable methods for control. Incorporate the site within the company weed control program.

! Early establishment of the marsh species, cattail (*Typha latifolia*), should be discouraged when vegetating fens and bogs by having no open water ponding on the site. Essential for weed control is the availability of proper water levels. This should be monitored and managed carefully. When water levels appropriate for the desired wetland site-type are present, both undesirable upland species and marsh species (e.g., Typha) will be largely controlled. Flooding for more than one week greatly enhances the opportunities for *Typha* to invade and establish.

! Sites should not have areas that dry out (with water levels greater than 10cm below the soil surface) as these are prime establishment areas for aggressive species such as bluejoint (*Calamagrostis canadensis)* and other upland species.

! To better control undesirable species, de-commissioned and abandoned pads or roads that remain idle before reclamation should not be planted with clover or grasses. These species should be completely removed and seed sources eliminated prior to reclamation.

Wildlife Interference

- If wildlife is inhibiting vegetation establishment, the following methods may be used:
    - Use of temporary fences around the wetland may be needed to prevent wildlife grazing.
    - Wire tree guards up to 1.5m high can limit beaver damage of tree/shrub species in riparian/upland areas (Urban Drainage and Flood Control District, 2016).

- If rodents (e.g. beaver, muskrat, etc.) are eating vegetation to the extent that it cannot re-establish, the animals may be trapped and relocated, with the appropriate authorization (CEMA, 2014). Contact the local Fish and Wildlife office.
- To prevent waterfowl from landing in the newly planted area, a placement of a wire grid system (3m on center) tied with brightly coloured flagging may reduce predation (Urban Drainage and Flood Control District, 2016).

Reclamation Milestone 4: Monitoring

The success of wetland reclamation will be largely evaluated based on the plant community. Early monitoring and management of the plant community will ensure that the investment in wetland reclamation up to this point is maintained and the project is on the right trajectory.

Note: that this section does not preclude the requirements for EPEA related reclamation monitoring. This milestone outlines only monitoring for wetland reclamation performance.

Milestone 4	Step 4.1: Develop Monitoring Plan	Develop monitoring plan
		Develop indicators
	Step 4.2: Monitoring & Focused Adaptive Management	Monitor to determine establishment success
		Adaptive management to solve or address issues

Step 4.1 Develop Monitoring Plan

Purpose: The goal of the monitoring plan is to keep the wetland on a trajectory towards certification by demonstrating performance against design goals and objectives.

Guidance:

Monitoring Plan

! Monitoring should occur during and after reclamation (Reclamation Milestone 2). In some cases, data collection that was begun prior to construction to inform the detailed reclamation plan will continue throughout the length of the project (e.g., water level measurement in wells). Monitoring during and after construction will provide early indications that design parameters or site expectations may need to be adjusted (see Step 4.2 – Adaptive Management).

✓ The monitoring plan should include:

- Overview of the monitoring program and monitoring objectives
- Study design.
- Sampling protocols, including:

    - Location, number, and size of study plots.
    - Indicators (see below), rationale for indicator selection, and threshold effect levels.
    - Sampling methods.
    - QA/QC program.
    - Data analysis and interpretation methods
- Monitoring reporting frequency (e.g., annually).
- Description of the focussed adaptive management program (see Step 4.2) and how the monitoring results will be used to apply corrective measures.

Indicators

- Metrics should be diagnostic, in as much as possible. They should determine if issues are caused by reclamation materials, water regime, or vegetation management (e.g., weeds). Metrics should indicate the degree of performance as measured against an established threshold.
- Generally, the site can be considered on the right trajectory if inhibitors, such as prohibited noxious weeds, as well as upland species and *Typha* are not present and if target species are establishing.
- Table 12 may be used to determine vegetation establishment success over the first 5 years of the project. AEP Peatlands Criteria (AEP, 2015) may also be used as a reference to inform the selection of indicators, measures, and performance targets.

Table 12: Peatland Establishment and Performance Indicators

Establishment (Years 1-2) Indicators	Performance (Years 3-5) Indicators
• Suitable germination of seeds or seedling establishment of desirable species. • Diversity and abundance of undesirable species. • Consistency of water table level with surrounding site-types. • Water/soil chemistry to determine changes in acidity and salinity. • Tree/shrub survival.	• Diversity and abundance of desirable species. • Diversity and abundance of undesirable species. • Consistency of water levels with surrounding site-types. • Water/soil chemistry to determine changes in acidity and salinity. • Tree/shrub growth.

Step 4.2 Monitoring and Focussed Adaptive Management

Purpose: Implement the Monitoring Plan, integrate monitoring results into management decisions, and take action in a timely manner to guide trajectories. Allow preparation of the application for reclamation certification.

Guidance:

- ✓ A reclamation monitoring operations plan should be created and regularly communicated to field crews. This plan will outline clear procedures and will contain forms to ensure collection of monitoring data in a consistent manner. Lack of consistency can cause an unnecessary increase in data variability, which can make data analysis and interpretation difficult.
- ! It is possible that some form of management or re-work will need to be completed on the site. Thus, it is important to have a good adaptive management system. Adaptive management should be used with consultation with the responsible regulating authority, particularly if vegetation establishment is not meeting performance targets. Figure 6 presents an example of an adaptive management process.
- Monitoring of vegetation establishment should occur for at least two growing seasons to ensure the plants have established and have biomass similar to benchmarks sites. Areas that have been reworked due to vegetation shortfalls may be monitored for an additional two growing seasons to ensure corrective work was successful.
- If the wetland is to be used against wetland replacement liabilities (as per the Alberta Wetland Policy) wetland assessments must be signed off by a Registered Qualified Wetland Science Practitioner (QWSP) to ensure suitable progress, including stabilization, expected water levels, water flow, and vegetation establishment. If progress is not satisfactory then additional actions may be needed, based on recommendations from QWSP (AEP, 2014).

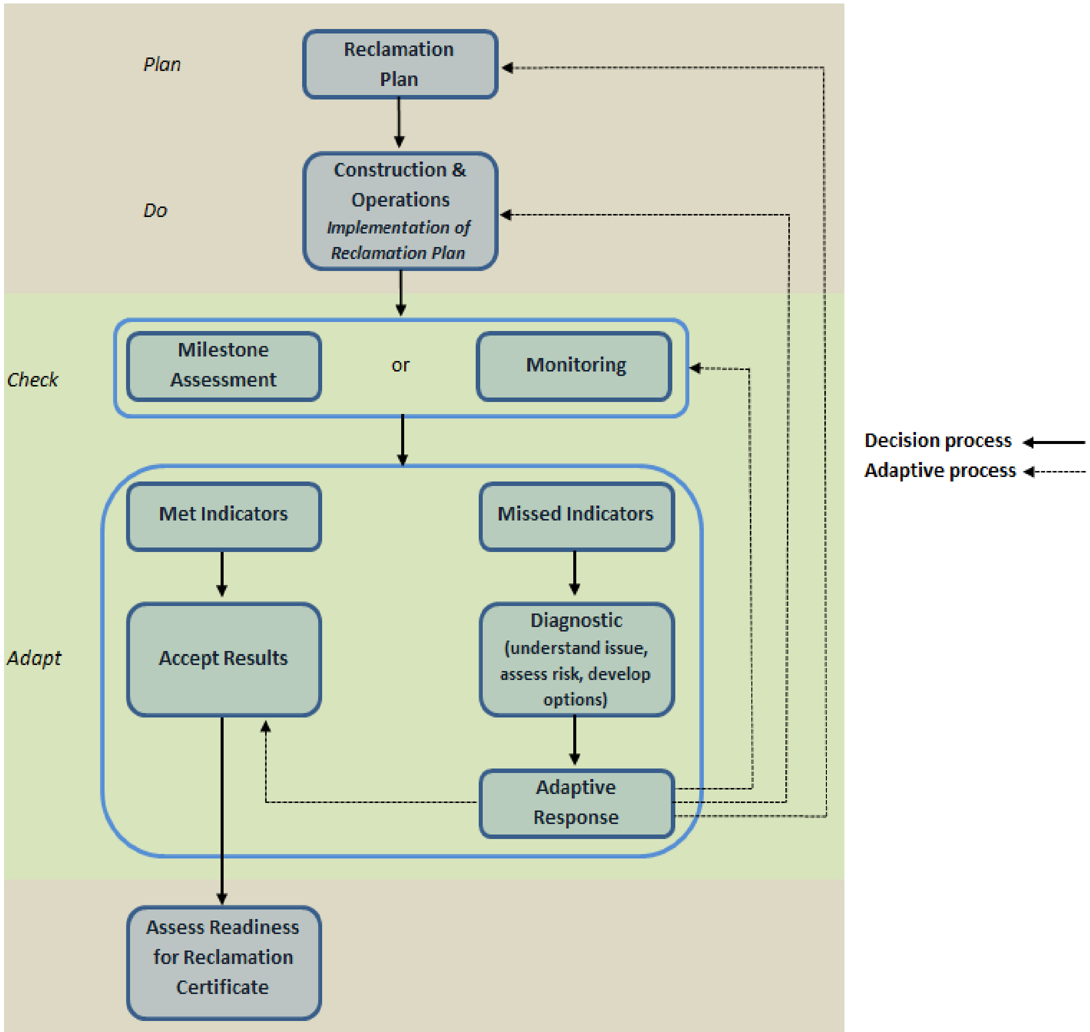


Figure 7: Example of adaptive management process to address any management or re-work that may be needed if monitoring results are not meeting performance targets. Four possible adaptive paths are listed: 1) a change to the reclamation plan and thus the rest of the subsequent reclamation steps; 2) earthworks or revegetation works (construction); 3) further monitoring; and/or 4) accept results of not achieving performance target where further diagnostics have revealed low risk.

About the Reclamation Certificate Application

The final step in reclamation in an OSR development is obtaining a Reclamation Certificate. The reclamation certification application process for EPEA Approvals is beyond the scope of this document.

Leases within the OSR regulated by an EPEA Approval are considered specified land. Reclamation certification for specified land is assessed against EPEA, CRR, and EPEA approval terms and conditions and applicable regulatory guidelines (AER(b), 2016).

As operators are approaching the application time for reclamation certification, pre-application meetings with the appropriate regulator are recommended to discuss site-specific history, establish mutual expectations on the readiness of a reclaimed site for certification, clarify application requirements, and determine the status of other regulatory approval requirements (AER, 2016).

References

AAFRD. (2004). *Soil Quality Criteria Relative to Disturbance and Reclamation (Revised).* Agriculture, Food & Rural Development, Soil Quality Criteria Working Group. Edmonton: Government of Alberta. Retrieved from http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag9469/$FILE/sq_criteria_relative_to_disturbance_reclamation.pdf

AEP. (2014). *Assessing Wetlands in Alberta.* Alberta Environment and Parks. Retrieved from http://aep.alberta.ca/water/programs-and-services/wetlands/documents/AssessingWetlandsAlberta-FactSheet-2014.pdf

AEP. (2015). *Reclamation Criteria for Wellsites and Associated Facilities for Peatlands.* Alberta Environment and Parks. Edmonton: Government of Alberta.

AER. (2013). *Integrated Standards and Guidelines: Enhanced Approval Process.* Government of Alberta. Retrieved from http://aep.alberta.ca/forms-maps-services/enhanced-approval-process/eap-manuals-guides/documents/EAP-IntegratedStandardsGuide-Dec01-2013.pdf

AER. (2014, October). *Guidelines for Submission of a PreDisturbance Assessment & Conservation & Reclamation Plan. Under an Environmental Protection and Enhancement Act Approval for Enhanced Recovery In-Situ Oil Sands and Heavy Oil Processing Plants and Oil Production Sites.* Alberta Energy Regulator. Retrieved from https://aer.ca/documents/manuals/Manual010.pdf

AER. (2016). *Application Submission Requirements and Guidance for Reclamation Certificates for Well Sites and Associated Facilities.* Specified Enactment Direction 002. (G. o. Alberta, Ed.) Alberta Energy Regulator. Retrieved from https://www.aer.ca/documents/manuals/Direction_002.pdf

AER. (2016). *Direction for Conservation and Reclamation Submissions. Under an Environmental Protection and Enhancement Act Approval for Enhanced Recovery In Situ Oil Sands and Heavy Oil Processing Plants and Oil Production Sites.* Specified Enactment Direction 001: Alberta Energy Regulator.

AER. (2016). *EPEA - Approved Reclamation Certificate Application Requirements*. Retrieved from Alberta Energy Regulator: http://www.aer.ca/abandonment-and-reclamation/epea-approved-reclamation-certificate-application-requirements

Alberta Environment. (2003). *Revegetation using Native Plant Materials: Guidelines for Industrial Development Sites.* Edmonton, AB.: Government of Alberta. Retrieved from Government of Alberta: https://extranet.gov.ab.ca/env/infocentre/info/library/5927.pdf

Alberta Queen's Printer. (1973). *Timber Management Regulation.* Retrieved 2016, from http://www.qp.alberta.ca/documents/Regs/1973_060.pdf

Alberta Queen's Printer. (2000). *Forests Act.* Retrieved from http://www.qp.alberta.ca/documents/Acts/F22.pdf

Alberta Transportation. (2013, December). *Alberta Transportation Pre-disturbance Assessment Guide for Borrow Excavations*. Government of Alberta. Retrieved from http://www.transportation.alberta.ca/content/doctype245/production/borrowproc.pdf

Alberta Transportation. (2014). *Environmental Construction Operations (ECO) Plan Framework.* Retrieved from Transportation Alberta: http://www.transportation.alberta.ca/content/doctype245/production/ecoplan.pdf

Bloise, R. 2007. Initiation and early development of boreal peatlands. M.Sc. Thesis, Southern Illinois University, Carbondale IL, 143 pp.

Boreal Research Institute. (2011). *Principles of Vegetation Managment.* NAIT. Retrieved from http://www.nait.ca/docs/Principles_of_Vegetation_Management.pdf

CEMA. (2014). *Guidelines for Wetland Establisment on Reclaimed Oil Sands Leases. Third Edition.* (West Hawk Associates, Ed.) Cumulative Environmental Management Association.

CEMA. (2012b). *Riparian Classification and Reclamation Guide, Revised Edition.* Cumulative Environmental Management Association.

Drozdowski, B., & Macyk, T. (2008). *Comprehensive Report on Operational Reclamation Techniques in the Minable OilSands Region*. Cumulative Environmental Management Association.

Eaton, B., Ross, L., Fisher, J., & et.al. (2014). *Chapter 3: Natural Wetlands in the Region*. In CEMA, Guidelines for Wetlands Establishment on Reclaimed Oil Sands Leases (p. Page 79).

ESRD. (2014, October). *Contaminated Sites Policy Framework.* Government of Alberta. Environment & Sustainable Resource Development. Retrieved from http://aep.alberta.ca/lands-forests/land-industrial/documents/ContaminatedSitesPolicy-C-Oct31-2014.pdf

Galatowitsch, S., & Van der Valk, G. (2003). *Restoring Praire Wetlands. An Ecological Approach*. First Ed. Iowa State University Press.

Golder Associates. (2010). *Best Management Practices User Manual for Aggregate Operators on Public Land.* Sustainable Resource Development. Government of Alberta.

Golder Associates. (2014). *Suncor: Firebag Borrow Pit 6 Reclamation Project.*

Government of Alberta. (1993). *Conservation and Reclamation Regulation.* Government of Alberta. Edmonton, AB.: Alberta Queen's Printer.

Government of Alberta. (2000). *Water Act.* Current as of December 17, 2014. Alberta Queen's Printer. Retrieved Current as of December 2014

Government of Alberta. (2009). *Management of Wood Chips on Public Land*. External Directive. Sustainable Resource Development. Lands Division. Land Managment Branch.

Government of Alberta. (2011). *Reclamation of Specified Land.* 2010 Reclamation Criteria (Updated June 2011), R&R 10-02. Government of Alberta.

Government of Alberta. (2013). *Alberta Wetland Policy*. Environment and Sustainable Resource Development. Retrieved from http://aep.alberta.ca/water/programs-and-services/wetlands/alberta-wetland-policy.aspx

Government of Alberta. (2014). *General Design Guidelines for a Constructed Habitat Wetland - Boreal Forest Natural Region.* Retrieved 2016, from Transportation Alberta: http://www.transportation.alberta.ca/Content/docType29/production/DGfCHW_BorealForestNaturalRegionofAlberta.pdf

Government of Alberta. (2015). *Surface Materials Reclamation Certificate Request*. Sustainable Resource Development.

Government of Alberta. (2016a). *Implementation Plan and FAQ's for the Guide to Water Act Authorizations Required for Dugouts, Borrow Pits and other types of Pits/Excavations.* Administrative Procedure No.3. Retrieved from http://aep.alberta.ca/water/legislation-guidelines/documents/ImplementationPlanFAQsWaterAct-Jun30-2016.pdf

Government of Alberta. (2016b). Alberta Forest Genetic Resource Management and Conservation Standards Volume 1: Stream 1 and Stream 2, 4th Version. Edmonton, AB. December 21, 2016. 158 pp.

Koropchak, S., & et. al. (2012). *Fundamental paradigms, foundation species selection, and early plant responses to peatland initiation on mineral soils*. In D. Vitt, J. Bhatti, & C. U. Press (Ed.), *Restoration and Reclamation of Boreal Ecosystems.* (pp. 76-100).

Kuhry, P. and J. Turunen 20116. The post glacial development of boreal and subarctic peatlands. pp. 25-41 In. Wieder RK and DH Vitt (Eds.). 2006. Boreal Peatland Ecosystems. Springer-Verlag, Berlin-

Heidelburg-New York.Magai, M. (2016, November). *First Review of COSIA Wetlands Document.* (D. D. Committee, Interviewer)

Martin, Joshua. 2017. Personal communication.

Native Plant Working Group. (2000). *Native Plant Revegetatio Guidelines for Alberta.* (H. Sinton-Gerling, Ed.) Edmonton, AB.: Alberta Agriculture, Food, and Rural Development.

Osko, T., B. Miller, K. Williams, and C. La Farge. (2016). Suncor Firebag pad 106 road reclamation ancillary projects. Report prepared for Suncor.

Polster, D. (2013). *Making Sites Rough and Loose: A Soil Adjustment Technique.* Boreal Research Institute. NAIT. Retrieved from http://www.nait.ca/docs/Making_Site_Rough_and_Loose.pdf

Rochefort, L., Quinty, F., & et. al. (2003). *North American Approach to the Restoration of Sphagnum dominated peatlands*. Wetlands Ecology and Managment, 3-20.

Ross, L., & Vitt, D. (2014). *Functional and Structural Attributes of Wetlands*. Appendix B. Guidelines for Wetlands Establishment on Reclaimed Oil Sands Leases Third Edition, p. 341.

Ross, L.; Gabruch, L. (2015). *Reclamation Guidance for Reclamation Guidance for Soil and Substrate Material Use and Placement in Newly Constructed Freshwater Marshes, Shallow Water Wetlands, and the Littoral Zones of Lakes.* Native Plant Solutions. Prepared for: Cumulative Environmental Management Association.

Schoonmaker, A., Marenholtz, E., Sobze, J., & Smreciu, A. (2014). *Native Boreal Shrub Seed Collection and Cleaning.* Boreal Research Institute. NAIT. Retrieved from http://www.nait.ca/docs/Shrub_Seeds_Collection_Cleaning.pdf

Shunina, A. 2014. Revegetation of fen peatlands following oil and gas extraction in Northern Alberta. A thesis submitted to the Faculty of Graduate Studies and Research. University of Alberta. Edmonton, AB.

Smreciu , A., & Sobze, J.-M. (2011). *Seeds Collection, Processing and Storage.* Boreal Research Institute.

Smreciu, A. (2011). *Alberta Native Plants and Seeds: Wild Harvest, Registration and Deployment. A Guide for Technicians and Practitioners.* NAIT Boreal Research Institute.

Sobze, J., & Rochefort, L. (2012). *Wellsite Clay Pad Removal and Inversion - A Peatland Restoration Pilot Project.* Canadian Reclamation. 12(1)., 4.

Soil Quality Criteria Working Group. (2004). *Soil Quality Criteria Relative to Disturbance and Reclamation (Revised).* Edmonton, AB.: Alberta Agriculture, Food, and Rural Development. Retrieved from http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag9469/$FILE/sq_criteria_relative_to_disturbance_reclamation.pdf

Urban Drainage and Flood Control District. (2016). *Chapter 13. Revegetation* . In Urban Storm Drainage Criteria Manual Volume 2.

Vitt, D., Wieder, R., Xu, B., & Koropchak, S. (2011). *Peatland Establishment on Mineral Soils: Effects of Water Level, Amendments, and Species after Two Growing Seasons*. *Ecological Engineering. 37.*, 354-363.

Basic Peatlands References

a) Canada Committee on Ecological (Biophysical) Land Classification, National Wetlands Working Group. 1988. *Wetlands of Canada*. Ecological Land Classification Series 24. Ottawa: Sustainable Development Branch, Canadian Wildlife Service, Conservation and Protection, Environment Canada.

A regionalized, detailed treatment of Canada's wetlands. Original data are presented for the first time for many of Canada's northern areas. The Canadian wetland classification is also presented in some detail.

b) Crum, Howard. 1992. A focus on peatlands and peat mosses. Ann Arbor: Univ. of Michigan Press.

Howard Crum writes about his fascination with peatlands, including wonderful literature quotes, and his views of peatland processes and plants.

c) Dierssen, Klaus, and Barbara Dierssen. 2001. Moore. Stuttgart: Ulmer.

A beautifully illustrated book on the peatlands of central Europe (in German).

d) Gore, A. J. P., ed. 1983a. Mires: Swamp, bog, fen, and moor: General studies. Ecosystems of the World 4A. Amsterdam: Elsevier.

Detailed treatise on the world's peatlands, including general processes in the first of two volumes.

e) Gore, A. J. P., ed. 1983b. Mires: Swamp, bog, fen, and moor: Regional studies. Ecosystems of the World 4B. Amsterdam: Elsevier.

The second volume of a two-volume detailed treatise on the world's peatlands, including reviews of regional peatland diversity and development.

f) Joosten, H., and D. Clarke. 2002. Wise use of mires and peatlands. Helsinki: International Mire Conservation Group and International Peat Society.

A review of the commercial use of peatlands, their preservation, and their restoration.

g) Loisel, J. and 53 co-authors. 2014. A database and synthesis of northern peatland soil properties and Holocene carbon and nitrogen accumulation. The Holocene DOI: 10.1177/0959683614538073.

An up-to-date synthesis of peatland characteristics based on 268 soil cores taken across the boreal zone.

h) Rydin, Håkan, and John K. Jeglum. 2006. The biology of peatlands. Oxford: Oxford Univ. Press.

The first real textbook on peatlands.

i) Vitt, D.H. 2008. Peatlands, pp. 2656-2664. In: SE Jorgensen and B. Fath (eds.). Encyclopedia of Ecology. Elsevier, Oxford.

j) Vitt, D.H. and J. Bhatti (Eds.). 2012. Restoration and Reclamation of Boreal Ecosystems. Cambridge University Press, Cambridge, 412 pp.

k) Wieder, R. Kelman, and Dale H. Vitt, eds. 2006. *Boreal peatland ecosystems*. Berlin: Springer Verlag.

A series of chapters devoted to our current understanding of boreal peatlands. This book contains comprehensive bibliographies of peatland-related scientific articles.

Appendix 1. Reclamation Task List

Task List	Commencement Date	Completion Date	Comments
Reclamation Milestone 1			
1.1. Confirm the Reclamation Approach and End Land Use			
1.1.1 Select the reclamation approach			
Determine fill removal option (Table 2)			
1.1.2 Select of peat site-type			
Review reclamation plan commitments			
Characterize available material (Table 3)			
Characterize the reference site (Table 4, Table 5)			
1.2 Information Gathering			
Elevation data			
Water table information			
Soil sampling (if necessary)			
1.3 Design			
Develop final design			
Develop topography map and wetland cross-section			
1.4 Revegetation Planning			
1.4.1 Plant species selection			
Determine vegetation layers (Table 5)			
Select species based on site-type (Table 6)			
1.4.2 Determine plant collection and establishment methods			
Select establishment method (Table 7)			
1.4.3 Scheduling revegetation			
Schedule according to Table 8, 9, 10			

Reclamation Milestone 2			
Task List	**Commencement Date**	**Completion Date**	**Comments**
2.1 Preparation			
Develop construction drawings			
Develop construction package			
Water management			
2.2 Materials Removal and Placement			
Communicate construction package and drawings to construction crew(s)			
Install mitigation controls			
Site grading & re-contouring			
Decompaction/roughing (if necessary)			
2.2.1 M-Pad Approach			
Partial fill removal			
Management options			
Revegetation			
2.2.2 I-Pad Approach			
Pad inversion			
Revegetation			

Reclamation Milestone 3			
Task List	**Commencement Date**	**Completion Date**	**Comments**
3.1 Revegetation			
Implement revegetation plan and follow Table 11			
3.2 Establishment Controls			
Manage for weeds			
Manage for wildlife			
Reclamation Milestone 4			
4.1 Develop Monitoring Plan			
Develop monitoring plan			
Develop indicators			
4.2 Monitoring and Focussed Adaptive Management			
Monitor for vegetation establishment			
Adaptive management to solve or address issues			

Appendix 2. Site-type - Bog

List of species found in Alberta, with characteristic species noted – these characteristic species are abundant and should be considered in reclamation design

Structural Layer	Species	Characteristic Species
Tree	*Picea mariana*	√
	*Larix laricina***	
Shrubs	*Chamaedaphne calyculata*	
	Kalmia polifolia	
	Ledum groenlandicum	√
	Oxycoccus microcarpus	√
	Vaccinium uliginosum	
	Vaccinium vitis-idaea	√
Field	*Carex pauciflora*	
	Eriophorum vaginatum	
	Rubus chamaemorus	√
	Smilacina trifolia	√
Ground	*Aulacomnium palustre*	
	Calypogeia sphagnicola	
	Cephalozia connivens	
	Dicranum undulatum	
	Ptilium crista-castrensis	
	Hylocomium splendens	
	Mylia anomala	√
	Pleurozium schreberi	
	Pohlia nutans	
	Polytrichum strictum	√
	Sphagnum angustifolium	
	Sphagnum balticum	
	Sphagnum capillifolium	
	Sphagnum fuscum	√
	Sphagnum magellanicum	√
	Stramiergon stramineum	
	Warnstorfia fluitans	
Lichen	*Cladina mitis*	√
	Cladina rangiferina	
	Cladina stellaris	
	Cladonia cenotea	
	Cladonia coniocraea	
	Cladonia cornuta	
	Cladonia crispula	
	Cladonia fimbriata	

	Cladonia gracilis	
	Cladonia multiformis	
Herb/Forb - acid fen species of wet (carpets and lawns) areas	*Carex aquatilis*	
	Carex limosa	
	Carex oligosperma	
	Carex utriculata	
	Scheuchzeria palustris	
Bryophytes	*Sphagnum angustifolium*	
	Sphagnum fallax	
	Sphagnum jensenii	
	Sphagnum lindbergii	
	Sphgnum majus	
	Sphagnum riparium	
	**Indicates a fen species found in bogs after disturbance	

Appendix 3. Site-type – Acid Fen

List of species found in Alberta, with characteristic species noted – these characteristic species are abundant and should be considered in reclamation design.

Structural Layer	Species	Characteristic Species
Tree	Larix laricina	
	Picea mariana	√
Shrub	Andromeda polifolia	√
	Betula glandulosa	√
	Betula pumila	√
	Chamaedaphne calyculata	√
	Ledum groenlandicum	
	Oxycoccus microcarpus	
	Vaccinium uliginosum*	
Herb/Forb	Calla palustris**	
	Carex aquatilis	√
	Carex limosa	√
	Carex oligosperma	√
	Carex pauciflora	
	Drosera rotundifolia	
	Equisetum fluviatile**	
	Eriophorum vaginatum*	
	Juncus stygius	
	Kalmia polifolia*	
	Menyanthes trifoliata	
	Pedicularis labradorica**	
	Rubus chamaemorus*	
	Sarracenia purpurea**	
	Scheuchzeria palustris	
	Smilacina trifolia	√
Bryophytes	Aulacomnium palustre	
	Pleurozium schreberi	
	Ptilium crista-castrensis	
	Hylocomium splendens	
	Pohlia nutans*	
	Polytrichum strictum*	
	Sphagnum angustifolium	√
	Sphagnum fallax	
	Sphagnum jensenii	
	Sphagnum lindbergii	
	Sphagnum magellanicum	√
	Sphagnum majus	
	Sphagnum riparium	
	Sphagnum russowii	
	Straminergon stramineum	

Structural Layer	Species	Characteristic Species
	Tomentypnum falcifolium	√
	Warnstorfia exannulata	
****Indicates a bog species that is also found in ombrotrophic microsites in poor fens.***		
*****Indicates a rich fen species found in minerotrophic or transition areas in poor fens.***		

Appendix 4. Site-type - Circumneutral fen (pH 5.5-7.0)

List of species found in Alberta, with characteristic species noted – these characteristic species are abundant and should be considered in reclamation design.

Structural Layer	Species	Characteristic Species
Tree	*Larix laricina*	√
	Picea mariana	
Shrub	*Betula pumila*	√
	Betula glandulifera	√
	Chamaedaphne calyculata	
	Ledum groenlandicum	√
	Myrica gale	
	Salix pedicellaris	√
	Salix petiolaris	
	Salix planifolia	√
Forb/Herb	*Andromeda polifolia*	
	Caltha palustris	
	Carex aquatilis	√
	Carex chordorrhiza	
	Carex diandra	√
	Carex disperma	
	Carex flava	
	Carex paupericula	
	Carex canescens	
	Carex interior	
	Carex lasiocarpa	√
	Carex leptolea	
	Carex limosa	
	Carex tenuiflora	
	Carex utriculata	√
	Cicuta maculata	
	Epilobium palustre	
	Eriophorum angustifolium	
	Eriophorum vaginatum	
	Equisetum fluviatile	
	Juncus stygius	
	Menyanthes trifoliata	√
	Parnassia palustris	
	Pinguicula vulgaris	
	Potentilla palustris	√
	Rubus arcticus	
	Scirpus cespitosus	
	Scirpus hudsonianus	

Structural Layer	**Species**	**Characteristic Species**
	Smilacina trifolia	
	Stellaria longifolia	
	Tofieldia glutinosa	
	Utricularia intermedia	
Bryophyte	*Aulacomnium palustre*	
	Brachythecium acutum	√
	Calliergonella cuspidata	
	Campylium stellatum	
	Drepanocladus aduncus	√
	Drepanocladus polygamus	√
	Hamatacaulis vernicosus	√
	Helodium blandowii	
	Hypnum lindbergii	
	Hypnum pratense	
	Plagiomnium ellipticum	√
	Pseudobryum cinclidioides	
	Ptychostomum pseudotriquetrum	√
	Sanionia uncinata	
	Scapania paludicola	
	Sphagnum contortum	
	Sphagnum fimbriatum	
	Sphagnum obtusum	
	Sphagnum subsecundum	
	Sphagnum teres	√
	Sphagnum warnstorfii	√
	Straminergon stramineum	
	Tomentypnum nitens	√

Appendix 5. Site-type – Alkaline fen (pH 7.0-8.5)

List of species found in Alberta, with characteristic species noted – these characteristic species are abundant and should be considered in reclamation design.

Structural Layer	Species	Characteristic Species
Tree	*Larix laricina*	√
Shrub	*Andromeda polifolia**	
	Betula glandulosa	√
	Betula pumila	√
	Ledum groenlandicum	
	*Oxycoccus microcarpus**	
	Salix pedicellaris	√
	*Vaccinium vitis-idaea**	
Herb / Forb	*Carex atrofusca*	
	Carex chordorrhiza	√
	Carex diandra	√
	Carex flava	
	Carex heleonastes	
	Carex lasiocarpa	√
	Carex limosa	
	Carex paupericula	
	Carex canescens	
	Carex atherodes	
	Carex microglochin	
	Carex utriculata	√
	Epilobium palustre	
	Epipactis palustris	
	Equisetum fluviatile	√
	Eriophorum angustifolium	
	Habenaria hyperborea	
	*Juncus stygius**	
	Liparis loeselii	
	Menyanthes trifoliata	
	Muhlenbergia glomerata	
	Parnassia palustris	
	Pinguicula vulgaris	
	Potentilla palustris	√
	Schoenus ferrugineus	
	Scirpus cespitosus	
	Scirpus hudonianus	
	Tofieldia glutinosa	

Structural Layer	Species	Characteristic Species
	Tofieldia pusilla	
	Triglochin maritima	√
	Triglochin palustre	√
Bryophyte	*Aulacomnium palustre*	
	Calliergon giganteum	√
	Calliergon richardsonii	
	Campylium stellatum	√
	Drepanocladus sordidus	
	Hamatocaulis vernicosus	√
	Hypnum pratense	√
	Mesoptychia ruthiana	
	Meesia triquetra	
	Paludella squarrosa	
	Plagiomnium ellipticum	√
	Pseudocalliergon trifarium	
	Ptychostomum pseudotriquetrum	√
	Sarmentypnum tundrae	
	Scorpidium cossonii	
	Scorpidium revolvens	√
	Scorpidium scorpioides	√
	Tomentypnum nitens	√
	Utricularia intermedia	

**Indicates a species that occurs in oligotrophic microsites*

Appendix 6. Site-Type – Saline Wetland

List of species found in Alberta, with characteristic species noted – these characteristic species are abundant and should be considered in reclamation design.

Structural Layer	Species	Characteristic Species
Sedges/Herbs	*Beckmannia syzigachne*	
	Calamagrostis stricta	√
	Carex aquatilis	
	Carex atherodes	√
	Carex lasiocarpa	
	Carex utriculata	
	Juncus alpino-articulatus	
	Juncus balticus	√
	Triglochin maritima	√
	Triglochin palustris	√
	Tofieldia glutinosa	
Mosses	*Aulacomnium palustre*	
	Ptychostomum pseudotriquetrum	√
	Drepanocladus polygamus	
	Drepanocladus aduncus	
	Campylium stellatum	√
	Tomentypnum nitens	
Saline Pools	*Puccinellia nuttaliana*	
	Carex prairea	
	Plantago maritima	
	Potentilla anserina	
	Salicornia europa	
	Scirpus pungens	
	Suaeda calceoliformis	

Appendix 7. Vascular plant species in the herbaceous and shrub layers that have potential for fen establishment

Scientific Name	Common Name	Layer
Beckmannia syzigachne	(American sloughgrass)	Graminoid
Calamagrostis inexpansa	(Bluejoint)	Graminoid
Calamagrostis stricta	(Slimstem reedgrass)	Graminoid
Carex aquatilis	(Water sedge)	Graminoid
Carex atherodes	(Wheat sedge)	Graminoid
Carex bebbii	(Bebb's sedge)	Graminoid
Carex canescens	(Polar sedge)	Graminoid
Carex chordorrhiza	(Creeping sedge)	Graminoid
Carex diandra	(Lesser panicled sedge)	Graminoid
Carex hysteriana	(Bottlebrush sedge)	Graminoid
Carex lasiocarpa	(Slender sedge)	Graminoid
Carex paupercula	(Boreal bog sedge)	Graminoid
Carex pseudocyperis	(Beaked sedge)	Graminoid
Carex utriculata	(Northwest Territory sedge)	Graminoid
Eriophorum angustifolium	(Narrow-leafed cottongrass)	Graminoid
Juncus alpino-articulatus	(Northern green rush)	Graminoid
Juncus balticus	(Alaska rush)	Graminoid
Juncus tenuis	(Greater poverty rush)	Graminoid
Scirpus atrocinctus	(Wool-grass)	Graminoid
Scirpus lacustris	(Hardstem bulrush)	Graminoid
Scirpus validus	(Soft-stemmed bulrush)	Graminoid
Scirpus microcarpus	(Small-flowered bulrush)	Graminoid
Triglochin maritima	(Seaside arrowgrass)	Forb
Triglochin palustris	(Seaside arrowgrass)	Forb
Caltha palustris	(Yellow marsh marigold)	Forb
Betula glandulifera	(Swamp birch)	Shrub

Appendix 8. Bryophyte species occurring in the ground layer that have the potential for acid, circumneutral, and alkaline fen establishment.

Best Choice – Mineral Soil	Best Choice – Peaty Soil	Other Choice
Campylium stellatum	*Aulacomnium palustre*	*Calliergon giganteum*
Drepanocladus (Campylium) polygamus	*Polytrichum strictum*	*Hamatocaulis vernicosus*
Drepanocladus aduncus	*Sphagnum teres*	*Marchantia polymorpha*
Leptobryum pyriforme		*Scorpidium revolvens*
Ptychostomum (Bryum) pseudotriquetrum		*Tomentypnum nitens*
		Warnstorfia fluitans

Appendix 9: Approved Commercial Seed Processing and Testing Facilities

Alberta Government

Environment and
Sustainable Resource Development

Approved Commercial Seed Processing and Testing Facilities

Approved Commercial Seed Processing Facilities

Bonnyville Forest Nursery Inc.
5110-55 Avenue
Bonnyville, AB T9N 2M9
Dan McCurdy
780 826-6162

British Columbia Tree Seed Centre
Heather Rooke
604 541-1683

Chickadee Reclamation Services
7624-88 Avenue NW
Edmonton, AB T6C 1K8
Eckehart Marenholtz
780 722-9761

Grumpy's Greenhouses and Gardens Ltd.
Box 2488
Pincher Creek, AB T0K 1W0
Debbie Everts
403 627-4589

PRT Prince Albert Nursery
Box 2901
Prince Albert, SK S6V 6J9
Doug Gullickson
306 953-4700

Smoky Lake Forest Nursery Ltd.
Box 220
Smoky Lake, AB T0A 3C0
Stuart Howarth
780 656-4130

Yellow Point Propagation Ltd.
13735 Quennell Road
P.O. Box 669
Ladysmith, BC, V9G 1A5
Don Pigott
250 245-4635

Approved Commercial Seed Testing Facilities

British Columbia Tree Seed Centre
Heather Rooke
604 541-1683

Smoky Lake Forest Nursery Ltd.
Box 220
Smoky Lake, AB T0A 3C0
Stuart Howarth
780 656-4130

PRT Prince Albert Nursery
Box 2901
Prince Albert, SK S6V 6J9
Doug Gullickson
306 953-4700