Reclamation Criteria for Wellsites and Associated Facilities for Peatlands

Alberta Government

acknowledgement

The Reclamation Criteria for Wellsites and Associated Facilities for Peatlands rely on the foundation set in the *2010 Reclamation Criteria for Wellsites and Associated Facilities Criteria*. The Peatlands Development Committee wants to acknowledge the extensive collaboration completed by the Reclamation Criteria Advisory Group.

The Peatlands Reclamation Criteria were initiated in November 2014. The Development Committee included:

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Information and copies may be obtained from http://aep.alberta.ca

This document may be cited as:
Environment and Parks. 2015. Reclamation Criteria for Wellsites and Associated Facilities for Peatlands, October, 2015, Edmonton, Alberta PP 142.

Title	Reclamation Criteria for Wellsites and Associated Facilities for Peatlands
Number	AEP, Land Policy, 2015, no. 6
Program Name	Land Policy Branch
Effective Date	Required for reclamation certification applications received after April 15, 2016.
This document was updated on	

ISBN: 978-1-4601-2386-7 (Printed Edition)
ISBN: 978-1-4601-2387-4 (On-line Edition)
Printed October 2015

preface

Alberta initially released *The Reclamation Criteria for Wellsites and Associated Facilities* (C&R/IL/94-1) in 1994, followed by the 1995 Update (C&R/IL/95-3). It included sections for Cultivated, Grassland, Forest, and Peatlands. Through 2006-2010 the Reclamation Criteria Advisory group (RCAG), a multi-stakeholder committee, updated the Reclamation Criteria and released criteria documents for Cultivated, Forested and Native Grasslands (Environment and Sustainable Resource Development 2013). As much of the research in peatland reclamation was not yet complete at the time of these criteria, the Peatland subcommittee was disbanded in 2009 and the 2010 Reclamation Criteria for Wellsites and Associated facilities (2010 Reclamation Criteria) was released without a Peatland Criteria document.

Energy and resource extraction industries continue to expand within peatland ecosystems in Alberta. The completion of the *Wetland Policy*, the move to provide consistent reclamation objectives and outcomes for all activity types in Alberta, and positive research results for peatland reclamation provided the necessary policies and scientific background for completing this document.

The following document provides the reclamation certification criteria for wellsites, access roads, and associated facilities reclaimed to peatlands on Private and Crown lands in Alberta. It is designed for minimal disturbance winter access and all season clay padded sites.

Note that this document is not intended as a construction guide, but must be considered when planning for oil and gas construction, specifically the use of clay pads. It is hoped that construction techniques, such as clay pad installation, will evolve to support the re-establishment of a peatland type, in areas with specific land use objectives. This document does provide some guidance for reclamation procedures, included in the appendices.

When this document was drafted, it was actively aligned with the 2010 Reclamation Criteria where appropriate. The background and classification sections were also aligned with the *Guidelines for Wetland Establishment of Reclaimed Oil Sands Leases 3rd Edition* (CEMA 2014) through the utilization of a common author. This alignment recognizes that the disturbance types covered by this document and the Oil Sands document differ greatly but makes use of commonalities in reclamation approach where possible. The scope of this document is limited; for a broader view of wetland reclamation, it is suggested the Guidelines for Wetland Establishment of Reclaimed Oil Sands Leases 3rd edition be reviewed prior to initiation of peatland reclamation project.

While not all function will be restored in a disturbed site for decades or millennia, pre-disturbance function such as peat accumulation (Loisel et al., 2014), carbon sequestration, water storage/filtration and wildlife habitat are the desired reclamation outcomes in the long-term. This guide is presented as a first approximation, recognizing that revisions will be required as our knowledge of peatland communities and reclamation methods increases. Revisions will also be required as reclamation practitioners and industry respond to the challenges of peatland reclamation with new technology designed to reduce the industrial footprint in peatland communities.

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1. reclaiming to peatlands

Peatlands are defined in North America as landscape covered by peat to a minimal depth of 40 cm (Tarnocai, 1980). Peat is a deposit of plant and animal remains that over time has accumulated under water-saturated conditions through incomplete decomposition.

A combination of ground-layer-dominated vegetation (typically bryophytes), hydrology, regional climate, and landscape forms is needed for peatlands to develop. Peatlands presently occupy 103,000 km^2 of Alberta, 16.3 per cent of the total land base, and between 30 and 40 per cent of northern boreal areas (Vitt et al. 1995). Peatlands, like other wetlands, serve important functions on the landscape: namely, (1) water storage; (2) a filter for surface water as it moves into ground water; (3) a habitat for wildlife (Mitsch & Gosselink 2000) and, (4) a carbon sink (Yu et al. 2001). Peatlands in Alberta contain an estimated 48 petagrams (=Gt) (Pg) of carbon (Vitt et al. 2000), compared to 2.7 Pg contained in the forests and 0.8 Pg in the grasslands (Vitt 2006). Undisturbed boreal peatlands store about one-third of the global soil carbon (Gorham 1991). A more detailed primer on western Canadian peatlands has been included in Appendix A.

When clay pads are placed within peatlands, mineral upland islands or peninsulas are created and organic matter accumulation of the peatland stops for these areas. Gravel roads and wellsite clay pads, in particular, may impact the function (hydrology and vegetation) of peatland ecosystems, and result in the loss of carbon from the peatland carbon sink – both from (1) the organic matter under the constructed road and pad that undergoes anaerobic decomposition and releases methane (CH_4); and, (2) the loss of living plants that capture atmospheric CO_2. Thus, return of these areas to equivalent land capability includes a return to peatland communities that are capable of sequestering carbon (Vitt et al. 2011).

The aim of reclamation under the Environmental Protection and Enhancement Act is to obtain equivalent land capability. **"Equivalent land capability"** is defined in the Conservation and Reclamation Regulation as **"the ability of the land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical."**

The reclamation criteria in this document are to be used to evaluate whether a site has met or is on a trajectory to meet equivalent land capability. The criteria are based on land function that will support the production of goods and services consistent in quality and quantity with the surrounding landscape. When reclaiming to peatlands, it is acknowledged that due to the slow accumulation of decomposed organic matter a site may not have the 40 cm of undecomposed peat that defines a peatland. Rather the reclamation will re-establish the landscape and vegetation components that will provide a trajectory to future peatlands. A backgrounder on Peatland Reclamation Strategies and list of Peatland Reclamation Literature, relevant to Alberta, are included as Appendices B and C.

2. reclamation criteria, land types and change in land use

2.1 Reclamation Criteria

The reclamation criteria apply to wellsites, pipelines, access roads, and associated facilities such as pits, campsites, log decks, and offsite sumps. With written agreement from the Land Manager, they do not apply to facilities or features that are left in place as developed (e.g., roads, pads, dugouts) although these facilities or features must serve a purpose, be stable, non-erosive, non-hazardous and have no impact to off-lease lands.

Note: The criteria in this document do not preclude the need to meet specific requirements identified prior to the activity commencing by the local Authority (e.g., Municipality, Public Lands approval) and/or an agreement, or land use plan.

2.2 Land Types

The 2010 Criteria identified the following land types: Forested Lands, Cultivated Lands, Native Grasslands and Peatlands. The definitions of the land uses follow:

Forested Lands includes any treed land, with less than 40 cm of organic matter accumulation, whether or not the forest vegetation is utilized for commercial purposes. Treed (bush) lands in the White Area (deedable land) that is to be maintained as ‘treed’ must meet the forested criteria. Land in the White Area where a land use has been changed to cultivation must meet the cultivated criteria. In the Green Area (crown land), native meadows or range improvement areas in grazing dispositions may be assessed using the grasslands or cultivated lands criteria, with approval from the Land Manager.

Cultivated Lands include lands managed under conventional, minimum or zero till practices for agricultural purposes. Land use changed from peatland, forested land or grassland to cultivated land is included here. The cultivated land criteria also apply to trees planted for agroforestry (i.e., tree farms), tame forages, tame pasture, hay lands or areas seeded to perennial agronomic species.

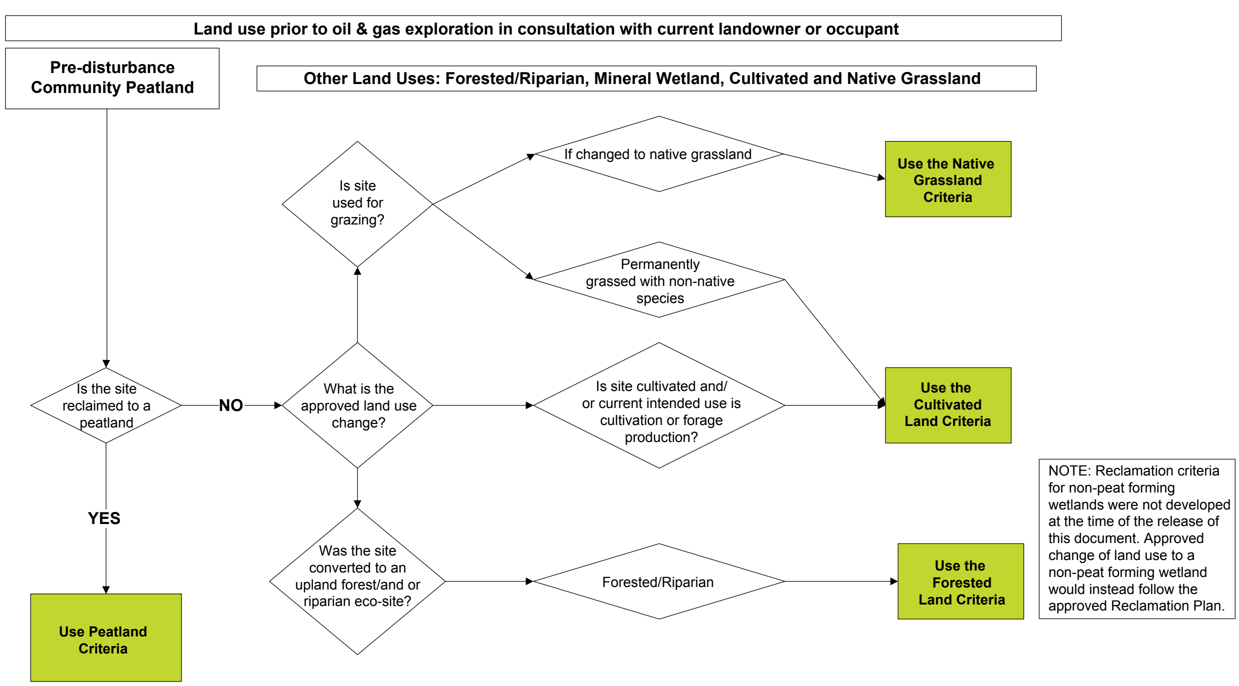
Native Grasslands include lands that are permanently vegetated by native herbaceous species. Native grasslands commonly present a mixture of different native grass species, forbs (i.e., flowering/broad-leaved species), shrubs (i.e., woody species) and tree species, whereas tame grasslands (i.e., forage and tame pasture) produce agronomic seeded grass and legume species such as timothy and alfalfa. Grasslands occur primarily in the Grassland Natural Region, but they can also be found in other Natural Regions of Alberta, including the Parkland, Rocky Mountains and Foothills Natural Regions. Grasslands include range improvement areas, grazing dispositions on public lands(White Zone and Green Zone areas), native prairie and grassland areas, Special Areas, and the Eastern Irrigation District. Riparian areas may also occur in Grassland sites. Riparian areas are the moist habitats found along creeks and sloughs, that include wetland grasses, forbs, shrubs and trees. For grasslands that have been cultivated/seeded to agronomic species and the land use goal is to be managed as tame forage for hay or pasture, they shall be assessed under the Cultivated Land criteria.

Peatlands include lands covered by peat to a minimal depth of 40 cm (Tarnocai, 1980). Where disturbed peatlands are to be reclaimed to an alternative end land use (i.e., cultivated lands or forested lands), agreement with the Land Manager must be reached and the reclamation criteria for that agreed land use are to be used for assessment purposes.

2.3 Land Use Changes

Where a site within peatland has been partially or fully reclaimed to another land use, a change in land use is required. If a site changes land use, the Land Manager must be involved in the discussion and any such changes will require their written agreement. If a land use change occurs, the Assessors must refer to the appropriate Criteria to use for conducting the reclamation assessment (Figure 1).

Choosing Land Use Reclamation Criteria



3. undisturbed and distributed peatlands

Industrial activities in peatlands are often conducted on undisturbed sites during frozen ground conditions or constructed for all seasons with the addition of a stabilization layer, such as a clay pad. These varying construction practices are the primary driver in peatlands reclamation criteria for the Undisturbed and Disturbed scenarios outlined below.

3.1 Undisturbed

Activities that utilize minimal disturbance techniques, such as construction in frozen conditions, may result in a site that for the purpose of these reclamation criteria is classified as undisturbed. **Undisturbed** is defined as a peatland with the original ground cover layer intact. The undisturbed vegetation assessment is designed to determine intactness.

>> **Note: A site that fails the undisturbed "intactness" criteria is considered disturbed and must be assessed with the disturbed assessment criteria. Refer to Section 11.4.**

3.2 Disturbed

Sites that are considered disturbed for the purpose of the reclamation criteria will include clay padded sites and any minimal disturbance sites that do not pass the undisturbed vegetation assessment. In some cases, even though padding was not conducted, traffic may have caused compaction, pulverized organic soil, rutting or clodding to the extent that the native community (i.e., species and/or layers) has been altered or removed (e.g., organic soils that were not frozen during later winter access).

3.3 Partial Disturbance

Sites where the activity resulted in both undisturbed and disturbed areas can be stratified and assessed individually. The criteria for classifying a site as undisturbed and disturbed are contained within the Vegetation Assessment Section.

4. use of professional judgment

When assessors are using the Reclamation Criteria for Peatlands, the assessor can use their professional judgement in determining if a site should pass or fail. The use of a justification to explain why a site should pass will result in a further technical review and require acceptance by the Regulator. The justification must be documented in the Exemption Justification Form.

5. required information in detailed site assessment

The assessment tool that accompanies the 2010 Reclamation Criteria for the other land uses was not developed for peatlands at the time this document was released. Until such time as additional guidance is provided, the following is intended to outline essential detailed site assessment reporting.

- **Site Background:** The site background section documents site history, land use changes, special land management conditions, and land manager comments. The dates of the site construction, reclamation (initial contouring/ vegetation establishment), herbicide application or land manager approved amendments must be included. The area (ha) of wetland disturbed and the amount of wetland reclaimed (includes both non-peat forming wetlands and peatlands) must also be reported.
- **Site and Lease Sketches:** The site sketch must delineate the areas of the lease affected by construction or other activities. Careful attention must be paid to these areas. The site sketch must include changes to drainage patterns, slope, vegetation and any anomalies of offsite versus onsite. Site and lease sketches must be included with the application.
- **Landscape and Vegetation Components (Onsite/Offsite):** A full detailed site assessment for all landscape and vegetation components of the criteria for all areas must be included. Missed components may result in the application being rejected as incomplete.
- **Stratified sites:** Sites that are stratified with multiple land use criteria but are dominantly peatland can be included in one application and one report. If the site is dominantly one of the other land use criteria, the applicable assessment tool must be submitted as directed for that land use's criteria.
- **Amendments and Herbicide Use:** Any use of amendments or herbicides must be documented (type, application rate, date(s)), comply with applicable guidelines, and have the agreement from the land manager on private lands and approval from the Regulator on public lands. There is a two year waiting period (two full growing seasons) after application of amendments (including fertilizers) and herbicides before applying for reclamation certification.

>> **Note: The Regulator reserves the right to request additional information as required to make the Pass/Fail decision for reclamation certification or audit.**

6. determining sampling intensity

For reclaimed sites, sampling intensity (i.e., number and spacing) onsite and offsite must address the variability in site conditions. The sampling plot sizes are outlined below for non-linear and linear sites.

6.1 Non-Linear Reclaimed Sites

The assessment locations must include the following five locations if known: well centre, sump, flare pit, production areas and entrance to the lease. The well centre plot must be as close to the wellbore location as possible to assess the reclamation conditions at this heavily affected location. To ensure that small anomalous conditions are not used to describe the site, the vegetation sampling method is a grid system.

Assessment point spacing must be adjusted to evenly cover the entire lease. Spacing must be adjusted for different sized and shaped leases (Table 1).

Table 1. Sampling intensity based on size of disturbance on the site.

Disturbed Assessment		
Maximum disturbance size (m)	**Minimum number of onsite grids**	**Offsite Assessment**
Up to: 40 m x 40 m (1600 m^2)	1	Landscape Overview
80 m x 80 m (6400 m^2)	4	
120 m x 120 m (14, 400 m^2)	9	
>120 m (>14, 000 m^2)	9 (+1 more for each additional 1600 m^2)	
Undisturbed Assessment		
<40 m x 40 m	1	Landscape Overview
Greater than 40 m x 40 m	4	
Greater than 120 m x 120 m	4 (+ 1 more for each additional 3600 m^2)	

Note: An increase in sampling intensity can also be triggered by a variable site requiring stratification, larger lease sizes or different landscape units.

6.2 Linear Reclaimed Sites

The assessment points along linear features such as pipelines or access roads are designed to capture the increased landscape variability associated with linear features. Assessment points must consider both the landscape variability and capture areas where high traffic or construction practices resulted in greater levels of disturbance. The sampling units are outlined below.

For linear sites, the landscape overview (Section 10 Landscape Assessment) and vegetation assessments (Section 11) must use paired comparisons (one undisturbed representative offsite and one onsite assessment location). The purpose of the paired assessment is to meet the requirements in the undisturbed decision tree. For the disturbed assessment, the purpose of the offsite comparison it is to determine the woody species structural layer requirement. Note, that areas that are not in peatlands must be compared to the appropriate Land Use Criteria.

Linear features are assessed at the following intensity levels:

- ≤400 m: assessment points must be located at a maximum spacing of 100 m (Figure 2A)
- >400 m: assessment points must be located to reflect different mapping units, (i.e., topographic, vegetation and/or soils variability) with a minimum of one (1) assessment point per map unit or a minimum of one (1) assessment point per 800 m (Figure 2B) The minimum number of assessment points is five (5).

Note: Areas impacted offsite (e.g., flooding) along a linear disturbance must be assessed as outlined in Section 10.3.

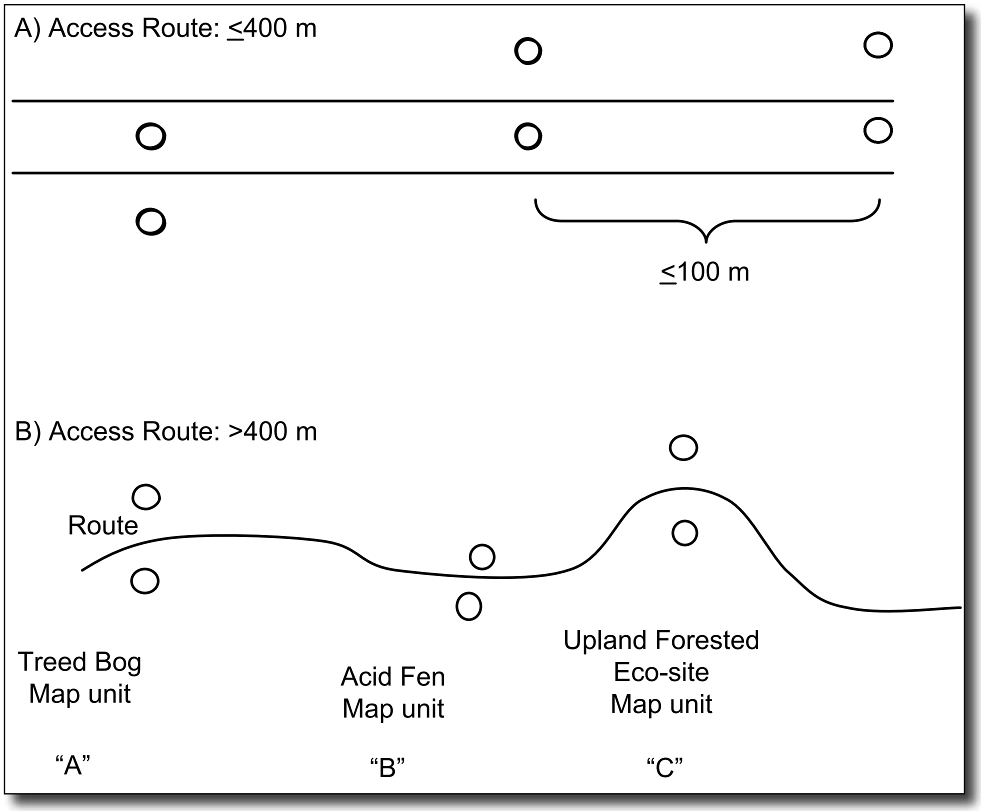


Figure 2. Vegetation assessment locations along access routes that are ≤400 m (Figure 2A) or >400 m (Figure 2B).

7. sampling on variable sites

On variable sites (such as sites with varying moisture regimes, soils and plant communities) more than the standard nine assessment points may be required to accurately assess plant or use multiple land use criteria. If the landscape has two distinct zones, conduct the assessment at points on and offsite in each of the two zones (Refer to Figure 3, Assessing and sampling a stratified site)

8. variable scale assessment methodology

To accommodate vegetation variability, onsite assessments must be completed using the variable scale sampling methodology as outlined below and in Figure 3. The assessment begins with a landscape level overview of both offsite and onsite areas. The onsite assessment then continues by dividing the reclaimed area into grids and proceeding with vegetation assessments within the full grid and representative plots, as described below. Landscape assessment parameters are described in Section 10. Vegetation assessment parameters are described in Section 11. The methodology for determining a “pass” or “fail” from the assessment results is provided in Section 12.

- **Landscape overview** – The assessment is a site level evaluation and is required for all landscape assessment components on and offsite, except the identification of open water/ponding or upland eco-sites, which is completed as outlined below. The peatland type, any other land uses and the presence of woody species are also collected during the landscape overview.

- **Full Grid** – Open water/ponding or upland eco-sites are assessed on a grid level as outlined in the Landscape Assessment.

The following vegetation sampling methodology is depicted on Figure 3.

- **Meandering Grid** – Species richness is assessed on a grid level by completing a timed meandering vegetation assessment, where all species are noted within that timeframe. Assessors complete a walk through (meander) within each grid for species identification until no new species are identified (for example an experienced assessor may complete a 10 minutes meander per grid.) The time spent at each grid must be consistent and length of time is determined by the assessor’s professional judgement. Microhabitats present (pools, carpet, lawn and hummocks) must be captured in the meander (see Newmaster et al. 2005) and are defined in Section 11.2.4 .

- **Vascular plant plot** – A representative plot of the vascular plants, (trees, shrubs, graminoids (primarily sedges) and herbs are assessed within a 1.78 m radius (10 m^2) assessment method. The plot location must be representative of the area inside the grid. Trees and shrubs are reported as stem counts or percent canopy cover. Sedges and herbs are reported as overall percent canopy cover, not by species.

- **Bryophyte plot** – Bryophytes are assessed within a 1 m^2 plot. To capture natural variability, 4 randomly placed 1 m^2 plots will be averaged. This is not a species assessment but overall bryophyte percent canopy cover.

Note: For linear assessments the above sampling methodology applies. The desirable species cover assessment (vascular plant plots and bryophyte plots) frequency is as described in Section 6.2. For the full grid assessment, an approximate 40 m length can be used to assess open water/ponding or uplands not present offsite and complete the meandering assessment.

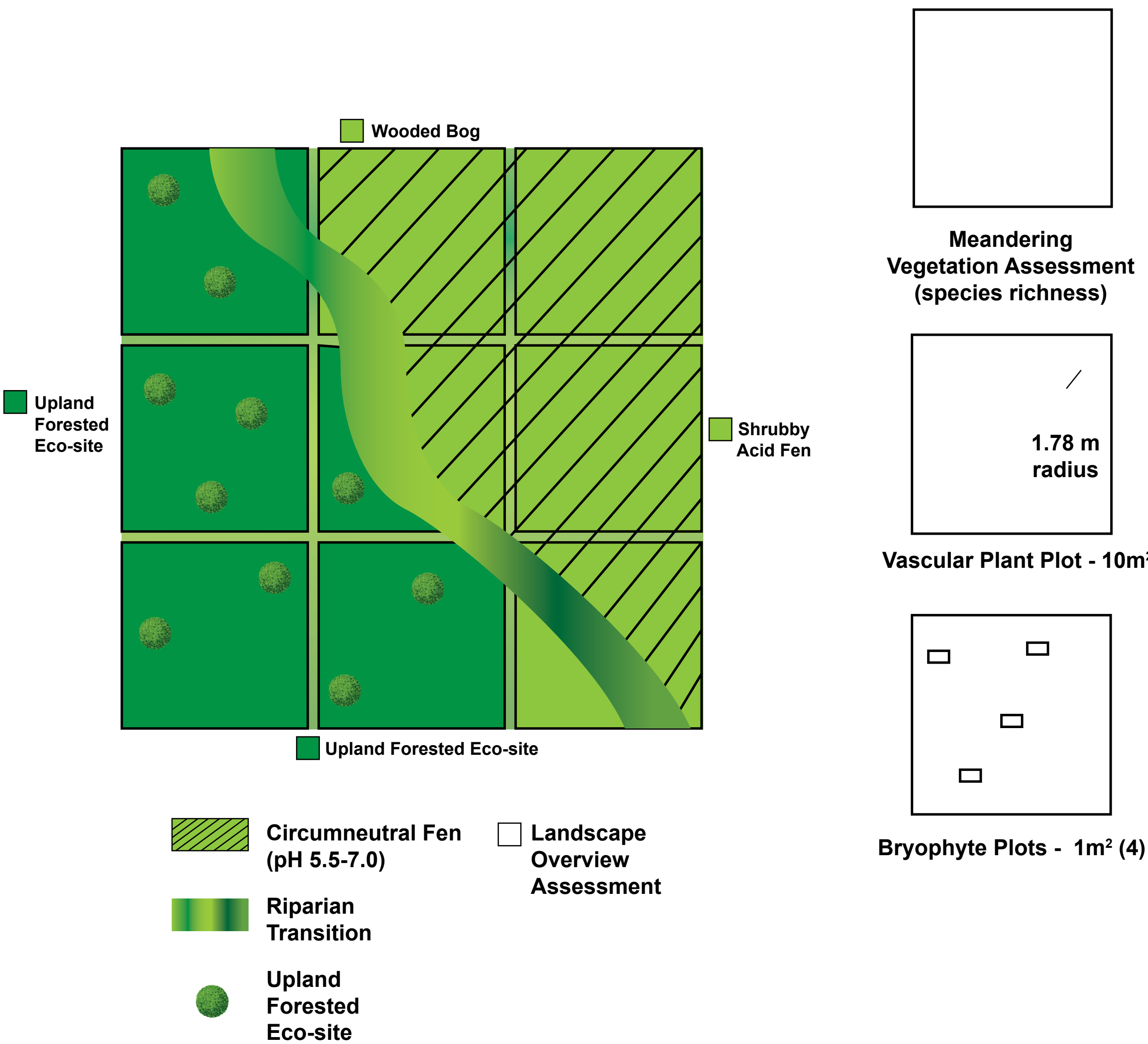


Figure 3. Assessing and sampling a stratified site

9. aerial assessments

For sites that are not accessible by aerial landing, Argos, or all-terrain vehicles and the distance is too remote to access by foot, then an assessor may perform an alternative aerial assessment. For Oil Sands Exploration leases the "Coal and Oil Sands Exploration Reclamation Requirements" apply.

Where the sites are not accessible as outlined above, but the native woody species have recovered across the site, the following assessment applies:

- Landscape assessment as outlined in Section 10.
- List of dominant species or genus by structural layer (ground, field, shrub, tree).
- Average canopy height to approximately 0.25 m
- Percent canopy cover by ground layer and identification of visibly evident plant species.
- Aerial photos including low level views of the vegetation cover and landscape shots, clearly annotated to the detailed site assessment data.

Aerial assessments on long access roads (>400m) must visually assess variability along the linear feature and adjacent impacts. Aerial photos and the location selection must at a minimum cover all landscape units (e.g., bog, circumneutral fen, alkaline fen, upland eco-sites, riparian areas). Assessment areas must be completed as outlined above and the assessment points be included on a corresponding diagram in the DSA.

Note: Where the sites are not dominated by woody species, or where damage due to access may result in site failure, formal approval from the regulator must be obtained prior to submitting an aerial assessment as outlined above.

10. landscape assessments

Landscape criteria components are assessed at a landscape overview scale (Section 8). The assessor reviews the site as a whole from several vantage points on the site and compares the site with the pre-disturbance conditions or adjacent land. The differences between the site and the adjacent land for landscape components outlined below must not interfere with peatland vegetation and not show a negative impact on or offsite.

>> **Note: All landscape components are assessed at a landscape overview site assessment scale, except the identification of open water/ponding or upland eco-sites which are completed within each grid. The pass/fail determinations for Landscape criteria components are presented in Section 12.1.**

10.1 Moisture Regime

An important landscape parameter for peatlands is the site moisture regime. It is a key indicator that the site can support peatland vegetation. This is affected by landscape components such as micro and macro contour, surface flow, drainage and elevation relative to offsite. Moisture regime must be documented for both on and surrounding offsite vegetation communities. The re-establishment of moisture conditions that result in the site being covered by 1-10 cm of water in the spring and moist all year round is essential to the survival of peat accumulating species. Sites where alternate end land use or multiple end land uses (peatland, riparian, upland complex) will have multiple moisture regimes and must be stratified and the appropriate land use criteria applied.

10.2 Open Water/Ponding or Upland Eco-sites

Where open water does exist, species typical of these moisture regimes may not be peat accumulating or may result in eutrophic conditions not conducive to a peatland trajectory. As a result, sites reclaimed to peatlands are limited in how much open water is allowed and how much of the site can be reclaimed to upland eco-sites.

Open water/ ponding for the purpose of these criteria are defined as permanently water-filled areas without living, peat-forming vegetation (both vascular plants and bryophytes). When assessing the size of the open water/ponded area, the non-peat forming vegetation (such as submerged vascular plants), and surrounding non-peat-forming vegetation (such as cattails) are included in the area documented as open water/ponding. Any area of the site where open water/ponding is present, but has ≥50 percent canopy cover of peat forming species, and ≤20 percent undesirable species, is not considered open water as defined in the criteria, and does not result in a failure for this parameter.

Note: Shallow open water with abundant, established peat accumulating species dominating (>50 per cent canopy cover of species) such as sedges with ≤20 per cent canopy cover of undesirable species, does not result in a failure for open water even if greater than the size criteria outlined below.

Where small upland forested eco-sites are present on-site, not associated with a site stratification to offsite uplands or a change in land use, the area per grid is restricted as outlined in the criteria below. Areas reclaimed to upland eco-sites must reflect the Forested criteria.

Open water/ponding or upland eco-sites in the **disturbed** assessment are limited to ≤15 per cent of the area within the grid (15x15 m on a typical 40x40 grid size), cumulatively. This area includes both the open water and the surrounding non-peat accumulating species such as cattails (*Typha* spp.). For upland eco-sites it includes non-peat accumulating riparian vegetation. The potential for small low areas on lease or settling and/or subsidence at well centre is reflected here.

Note: For areas that have received a change in land use (e.g., non-peat forming wetland, upland eco-site) or a site stratified to reflect the pre-disturbance landscape variability (i.e., fen/marsh complex), the Peatland Criteria do not apply to any non-peatland areas. Reclamation criteria for non-peat forming wetlands were not established at the time of this document and until such time as they are, final reclamation for a non-peat forming wetland must be approved by the Regulator and/or Land Manager, typically through a reclamation plan.

10.3 Offsite drainage (cross-site flow; water movement off the lease)

Cross-site flow disruptions are most likely to occur with long linear features (roads) or large facilities, but the extent of the impact depends on the local hydrology and geology. The location of a lease may result in drainage patterns being disrupted. Ensuring the surrounding contours are carried into the lease and that landscape features adjacent to it are conserved may prevent a change in the pattern of flow. Where onsite drainage may serve to collect and re-direct water, offsite sediment fans, deposition of organic matter fans, unhealthy or dead vegetation and/or ponding on the up or downslopes adjacent to the lease, are evidence of offsite impacts to surficial drainage.

10.4 Riparian Areas, Bank & Shore Stability

Riparian lands are transitional zones between land and water bodies and include any geographic area that adjoins or directly influences a water body (e.g., streams, lakes, ponds and wetlands which may include floodplains) and land that directly influences alluvial aquifers and may be subject to flooding.

Sites that are stratified, whether for a change in land use or due to multiple offsite plant communities, may have riparian transitions between communities.

If the reclaimed area includes a riparian area or if the lease abuts a water body's bank or shore, there must be no evidence of shore/bank instability (e.g., slumping, channeling within banks, etc.) greater than is found on the offsite bank or shore. The vegetation must be a comparable, self-sustaining native vegetative community or provide evidence that it is on the corresponding successional trajectory to the surrounding area. Short lived non-native species may be appropriate to assist with shore/bed stabilization when approved by the land manager or Regulator.

AER Directive 056 (Energy Development Applications and Schedules) along with other applicable provincial and federal legislation (i.e., *Environmental Protection and Enhancement Act, Water Act, Public Lands Act* and the *Navigable Waters Protection Act*) requires water bodies be protected during construction and through the operating life of the project. For more details on reclaiming riparian areas refer to Appendix D,

10.5 Erosion

10.5.1 Water Erosion

Gullying: This is evidence of a major flow problem and its presence would normally preclude reclamation certification; however, gullying may be part of the normal processes on certain sites. If so, evidence must be provided to substantiate that the degree, spatial extent, rate and severity of the documented onsite gullying is consistent with the surrounding area or pre-disturbance conditions.

Rilling, pedestaling or presence of depositional fans: These are evidence of excessive surface water flow and often result in a change in vegetation community. Movement of soil across the site and especially to offsite areas are significant concerns as these conditions can reduce the productivity of the site. Evidence of small-scale erosion (i.e., movement of materials at the centimetre scale) does not constitute risk to a site's functioning and is not considered a negative characteristic. Small scale is defined as erosion occurring only on site and the material remaining on site rather than being lost.

10.5.2 Wind Erosion

Leaf abrasion, plant pedestaling and soil deflation are evidences of wind erosion, which may result in a loss of vegetative health. Evidence of wind erosion cannot be greater onsite than in the surrounding landscape.

10.6 Bare Areas

Bare areas are devoid of vegetation and do not include sparse vegetation on natural recovery sites. These areas must be recorded on the site diagram and if greater than offsite, a justification must be provided. Bare areas do not include open water.

10.7 Gravel and Rock

Presence of naturally occurring stones within reclaimed areas is assumed to present no significant risks to ecosystem functioning. Vegetation criteria should capture any detrimental effects should there be excessive concentrations of stones/rocks present beyond that found in the surrounding area.

10.8 Industrial Debris

Industrial and domestic refuse is not acceptable and must be removed.

11. vegetation assessments

Vegetation is the longterm indicator of biogeochemical conditions of a peatland; however, disturbance leads to chemical and/or water level changes that affect vegetation. In peatlands, the ground layer (i.e., bryophytes) is most strongly affected by these changes, leading to disruption of peat accumulation functions.

The vegetation assessment is designed as the primary indicator of the desired reclamation outcome, which is a self-sustaining vegetation community on a trajectory to an early successional peatland. The intent, when the site has been padded or ground layer removed, is to recognize that a peatland's organic matter deposits establish on decadal or millennial timeframe, but that some of the ecological function of the peatland may be returned in the early successional community (Loisel et al. 2014)

11.1 Peatland Types

For the purpose of these criteria the classification of peatlands in Alberta was simplified to include five basic peatland types: Bog (pH 3.0-4.2), Acid Fen (4.0-5.5), Circumneutral Fen (pH 5.5-7.0), Alkaline Fen (pH 7.0-8.5) and Saline Fen (pH 7.0-8.5). A description, history and correlation with other peatland classification systems, such as the Alberta Wetland Classification System, is included in Appendix A – Table 1.

Note: The offsite and onsite peatland type may not be the same or at a very different successional stage. Therefore, there is no direct comparison to offsite peatland types in the disturbed assessment. In the undisturbed assessment, a large shift in community does trigger a disturbed assessment as part of the decision tree process outlined in Section 11.3.

When determining the peatland type for the vegetation assessment, the site characteristics, such as moisture regime, water chemistry (pH and salinity) as depicted in Figure 4 and species lists by peatland type, included in Appendix E, Tables 1-5 can be used to determine the peatland type. The characteristic species of each peatland type, have been added to the species lists for quicker identification of the reclaimed onsite peatland type. For typical sites, the characteristic species and pH should be sufficient to determine the most appropriate peatland type. The species lists for that peatland type describe the reference community for the vegetation assessment parameters; desirable species cover, undesirable species cover and species richness.

Lastly, the peatland type information in these criteria can also assist with planning peatland reclamation projects, as the site characteristics present at the time of reclamation will drive the reclamation outcomes (i.e., site suitability for peatland species and peatland types). Appendices A and B provide further background on using the site characteristics and peatland types for reclamation strategies and planning.

Note: The species list can also be used to determine the reclaimed peatland type.

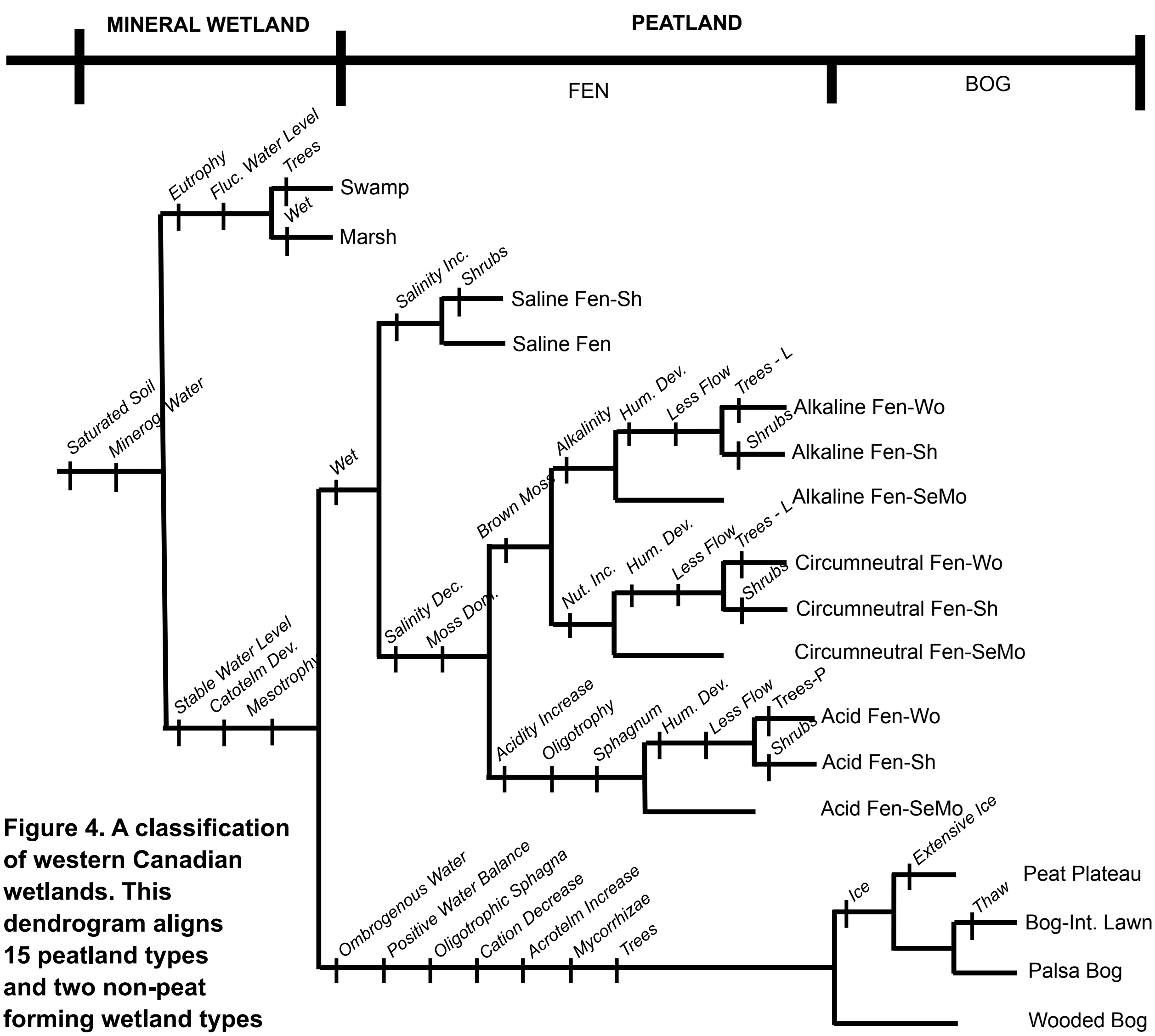


Figure 4. A classification of western Canadian wetlands. This dendrogram aligns 15 peatland types and two non-peat forming wetland types according to similarities in developmental characteristics. Wetland, fen, and bog are successional grades, each grade requiring a specific set of developmental characteristics – indicated by the short vertical lines. Characteristics are additive along contiguous branches. Fens can be further divided into two types depending on pH; Circumneutral fens pH 5.5-7.0 or Alkaline fens pH 7.0-8.5.

Abbreviations: Dec=decrease, Dev=development, Dom=dominant, Fluc=fluctuating, Hum=hummock, Inc=increase, Int=internal, Minerog=minerogenous, Nut=nutrients, SeMo=sedge-moss, Sh=shrub, Trees-L=*Larix laricina*, Trees-P=*Picea mariana*, Wo=wooded.

11.2 Vegetation Assessment Components

The components for the vegetation assessment include: structure, desirable species cover, undesirable species cover and species richness.

11.2.1 Structure

The vegetation of peatlands is organized into one or more structural layers: These structural layers include:

- **Ground layer:** The layer of vegetation at ground elevation consisting of bryophytes and lichens.
- **Field layer:** The layer of vegetation consisting of herbs, forbs and graminoids in peatlands; graminoids are mostly Cyperaceous plants (sedges and rushes).
- **Shrub layer:** The layer of vegetation consisting of woody multi-stemmed plants, in peatlands these are often dwarf Ericaceous shrubs.
- **Tree layer:** The layer of vegetation consisting of woody plants with one central stem, in boreal peatlands usually either *Larix laricina* (Larch) or *Picea mariana* (black spruce).

As part of the return of the function to the early successional peatland community, the presence of similar structural layers as found offsite is required. The ground layer and field layers are captured in the total percent canopy cover and species richness parameter.

To ensure a woody species component is present when a woody structural layer (shrub and/or tree layer) is present offsite, there is a woody structural layer required. The criteria do not require both the shrub and tree layer, but allows for either to indicate the woody layers are recovering.

11.2.2 Desirable Species Cover

Desirable species cover is measured using percent canopy cover of peat forming species found in all structural layers, including bryophytes, herbs, graminoids (primarily sedges) and woody species.

The calculation of desirable species cover is specific to the undisturbed and disturbed assessments. The undisturbed assessment requires a separate desirable species calculation for the ground cover (i.e., *Sphagnum* mosses or true mosses) and the vascular plants (e.g., peat forming graminoids (primarily sedges), herbs and woody species) as part of the decision tree process outlined in Section 11.3. To calculate the desirable species in the disturbed assessment, the canopy cover of the bryophyte plots (averaged four 1m^2 grids) is added to the canopy cover of the vascular plant plots (10m^2 grid), including trees, shrubs, graminoids (primarily sedges) and herbs.

11.2.3 Undesirable Species Cover

Presence of upland species, marsh species (species associated with non-peat forming wetlands), non-native or agronomic species are indicators of an inappropriate trajectory and do not contribute to the percent canopy cover of desirable species. The percent canopy cover of undesirable species must be taken in the vascular plot grid (10m^2 grid). Care should be taken where ponding exists within the peatland, that sedges are established prior to the colonization of cattails. Refer to Peatland Reclamation Strategies in Appendix B.

Restricted and noxious weeds must be destroyed and controlled as per current provincial and municipal weed control regulations.

Note: The undesirable species percent canopy is assessed in the vascular plant plot; however undesirable species surrounding open water/ponding (such as cattails) are captured in the open/water ponding criteria (Section 10.2).

11.2.4 Species Richness

To assess species richness as indicated in Section 8, it is important to ensure the assessment captures the microhabitats present. Microhabitats are a locality at a small scale (generally <1 m in size) distinguished by a particular set of environmental factors. In boreal peatlands, height above water level is a key environmental factor influencing individual microhabitats.

Typical microhabitats that may occur in the meandering assessment include:

- **Pools:** permanently water-filled basins with some vascular plant vegetation.
- **Carpets:** areas with emergent populations of bryophytes generally from 5 cm below to 5 cm above water table, usually with sparse graminoid cover and a dominance of bryophytes.
- **Lawns:** areas from 5-20 cm above water table with graminoids and firm moss cover.
- **Hummocks:** are raised above water table 20-50 cm or more and characterized by shrubs and herbs along with hummock-forming bryophytes.

When measuring species richness, assessors compare to the most representative Peatland Type species list (Appendix E). For the undisturbed assessment, assessors are required to tally the species, but specific identification is not required.

For the disturbed assessment, the onsite species must be identified, counted and this information provided as part of the vegetation data. A key and habitats for bryophytes has been included as Appendix F.

>>

Note: The species tables can also be used to determine the peatland type established onsite. For the undisturbed assessment the decision tree will not allow large changes in peatland type (e.g., *Sphagnum* dominated to a non-*Sphagnum* dominated peatland type) as this is considered an indicator of disturbance. There is no requirement to use a species list for a specific peatland type when conducting a disturbed assessment. The species list, by peatland type, that best fits the site should be used.

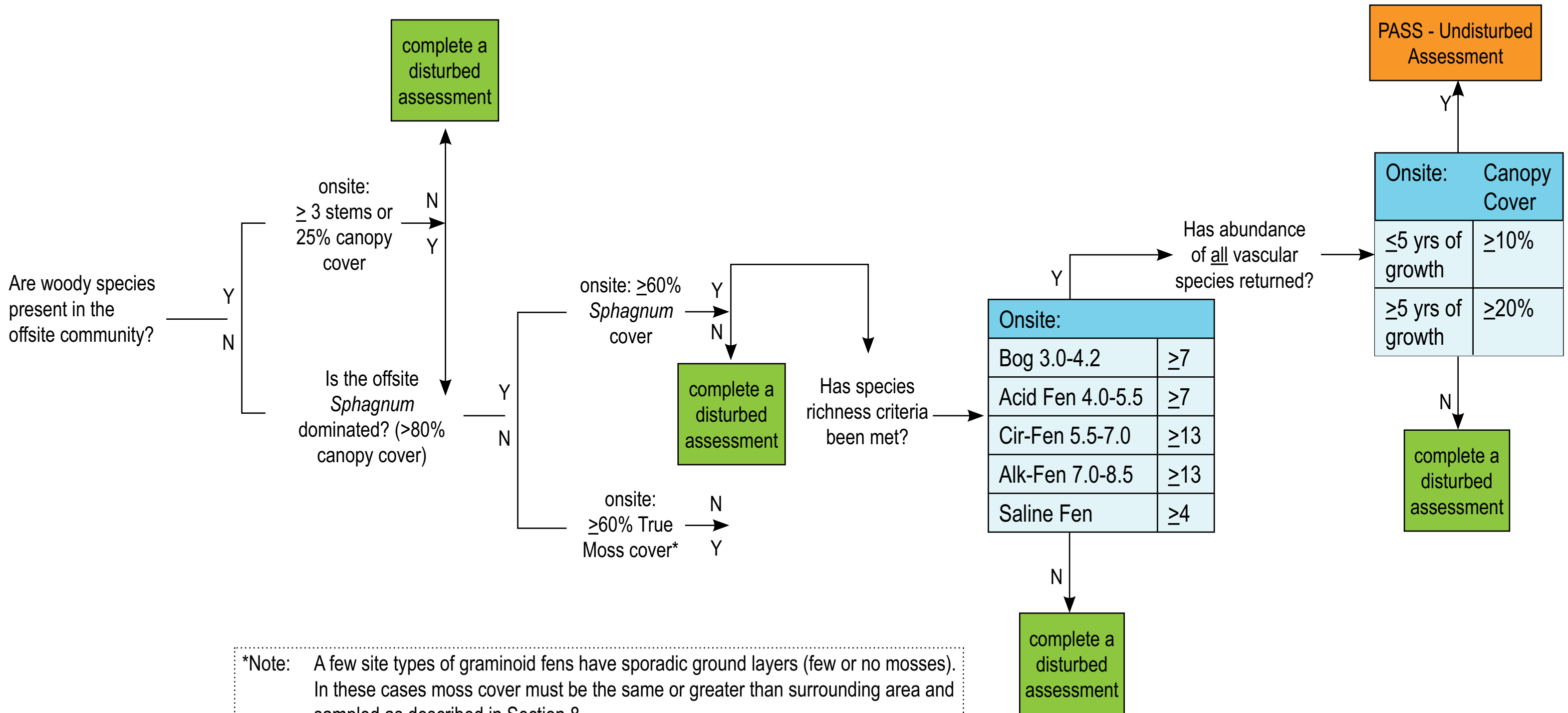
11.3 Undisturbed Vegetation Criteria

Peatland type is a key component of the determination that a site is undisturbed. However, small shifts in community will likely occur and will not trigger a disturbed assessment. For example, a *Sphagnum* dominated bog shifting to a *Sphagnum* dominated acid fen may result from modifications to moisture and/or slight compaction. It would proceed through the undisturbed assessment if the other components outlined below were present. A large shift in community, such as a *Sphagnum* dominated bog community that has been modified into an alkaline fen, with no *Sphagnum*, would be an indication that disturbance has occurred. This would result in the requirement of a more detailed assessment (disturbed assessment protocol) to ensure the peatland trajectory has been established.

>>

Note: Large shifts in peatland types result in a disturbed assessment rather than being a pass/fail point for the site.

The undisturbed assessment is designed as a decision tree and is outlined in Figure 5 below. The assessment component, measurements and criteria for the assessment parameters in the decision tree are provided in Table 2. A minimum 4 grids are required for this assessment; the area within all 4 grids must pass for the site to be considered undisturbed.



*Note: A few site types of graminoid fens have sporadic ground layers (few or no mosses). In these cases moss cover must be the same or greater than surrounding area and sampled as described in Section 8.

Cir-Fen - Circumneutral Fen pH 5.5-7.0

Alk-Fen - Alkaline Fen pH 7.5-8.5

Figure 5. Undisturbed Assessment Decision Tree

Table 2. Undisturbed Vegetation Assessment Measure, Method and Criteria

Vegetation Assessment Component	Measure	Method	Criteria
Desirable Species Cover	Percent canopy cover	**Bryophyte plot** *(Moss and liverwort species)* Average a minimum of four $1m^2$ assessment points per grid	≥60% canopy cover of bryophytes
		Vascular plant plot *(Sedges, Herbs, Woody Species)* $10m^2$ representation plot	**Assessed ≤5 growing seasons** ≥10 per cent canopy cover
			Assessed ≥5 growing seasons ≥20 per cent canopy cover
Undesirable Species	Percent canopy cover	**Vascular plant plot** *(Non-peat forming species)* $10m^2$ representation plot	≤10 per cent canopy cover ($10m^2$ plots).
Species Richness	Species tally**	**Meandering grid assessment** (All peat forming species)	Bog ≥7 species
			Acid Fen ≥7 species
			Circumneutral Fen (pH 5.5-7.0) ≥13 species
			Alkaline Fen (pH 7.0-8.5) ≥13 species
			Saline Fen ≥4 species
Woody Species*	Stem counts or percent canopy cover of woody species (shrubs and/or trees)	**Vascular plant plot** *(Trees, shrubs)* $10m^2$ representative plot	≥3 stem **or** 25 per cent canopy cover

***Woody species are only required if present offsite.**

****Species richness in the undisturbed assessment is a tally of species. Identification of plant species is not required for the undisturbed assessment.**

11.4 Disturbed Vegetation Criteria

The disturbed assessment utilizes the species lists located in Appendix E, Table 1-5. In order to use these lists, the on-site peatland type must be identified. Therefore, a detailed offsite community list is not required to be completed by the assessor. The offsite peatland type must be recorded and all data associated with the disturbed assessment provided. The criteria for each Vegetation Assessment Component are provided below in Table 3.

Table 3. Disturbed Vegetation Assessment Measure, Method and Criteria

Vegetation Assessment Component	Measure	Method	Criteria
Desirable Species Cover	Percent canopy cover	**Bryophyte plot** *(Moss and liverwort species)* Average a minimum of four $1m^2$ assessment points per grid	≥50% canopy cover (Combine data from $1m^2$ and $10m^2$ plots)
		Vascular plant plot *(Sedges, Herbs, Woody Species)* $10m^2$ representation plot	
Undesirable Species	Percent canopy cover	**Vascular plant plot** *(Non-peat forming species)* $10m^2$ representation plot	≤20% canopy cover ($10m^2$ plots).
Species Richness	Species identification**	**Meandering grid assessment** (*All peat forming species*)	Bog ≥7 species
			Acid Fen ≥6 species
			Circumneutral Fen (pH 5.5-7.0) ≥9 species
			Alkaline Fen (pH 7.0-8.5) ≥8 species
			Saline Fen ≥4 species
Woody Species*	Stem counts or percent canopy cover of woody species (shrubs and/or trees)	**Vascular plant plot** *(Trees, shrubs)* $10m^2$ representative plot	≥1 stem **or** 25% canopy cover

***Woody species are only required if present offsite.**

****Species richness in the undisturbed assessment requires the identification of plants species recorded in the detailed site assessment.**

12. disturbed assessment site determination for pass or fail

12.1 Landscape Assessment

Each component in the landscape assessment, excluding only the Open Water/ Ponding or Upland Eco-sites, is designed as a pass/fail determination as outlined in the table below. This is a qualitative assessment and is in addition to the Parameter Point System in Section 12.2.

Table 4. Landscape Assessment Criteria

Landscape Assessment	Criteria	Required for Assessment
Moisture Regime: Does the site have the appropriate moisture regime for peat forming species?	Section 10.1	Response to Question: Pass or Fail
Open Water/ponding or Upland Eco-site: See grid assessment.	Section 10.2	Component of the Parameter Point System
Drainage: Is the surface water flow and onsite drainage (e.g., cross site flow, direction, dispersion, ponding, depressional storage) impacting offsite vegetation?	Section 10.3	Response to Question: Pass or Fail
Riparian Areas: Have areas been reclaimed to riparian vegetation? If so, is bank stability or shore stability comparable to off-site?	Section 10.4	Response to Question: Pass or Fail or Not Applicable
Erosion: Is soil erosion (e.g., rills and/or gullies) onsite comparable to offsite? (Based on a qualitative assessment of bare soil in relation to cover)	Section 10.5	Response to Question: Pass or Fail
Bare Areas: Is the amount, frequency, density of landscape scale bare areas onsite comparable with offsite?	Section 10.6	Response to Question: Pass or Fail
Debris: Has industrial (including domestic) refuse been removed?	Section 10.8	Response to Question: Pass or Fail
Comments		

12.2 Parameter Point System

The following system applies to the **Disturbed Assessment only**. Sites that fail the undisturbed assessment must be assessed with the disturbed assessment methodology and criteria.

The Parameter Point System is designed to reflect the importance of establishing a peatland **plant** community. It is specific to the Peatland Criteria, where the hydrology and establishment of self-sustaining peat accumulating communities are used as indicators of reclamation success. The landscape qualitative criteria above must also be met. Figure 5 provides an example of the Parameter Point System.

Only the quantitative parameters contribute to the **Parameter Point Component** and the site score including:

- Open water/ponding or Upland Eco-sites (Section 10.2)
- Desirable Species Cover (Section 11.4)
- Undesirable Species Cover (Section 11.4)
- Species richness (Section 11.4)
- Woody structural layer for treed and shrubby sites only (Section 11.4)

Each parameter point component that passes criteria in a grid equates to 1 point. For example, for a treed site, if all 5 of the above parameters passes in a grid, the grid would be assigned 5 points.

Total points possible are determined by multiplying the number of grids by the number of parameters (4 per grid for open sites, 5 per grid where the site is located in treed or shrubby peatlands). A nine grid open site would have 36 and a treed site would have 45 total possible points. Based on the size of the site, the minimum points to pass are presented in Table 5a and 5b. The number of grids that can fail for the same parameter is limited based on the size of the site (Table 5).

Table 5a. Parameter Point System for Non-Wooded Sites

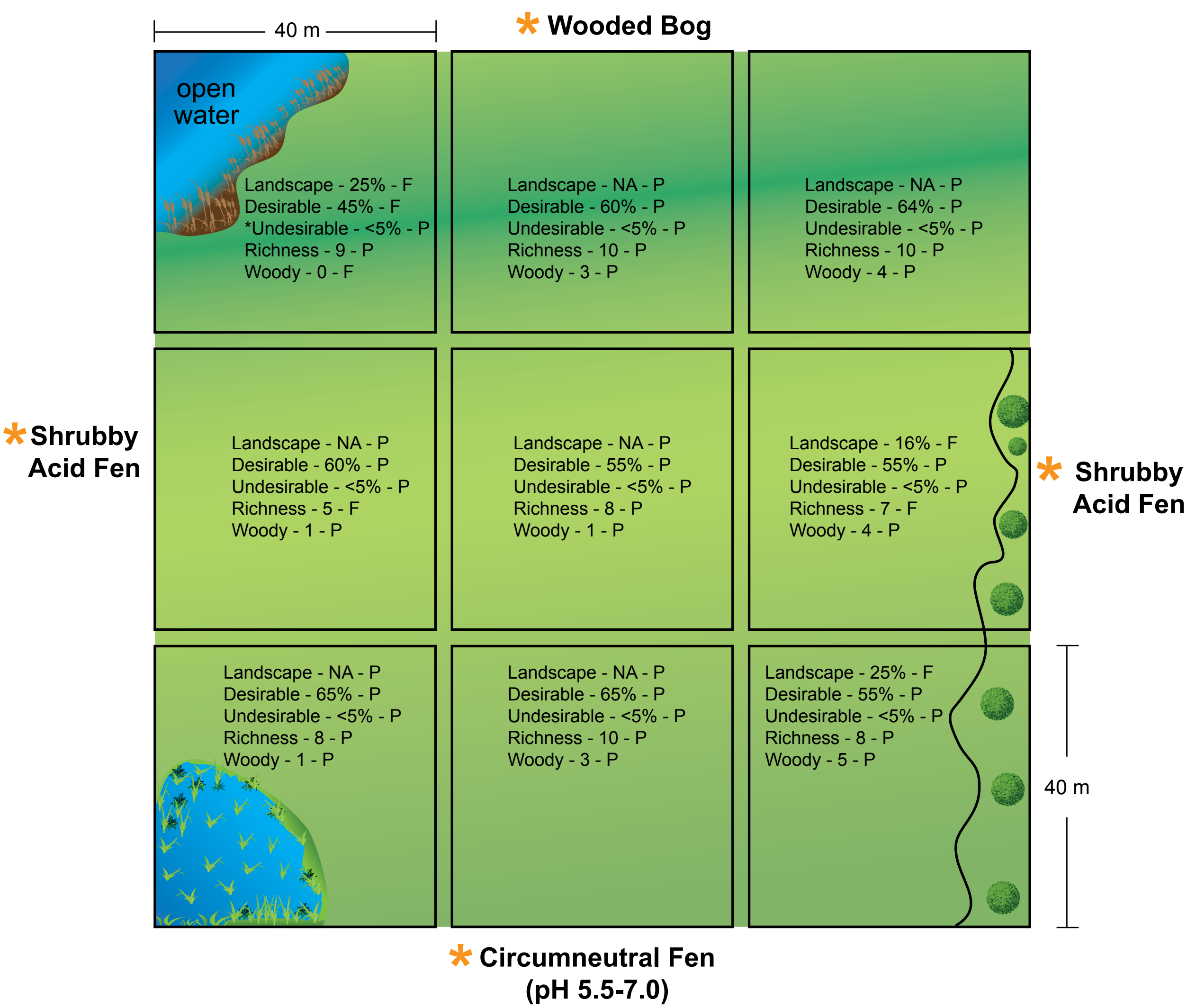
Grids	# of Parameter Point Components (PPC) per Grid Non-Wooded Sites	Total Points Possible (# of Grids x PPC)	Points Required to Pass	Maximum number of grids that fail for the same parameter
9	4	36	29	4
8	4	32	26	4
7	4	28	23	3
6	4	24	20	3
5	4	20	16	2
4	4	16	13	2
3	4	12	10	0
2	4	8	7	0
1	4	4	4	n/a

Table 5b . Parameter Point System for Wooded Sites

Grids	# of Parameter Point Components (PPC) per Grid Non-Wooded Sites	Total Points Possible (# of Grids x PPC)	Points Required to Pass	Maximum number of grids that fail for the same parameter
9	5	45	36	4
8	5	40	32	4
7	5	35	28	3
6	5	30	24	3
5	5	25	20	2
4	5	20	16	2
3	5	15	12	0
2	5	10	8	0
1	5	5	5	n/a

Note: Where the offsite is has trees and/or shrubs, the onsite requires a woody species structural layer. These sites are referred to as “wooded” sites.

>> **Note: For sites greater than 9 grids, the site score must be ≥80 per cent of total points possible and the maximum number of grids that can fail for the same parameter is 4. For linear sites, grids are each assessment location (Section 6.2).**



Typha spp.

Sedge Dominated Ponding

Upland Eco-site

P Pass

F Fail

* Landscape Overview Assessment

Parameter Point System	
Total points possible	45
Required points to pass	36
Total PPC that pass	38
Max grid failure for 1 parameter	= 4
Actual # of grids failing for 1 parameter	= 3
Site Pass	

Parameter Point Components

Landscape - Percent area of grid that is open water/ponding or upland eco-sites.

Desirable - Combined percent canopy cover of the vascular plant plot and the bryophyte plots.

Undesirable - Percent canopy cover of non-peat forming plant species

Richness - Number of species identified in the meandering grid.

Woody - Woody stem count

*Note: The undesirable species percent canopy is assessed in the vascular plant plot. The cattails in grid 1 are part of the open water/ ponding criteria and should not be included in your undesirable species percent canopy data.

Figure 6. Parameter Point System Example – Clay Pad Reclaimed to an Alkaline Fen (7.0-8.5)

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appendix a: primer on peatlands in western canada

Background Information for Peatlands in Alberta

A ‘peatland’ is an area on the landscape covered by peat to a minimal depth of 40 cm (Tarnacai 1980 - 30 cm in Europe). Peat is a deposit of plant and animal remains that over time has accumulated under water-saturated conditions through incomplete decomposition. A mire is a wet area dominated by living peat-forming plants (Sjörs 1948, Rydin & Jeglum 2006). Thus a drained, cutover site used for peat harvesting is a peatland, but because there are no peat-forming plants and the process of peat-formation is not occurring, it is not a mire. Likewise a site initially reclaimed with a substrate of peat may be a peatland, but not a mire until living peat-forming plants are present. On-the-other-hand, a young, developing (paludifying) natural wetland that is actively accumulating peat through the action of peat-forming plants, but has less than 40 cm of peat is not a peatland, but it is a mire. Fens and bogs are wetlands with peat-forming plants that facilitate active accumulation of peat; both can be considered mires, but are not peatlands if they contain less than 40 cm of peat.

For the purpose of the Peatland Reclamation Criteria, the relationships and terminology are simplified to the undisturbed ‘Peatlands’ as defined above and reclaimed “early successional Peatlands’ defined as mires.

Types of Peatlands

Defining fens and bogs from a historical perspective. C.A. Weber (1911) first used the term ‘ombrogenous’ for peatlands that he thought received all of their water from rainfall. These Hochmoore (or bogs) were defined based on the source of the water supply and differ from peatlands with topogenous (influenced by stagnant waters), soligenous (influenced by seepage), or limnogenous (influenced by flood waters from water courses) (original terms mostly from von Post and Granlund 1926). These peatlands supplied with water from the surrounding area are fens, and have waters that contain dissolved ions derived from these mineral soils. These minerogenous waters have nutritional and buffering effects. DuReitz (1954) introduced the term minerotrophic to express the ecosystem effects of these waters, and the bogs are thus ombrotrophic in this ecological sense.

The division for peatlands into ombrogenous and minerogenous systems began in Germany and the Netherlands (Weber 1911 was perhaps the first). This simple division based originally on hydrology has been adopted nearly worldwide.

The ombrotrophic bogs, dominated by oligotrophic species of peat mosses (the genus *Sphagnum*) are on one end of a water chemistry gradient while a series of variable fen types make up the remainder of the gradient. *Sphagnum*-dominated, acid fens with a rather poor flora were designated 'fattigkarr' or poor fens by DuReitz (1942), while basic and alkaline fens with a much richer flora largely dominated by brown (true) mosses were termed 'rikkarr' by DuReitz. Fens dominated by a set of calcareous species were termed 'extremrikkarr' or extremely rich fens while those with less exacting species were called 'medelrikkarr' or moderately rich fens (earlier called transitional rich fens by DuReitz). In 1952, Hugo Sjörs correlated pH and electrical conductivity to this set of fen types and introduced 'mellankarr' or intermediate fens to the spectrum of fen types, these being characterized by a distinctive suite of species less tolerant of strong acidity and an intermediate ionic chemistry. Thus poor fens and rich fens are generally recognized based on both floristic and water chemistry (pH and base cations) criteria (Table 1).

Table 1. Generalized Peatland site type characteristics and a comparison of classification used here with the Alberta Wetland Classification System (AWCS).

Classic Name	**Bog**	**Poor Fen**	**Rich Fen**	
Site Name in Peatland Reclamation Criteria	Bog	Acid Fen	Circumneutral Fen	Alkaline Fen
Alberta Wetland Classification System Name (AWCS)	Bog	Poor Fen	Moderate-rich Fen	Extreme-rich Fen
Chemistry				
pH Electrical conductivity used in AWCS (uS/cm)	3.0–4.2 < 100	4.0–5.5 < 100	5.5–7.0 100-250	7.0–8.5 250-2000 (includes saline fens)
Reduced Electrical conductivity used here (uS/cm)*	< 40	< 60	50-150	150-600
Calcium (mg/L)	0–3	3–10	10–40	30–100
Alkalinity (ueq/L)	0	0-350	350-800	(800)1000-2000
Ground layer vegetation	*Sphagnum*	*Sphagnum*	True Mosses	True Mosses
Hydrology	Ombrogenus	Minerogenous (Surface and/or groundwater)		

**As used traditionally in peatland literature, reduced electrical conductivity is a measure of salinity derived solely from base cations and their associated ions. Conductivity resulting from H+ ions is not included. Reduced electrical conductivity has been corrected to remove the influence of H+ ions using a formula presented by Sjors (1952). EC that includes H+, as used in AWCS, is not a measure of salinity at pH's at <pH 5.5.*

Rich fens are rich owing to a relatively high number of species (especially true mosses) that have high fidelity to the calcareous conditions of the sites. In comparison, poor fens are relatively poor in differential species. Bogs have few if any of these fen indicators. Sjörs (1983) and Vitt and Chee (1990) provided lists of characteristic species from Sweden and Canada, respectively. Among numerous publications that provide listings of species for northern peatlands, Ruuhijärvi (1960) and Eurola (1962) both provide extensive lists of species for a variety of fen communities in Finland, Vitt and Belland (1995) for bryophytes, and Anderson and Davis (1998) provide lists for bogs in North America. These species, in addition to the original defining features proposed by DuReitz (1954), characterize the principle peatland types: poor fens are acid, have low concentrations of base cations, no or little alkalinity (bicarbonate ion), and are dominated by *Sphagnum*; while rich fens are basic to slightly acid, have higher concentrations of base cations (especially Ca^{2+}), have bicarbonate as a dominant anion, and are dominated by true mosses and some mesotrophic species of *Sphagnum* (reviewed in Vitt & Chee 1990). Each of these peatland types are vegetationally (structurally) diverse, and each can be dominated by species in the tree layer, the shrub layer, the field layer (sedges, forbs, and grasses), or the ground layer (mosses); thus vegetation does not add to the definition of the basic peatland types. In contrast, non-peat forming wetlands are well distinguished by either being dominated by species in the field layer (marshes) or species in the tree layer (swamps).

In summary, it is generally recognized that boreal peatlands can be divided into three types – bogs, poor fens, and rich fens (the latter composed of two subordinate types), these peatlands, along with non-peat forming wetlands - marshes and swamps – makeup the large majority of Albertan wetlands. This was recognized in the Canadian Classification of Wetlands (Zoltai & Pollett 1983, National Wetlands Working Group 1988), and conceptualized by Vitt 1994 (Fig. 1). This classification reflects for peatlands a base cation, alkalinity, acidity gradient, and associated change in plant species (flora). It is noteworthy that vegetation (structure) is not associated with this gradient. Also important to recognize is that the terms ‘poor’ and ‘rich’ were not originally defined to include either a change in nutrient (N, P) status nor overall species richness, but only indicate the number of plant species having high fidelity to each peatland type. Although species richness does not increase at the site level across this peatland gradient, overall richness for each site type does (Vitt et al. 1995a). Furthermore, this classification divides non-peat-forming wetlands from peatland types along a nutrient and water stability gradient.

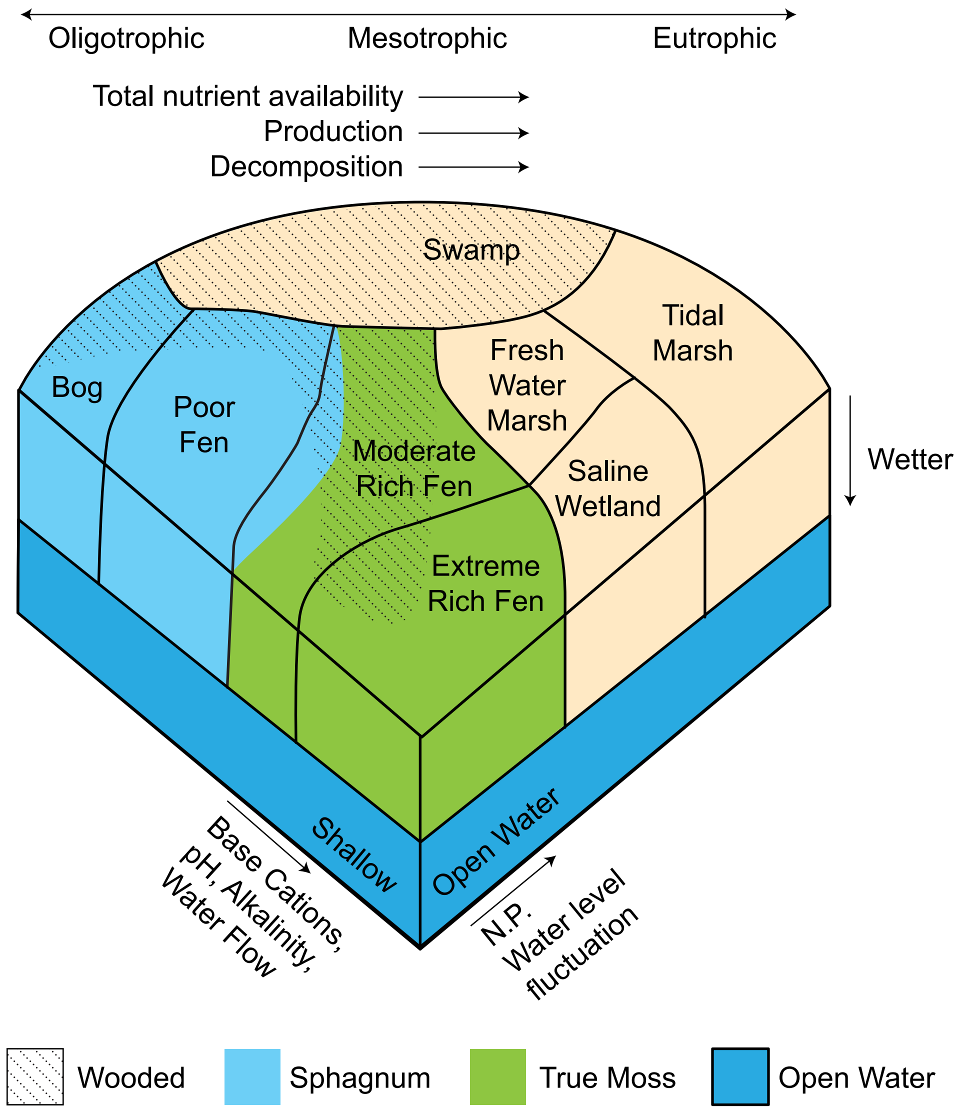

Figure 1. Relationships of boreal wetlands to important environmental gradients (from Vitt 1994).

Peatland Initiation and Succession

Fundamental to wetland reclamation is an understanding of the processes of wetland and mire initiation that eventually gives rise to peatlands. These initiation and successional processes can be best understood using the historical record. Mires in continental western Canada began to initiate soon after the retreat of glaciers, some 12,000 to 15,000 years ago by *primary peat formation* directly on wet, mineral soils. Wet, cold, and anoxic conditions provided the conditions for the accumulation of organic matter, and gradually a shallow deposit of organic matter began to form. Also, the retreating glaciers stagnated leaving isolated blocks of ice scattered on the landscape that were soon covered by eroding mineral soil. When these blocks of ice melted there remained depressions with steep sides and these ‘kettle holes’ soon filled with water. Surrounding and encroaching on these depressions, wetland vegetation developed and over time the water-filled basins were filled in by decomposing peaty materials, thus forming a peatland vegetative cover from *terrestrialization*. Both primary peat formation and terrestrialization were common processes in the early Holocene and the former continues to be a common initiation process in the Hudson Bay Lowland today as isostatic rebound provides new unvegetated surfaces. However, the modern landscape of western Canada and Alaska is largely the result of a third peatland initiation process that is termed *paludification*, or the swamping of previously dry, mineral soils with upland vegetation. Most of the peatland-dominated landscape of the boreal region of the continent has an ever-increasing cover of peatland landforms. This paludified landscape began to develop relatively late in the Holocene in western Canada, whereas it began earlier in the east. In general, peatlands are older in eastern Canada and younger in the west (Glaser & Janssens 1986). In Alberta, retreating glaciers left abundant, shallow, lakes. These shallow lakes were maintained for a few hundred to thousand years in the early Holocene, but most eventually dried, leaving a dense clay layer of lake deposits that later became vegetated with a variety of wetland or upland vegetation. During the mid-Holocene, many of these areas were re-wetted with the advent of wetter regional climate and organic matter accumulation was initiated – and today these peatlands exist on hydrologically isolated (perched) water tables. Rates of paludification, especially in the dry western portion of Canada were cyclic, with several episodes of paludification (Campbell et al. 2000), and these paludification events appear to be climate-related with higher rates of paludification associated with wetter, cooler climatic periods (Yu et al. 2003a).

After initiation, peatland development in western Canada proceeded along one of two successional pathways. First, early initiation from either infilling of ponds and from drier uplands resulted in the rapid development of marshes and then of either rich fens or poor fens, with these persisting to the present time continually influenced by surrounding water levels and chemistry (Kubiw et al. 1989, Kuhry et al. 1993, Bauer et al. 2003), with little successional change. In this case, allogenic (external) factors of climate and local water chemistry have over-riding effects and the fen communities persist for millennia (Yu et al. 2003a). Secondly, initiation of marshes or fens on wet ground may persist for some time, but autogenic (internal) changes such as peat buildup leading to isolation of the peat surface from the local surface and ground waters, acidification, and oligotrophification may provide the critical drivers and rapid succession from rich fen to poor fen to bog may occur (Bauer et al. 2003). Peatland landforms (bog islands, water tracks, patterning) evolve over time, and are secondary features of complex peatlands (Nicholson & Vitt 1990). This development of secondary landform features is strongly influenced by both allogenic and autogenic drivers (Glaser 1983).

Structural Attributes and Processes of Importance in Peatlands

Acrotelm/Catotelm Model. The basic concepts of long-term peat (and carbon) accumulation were first developed by Clymo (1984). In the Clymo model, a peat core is considered as two-layered - a top, aerobic layer (the acrotelm) and an underlying anaerobic zone - the catotelm (terms from Ingram 1978). The acrotelm is composed of the surficial ground layer of mosses and associated litter, roots, and decaying moss plants. The acrotelm is subjected to changes in climate, water level fluctuation, and plant productivity. The catotelm receives mass from the acrotelm that once there undergoes slow anaerobic decomposition. The Clymo model assumes plant production remains constant and that decomposition of the annual fractional mass loss of the catotelmic mass also is a constant (estimated exponential decay rate of 0.00014 year^{-1}), thus as the peat increases in thickness the amount of mass lost in total for the column every year also increases and the result, over thousands of years is a concave depth-age profile. Changes in acrotelmic inputs to the catotelm (owing to plant production and/or aerobic decomposition) may change the shape of this age-depth curve and at least in western Canada there is some evidence that inputs from plant production are greater in early succession (Yu et al. 2003b).

Organic Matter Accumulation

The surface height growth of a fen or bog ranges from one to several cm per year. A large part of this growing moss layer is space filled with water or air. During the passage to the acrotelm a portion of the biomass decays and the remains are compacted by the weight of new material and by snow. When the material passes to the catotelm the decomposition and compaction have reduced the biomass to about 1-2 mm/yr estimated at 5-10 per cent of original mass). Biomass that is retained in the catotelm very slowly continues to lose mass through anaerobic decomposition and is further compacted from weight above, gradually reducing the height increment. In general, long term (over hundreds of years) peat accumulation is variable depending on climate and peatland type, but perhaps a number of 0.5 to 1.0 mm per year over a thousand year period might be representative. If we assume a long-term rate of 1 mm per year, then to achieve the definition of a peatland (at 40 cm) it will take 400 years for peat to accumulate to that depth.

Important structural attributes for peat in western Canada are as follows: Bulk density of peatland peat from western Canada is 0.168 g/cm^3, much greater than the global average of 0.118g/cm^3. Organic matter content averages 91.6 per cent. Carbon content averages 45.0 per cent and nitrogen content 1.1 per cent, while C/N mass ratio averages 62.4 (all data from Loisel et al. (2014).

Nitrogen Utilization

In general, peatlands are a sink for nitrogen, globally holding 9.7 Gt of N (Loisel et al. 2014) and it has been estimated that boreal peatlands contain about 10 per cent of the global pool of N (Loisel et al. 2014). Despite this abundance of N in peatlands most of it is unavailable to plants, and nitrogen is in short supply in peatlands, especially in ombrotrophic bogs wherein N is supplied only from atmospheric sources and from N-fixation (Vile et al. 2014). As nitrogen is received by the peatland, it is sequestered by the ground layer, mineralized to DON (dissolved organic nitrogen), and redistributed to vascular plant roots and microbes. *Sphagnum* (or true mosses in rich fens) redistributes some of the N upward to new tissue (Aldous 2002a,b). In fens, ammonification is by far the most important process of N-mineralization, with nitrification providing only a small amount of available nitrogen.

Sulfate Reduction

Sulfur occurs in peatlands in a number of different redox states and conversions between these states are the result of microbial transformations. The deposition of S from precipitation adds S to peatland systems. One important transformation is sulfate reduction wherein sulfate (deposited from the atmosphere) and plant carbohydrates are transformed to CO_2 and H_2S gas. This transformation oxidizes plant material (peat) and over time could decrease the mass of carbon stored in a peat deposit (Vile et al. 2003). Although the S-cycle has been reviewed extensively for forest and aquatic systems the S-cycle in peatlands has only one critical modern review (Vile and Novak 2006). In addition to deposited S being transformed, it also can be lost from peatlands during periods of high water flow (Bayley et al. 1986).

Acidification

Bogs and poor fens are naturally acid with a pH range varying between 3.0 and 5.5. In 1963, Richard Clymo proposed that peatland acidity is produced by *Sphagnum* cell walls. The hydrogen ions of the carboxylic acid moieties of uronic acid cell wall components are exchanged for base cations found in the pore waters. In 1980, Harry Hemond recognized that this process occurs, but he thought that it was not sufficient to produce the acidity needed for the low pH's found in bogs. Hemond proposed that bog acidity is a result of hydrogen ion release from decomposition, releasing humic acids as DOC (dissolved organic carbon) into the pore waters. It is currently unclear whether peatland acidification occurs by *Sphagnum* cation exchange (Clymo 1963, Vitt 2000), decomposition and production of humic acids (Hemond 1980), or hydrological blocking of alkaline ground waters through peat accumulation (Soudzilovskaia et al. 2010).

Decomposition

Peatlands accumulate organic matter as peat due to decomposition and DOC export being less then plant production over the long term. Recently a global analysis of millennial carbon accumulation in peatlands of the boreal forest suggests that rates of carbon accumulation are strongly correlated to photosynthetically active radiation and rates of photosynthesis (Charman et al. 2012). However, decomposition is also an important process. As organic material is produced and as it passes through the acrotelm, rates of decomposition are largely determined by plant chemistry (Turetsky et al. 2008) as well as the amount of time the material spends in the acrotelm (Yu et al. 2003a). As a result, in established peatlands, a lowering of the water table may increase acrotelm depth and increase decomposition. Increased rates of decomposition and/or amount of decomposition lead to increased bulk density and decreases in height growth of the peat column. Development of an organic layer in initiating mires may be strongly related to anoxic conditions coupled with the establishment of peat-forming plant species.

Methanogenesis

Despite the fact that peatlands are a long-term carbon sink storing approximately one-third of the world's soil carbon, they also are important methane sources to the atmosphere. Northern peatlands contribute about 34-60 per cent of the global wetland CH_4 emissions (Bartlett & Harriss 1993). Methane is formed as the terminal step in a long and complicated degradation process only under anaerobic conditions in the catotelm by methanogenic Archaea (Garcia et al. 2000), and can be subsequently oxidized in the aerobic acrotelm. Methane is formed either by acetate dissimilation or by bicarbonate reduction (Westermann 1993). Variation in both vegetation and temperature contributes to which pathway dominates (reviewed in Vasander & Kettunen 2006). Isotopic studies of C have shown a link between vascular plant root exudates and methanogenesis, and ^{14}C-dated CH_4 collected directly from the peat column has been found to be 2,000 years younger than the surrounding peat suggesting that at least a part of the C in CH_4 originates from DOC in the pore water which in turn can be largely derived from root exudates (Charman et al. 1994). Strack and Waddington (2012) reviewed the effects of extraction and restoration on greenhouse gas exchange, concluding that while the abandoned cut-over fields are not a major source of methane in themselves, the associated wet ditches are. They also concluded that land-use change associated with extraction converts the ecosystem from a GHG sink to a source and that the sooner restoration is begun the sooner this effect will be reduced.

Floristic Patterns in Peatlands

Total plant richness (gamma diversity) for Alberta peatlands ranges from 127 species in bogs to 150 species in poor fens to 212 species in rich fens, overall increasing along this gradient (values are means for the peatland classes used by Halsey (2007). Vascular plant diversity also increases along the bog-fen gradient from 48 species in bogs, 84 in poor fens, to 112 in rich fens, but bryophyte diversity remains constant varying from 79 species in bogs, 66 species in poor fens, and 63 species in rich fens. The vascular plant/bryophyte ratio changes markedly across this gradient, from 0.7 in bogs, 1.3 in poor fens, to 2.1 in rich fens. The decreasing importance of vascular plants as acidity increases strongly influences the successional peatland gradient as well as the peat properties and rates of decomposition. Species richness of bryophytes at the site level (alpha diversity) is most closely correlated to the number of microhabitats (Vitt et al. 1995b). Rich fens are rich owing to a relatively high number of species that have high fidelity to the calcareous conditions of the sites. In comparison, poor fens are relatively poor in differential species. Bogs have few if any of these fen indicators.

The Peatland Reclamation Criteria utilizes species richness as an indicator of reclamation success. Species lists were generated to inform species richness criteria and were compilation of literature and personnel communications with Dale Vitt.

Western Canada Peatland Classifications

The classification included in the Peatland Reclamation Criteria and outlined below, mostly reflects the Canadian Classification of Wetlands for Peatland classification. However, it differs in the use of specific development characteristics as the defining features and replaces the often misunderstood 'poor' and 'rich' fen terms with identifiers from water chemistry.

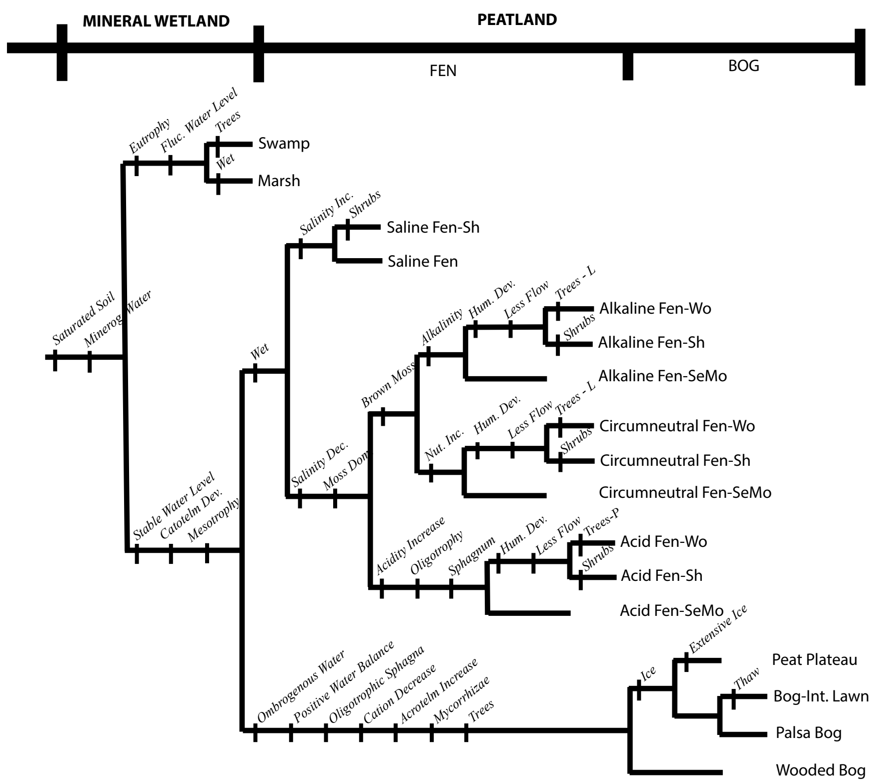

Figure 2. A classification of western Canadian wetlands. This dendrogram aligns 15 peatland types and two mineral-wetland types according to similarities in developmental characteristics. Wetland, fen, and bog are successional grades, each grade requiring a specific set of developmental characteristics – indicated by the short vertical lines. Characteristics are additive along contiguous branches. Reclamation strategies should resolve all characteristics leading to particular wetland/peatland site types.

Abbreviations: Dec=decrease, Dev=development, Dom=dominant, Fluc=fluctuating, Hum=hummock, Inc=increase, Int=internal, Minerog=minerogenous, Nut=nutrients, SeMo=sedge-moss, Sh=shrub, Trees-L=*Larix laricina*, Trees-P=*Picea mariana*, Wo=wooded.

Mires (peat-forming wetlands) and peatlands exist on the Alberta landscape as a number of distinct ecosystems composed of inter-related sets of species, vegetation, chemistry, and hydrology. These mire types form over long periods of time by development through a series of grades. These grades (e.g., wetland, fen, bog) are achieved by crossing a series of environmental and developmental characteristics and these same characteristics must also be crossed in the process of reclaiming wetlands. These characteristics are additive and as the more complex wetland grades are achieved a significantly greater number of characteristics must be present, making reclamation of some grades more difficult than others. Among the characteristics, a few are especially noteworthy.

1. Bogs and fens form deep layers of peat that accumulate over long periods of time due to low decompositional rates in the catotelm after spending a relatively short time in the aerobic acrotelm; however, it is the acrotelm that is strongly influenced by surrounding and changing environmental conditions

2. Bogs differ from all other wetlands in receiving only ombrogenous water.

3. Many bogs in northern Alberta have permafrost, either continuous within the peatland landform (peat plateaus) or discontinuous within the landform (bogs with frost mounds), some of which is actively thawing.

4. Fens have a moss-dominated ground layer that is very important for peat accumulation and a minerogenous water source.

5. Poor fens are acid and *Sphagnum*-dominated, while rich fens are to some degree alkaline and true moss-dominated. Here we call poor fens ‘Acid Fens’.

6. Rich fens are highly variable in chemistry and flora, some are slightly acidic to neutral and have relatively small concentrations of base cations – here we call these ‘circumnutral fens’, others are have much higher pH and have pore waters dominated by $Ca(HCO_3)_2$ and have a flora and fauna adapted to alkaline conditions. Here we term these ‘alkaline fens’. Both of these fen types have the ground layer dominated by true mosses. Additionally in the Province, there are fens dominated by high concentrations of Na_2SO_4/NaCl and have a flora and fauna adapted to saline conditions; in these fens the ground layer lacks mosses.

7. In Alberta, mature bogs are always wooded (presence of a tree layer with open canopy), while fen vegetation is variable, ranging from wooded, to no trees and the presence of a well-developed shrub layer, to no trees and shrubs present and dominated by sedges and mosses.

8. Unlike fens with a dominant ground layer, marshes are always dominated by a field layer of herbs and graminoids.

Note: Mire = Peat-forming wetlands (Bogs and Fens)

FEN (Fig. 3)
Fens receive water, nutrients, and minerals from the surrounding uplands and/or ground waters, and from precipitation. They vary in acidity and alkalinity and also in amount of flow and in nutrient supplies. In general, fens lack a well-developed acrotelm and have ground layers dominated by species of either *Sphagnum* or true mosses. Sedges are abundant, but vegetation development is highly variable, ranging from sites that are moss-dominated, sedge-dominated, or have canopies of either shrubs or trees. Vitt and Chee (1990) reviewed chemical and floristic characteristics of fens in Alberta. Three types occur in the Province.

Figure 3. Sedge-moss acid fen near Mariana Lakes, AB (*Sphagnum angustifolium* lawns in the fore-ground) Alberta.
Photo Dale Vitt, Mariana Lakes Alberta

Saline Fen
The abundance of the base cation, sodium, characterizes this fen type. The abundance of Na^+ is associated with a lack of mosses in the ground layer and an abundance of sedges. Salt tolerant species are evident (e.g.,*Triglochin maritima* and *T. palustris*). pH's are basic and the nutrient status is mesotrophic. Wet sites are dominated by species of Carex (especially *C. aquatilis, C. atherodes*, and *C. utriculata*, along with *Calamagrostis stricta*), whereas drier sites have individuals or groves of *Larix laricina* and occasional shrubs (*Salix* species). Saline fens occur along a gradient of sodium concentrations. Fens with EC's (electrical conductance) of less then 500 µS cm^{-1} generally are most influenced by Calcium ions (alkaline fens), those with EC's of 500-2000 µS cm^{-1} have been termed sub-saline, while those having EC's above 2000 µS cm^{-1} are saline (S. Bayley pers. comm.). Saline fens have been examined by Purdy et al. (2005) and Trites and Bayley (2009) in the Province.

Alkaline Fen

Alkaline fens have pH's from 7.0-8.0 or higher and are dominated by true mosses (often called 'brown mosses'). Characteristic species include *Scorpidium scorpioides, S. revolvens, Hamatocaulis vernicosus*, along with such rare indicators such as *Catoscopium nigritum, Mesoptychia rutheana*, and *Pseudocalliergon* Alkalinity is variable and ranges from 800-2000 meq L^{-1}; surface water reduced EC ranges from 150-600 μS cm^{-1} with calcium values from 30-100 mg L^{-1} and sodium values recorded from 2-50 mg L^{-1}. Water levels are variable and associated with vegetational differences. Alkaline fens (as rich fens) have been described by Slack et al. (1980).

Wet alkaline fens with water close to the surface are dominated by true mosses (species of *Hamatocaulis, Drepanocladus*, and *Scorpidium*) and/or sedges (Carex lasiocarpa, and *C. diandra*), drier fens have an abundance of shrubs (shrub *Betula* and *Salix* species), while drier sites have hummock development by true mosses (*Tomentypnum nitens*) and presence of a tree canopy (either *Larix laricina* or *Picea mariana*).

Circumneutral Fen

Fens with pH above 5.5 and below 7.0. These fens are sometimes slightly acidic and have only small amounts of base cations and associated anions. They are dominated by true mosses, but may have some abundances of mesotrophic Sphagna such as *S. teres, S. warnstorfii, S subsecundum*, and *S. obtusum*. Alkalinity is low and many sites have a rich flora of vacular plants. Historically these fens have been called moderate rich fens or transitional rich fens, however the distinctive pore water chemistry and associated plant species clearly define them. Circumneutral fens are among the most common fen type on the northern Alberta landscape and vegetationally may be wooded, shrubby, or moss/sedge-dominated. The lack of a ground layer with 100 per cent cover of Spgagnum distinguishes them from acid fens, while the lack of species such as *Scorpidium scorpioides*, and *S. revolvens* distinguishes them from the calcium-rich alkaline fens. Three common ground layer species, *Tomentypnum nitens, Ptychostomum pseudotriquetrum*, and *Campylium stellatum* have broad tolerances and are indicators of both circumneutral and alkaline fen types. Circumneutral fens have been studied in detail in the province by Chee and Vitt (1989 – as moderate-rich fens).

Acid Fen

Acid fens have pHs from about 4.5-5.5 and are *Sphagnum* dominated (*S. angustifolium, S. fallax*, and *S. majus*). They are nutrient poor (oligotrophic) and have few base cations (surface water: reduced EC=44-77 μS cm^{-1}, calcium 3-7 mg L^{-1}, and sodium 3-5 mg L^{-1}); alkalinity is less then 3 mg L^{-1}, but often zero or nearly so. Microsites within these fens consist largely of carpets and lawns, and if flow is sufficient, longitudinal pools (flarks) and ridges (strings) may be present. Acid fens (as poor fens) have been studied by Vitt et al. (1975), Vitt and Bayley (1984), and Nicholson and Vitt (1990).

As flow decreases owing to vegetation development, the vegetation of these fens changes. Wet fens are sedge and/or moss-dominated, with numerous lawns and carpets. Small pools may be present. Drier fens with less flow may be invaded by shrubs. Shrubs consist of *Chamaedaphne calyculata, Andromeda polifolia*, and species of shrub *Betula*. Low hummocks of *Sphagnum angustifolium* and *S. magellanicum* are present. Drier still are sites with abundant trees (*Picea mariana*); these wooded acid fens are rare, but do occur in transitional areas from shrubby acid fens to wooded bogs.

BOG (Fig. 4)
Bogs receive their nutrients, minerals, and water from the atmosphere (ombrogenous). They are acid (pH 4.0-4.9 or less) and mineral poor (reduced conductivity 43-89 µS cm^{-1}, sometimes less). Surface water calcium ranges from 5-12 mg L^{-1} and sodium from 3-5 mg L^{-1}. A relatively large aerobic zone (the acrotelm) positioned above the anaerobic catotelm is occupied by a small number of oligotrophic species of *Sphagnum*. Nearly all of the vascular plant species are woody and mycorrhizal. Alberta bogs have an open tree canopy of Picea mariana. Key indicator species are *Rubus chamaemorus*, and an abundance of hummocks of *Sphagnum fuscum* or *S. capillifolium*. Bogs in Alberta have been described by Belland and Vitt (1995). Four types occur in the Province.

Figure 4. A wooded bog with abundant shrubs and *Picea mariana* trees.
Photo Dale H. Vitt, North Central Alberta

Wooded Bog
Bogs with no permafrost or permafrost thaw features are dominated by an open, uniform canopy of *Picea mariana* and abundant hummocks of *Sphagnum fuscum* (or occasionally *S. capillifolium*). The complete absence of species of *Betula* and *Salix* and almost complete lack of *Carex* species are key features. See Belland and Vitt (1995) for more details on regional differences.

Figure 5. Ground layer of *Sphagnum fuscum* typical of bogs.
Photo Dale H. Vitt, North Central Alberta

Peat Plateau

When bogs develop a continuous layer of permafrost, they are peat plateaus. Peat plateaus are characterized by relatively large and dense individuals of *Picea mariana*, drier ground layer dominated by feather mosses and lichens, along with extensive high hummock development. Small round areas of wet lawns are either collapse features (collapse scars) or are areas that have never had permafrost. In either case, the surrounding peat surface is one meter or so higher than the collapse scar surface. Peat plateaus have been described by Tarnocai (1970), Zoltai and Tarnocai (1975), and Horton et al. (1979).

Bog with Internal lawns

Bog features with intermittent permafrost (frost mounds) and areas without permafrost as well as irregular wet areas (internal lawns) that have formed in the recent past from permafrost thaw are common in northern Alberta. Sites are characterized by the presence of internal lawns that are irregular wet areas surrounded by hummocky feather moss/*Sphagnum* ground layer, usually from 10-50 cm above the lawn surface. They have been described by Vitt et al. (1994) and Beilman et al. (2000).

Palsa Bog

Bog features with intermittent permafrost but without evidence of thaw are uncommon in the region. True palsas form when water in the peat column is abundant, and in these cases large peaty, ice-filled mounds form that are many meters high. The lack of abundant water in western Canadian bogs prevents large palsas from forming; however, large frost mounds that have not thawed may be present in some northern sites. These sites are best characterized by extensive, but localized hummock development associated with ground layers dominated by lichens and feather mosses.

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appendix b: peatland reclamation strategies

1. Key Developmental Characteristics for Well Site Reclamation

FENS (Minerotrophic peat-forming wetlands)

Developmental Characteristics

Seasonally wet saturated soils - Wet soils are developed on the landscape in two ways. 1) Shallow pools of water saturate the underlying soil material producing aquatic habitats that can infill with emergent wetland plants, gradually forming an organic layer beneath the water surface. 2) Local water tables at or near the soil surface provide wet saturated soils, either with vegetation or not, that can form organic matter directly on the soil surface. Both of these situations provide habitats for wetland plant species. Historically, fens develop through infilling of bodies of water through the process of terrestrialization, through primary peat formation wherein organic matter accumulates on saturated mineral soil surfaces or where organic matter accumulates on mineral soils that were previously dry and vegetated through the process of swamping (paludification).

Minerogenous water supply – In addition to precipitation, the supply of water to fen site types must include waters subjected to the influences of the surrounding landscape, either from surface runoff, ground water discharge, or lacustrine flood waters. This minerogenous water supply must be annually constant and contain a suite of elemental nutrients and minerals. High sediment loading is not desirable.

Stable water table - Water table fluctuation, both annually (generally less than 30 cm of drawdown over the growing season - Vitt et al. 1995) and longer term limits the number of species of plants that can establish. Likewise short residence times of the water leads to nutrient flushing and stream flow. Critical to the establishment of fen habitats is slow-moving to stagnant waters that enable limited overland sheet flow to take place on level or very gradual slopes. Water levels that are consistently above the soil surface limit fen plant establishment and encourages invasion of marsh plants, especially cattails (Typha species). High productivity along with high decomposition in cattail-dominated areas leads to eutrophic conditions and limits peat buildup and establishment of peat-forming plants.

Mesotrophy - High erosional rates, fluctuating water tables with relatively high flow rates, and high atmospheric deposition all provide waters with high amounts of nutrients (N, P, and K). These eutrophic conditions are limiting to the formation of a peatland because they lead to high plant production, but also to high rates of decomposition and thus high organic matter turnover rates and little if any organic matter accumulation. Mesotrophy results from increased water residency time, which decreases oxygen content, lowers water temperatures, and decreases turnover rates, thus allowing the development of a peat forming community.

Catotelm development - The development of a deep organic layer occurs when undecomposed plant material reaches the anaerobic layer (the catotelm). Key to organic matter accumulation is the development of a two-layered peat column, a lower anaerobic layer wherein decomposition takes place at a constant and very slow rate (Clymo 1984) and an upper acrotelm that is aerobic and wherein most of the decomposition occurs. A number of factors, including the time spent in the acrotelm, determine the decompositional state of the material when it reaches the catotelm. Due to high, relatively constant water tables, fen acrotelms are shallow allowing high quality plant material to be deposited in the catotelm to produce peat.

Reclamation strategies

Initializing the site for fen development should target four key areas.

Provide a constant water source delivered to the site as sheet flow. Although marsh site types such as emergent marshes may be successfully initialized by shallow pond development, peat-forming site types generally have initiated from paludification and primary peat formation rather than terrestrialization. There is little evidence that shallow ponds and marshes have succeeded to fens in the historical record for the mid-boreal region of western Canada (Bloise 2007), although bogs and fens that have succeeded from marshes and the infilling of shallow ponds are evident in the southern boreal zone (Kuhry et al. 1992, 1993).

Maintain a stable water level near the soil surface that does not have strong fluctuations. Although non-peat forming wetlands establish under fluctuating water regimes, many foundational fen plants, (especially mosses) require a relatively stable seasonal water level. Water levels maintained above the soil surface result in the invasion of *Typha* as well as providing an evaporative surface and should be avoided. These high water levels also reduce the opportunity for establishment of peat-forming plants.

Reduce the available nutrients on unvegetated substrates. Bare peat surfaces contain relatively high amounts of dissolved inorganic nitrogen (DIN) (Wind-Mulder et al. 1996) as do mineral soils. Mineral soils have N available as DIN, whereas organic soils have little available DIN, but large amounts of dissolved organic nitrogen (DON). We know little about the microbial flora and its functioning in wetland soils, especially on reclaimed or restored sites (see Andersen 2012 for a review). Despite this lack of data, the following strategy and recipe should be considered: The strategy is to tie up the original high amounts of DIN in persistent plant material with a subsequent slow release of N as DON. The recipe: 1) As soon as possible after site abandonment on either a mineral or organic soil base, establish a vegetation layer. On mineral substrate the introduction of nursery stock would provide plant cover more quickly as compared to seed dispersal. 2) Fertilizer is not required. 3) Maintain constant water supply and reduce water table fluctuation thus maintaining anaerobic conditions close to the soil surface. 4) Maintain water levels near, but beneath the soil surface in order to reduce microbial activity. 5) On organic substrate, introduce plant species with high polyphenol contents (e.g., mesotrophic species of *Sphagnum*, true mosses, and sedges) that provide resistance to decomposition, these acting to further sequester N in un-decomposed organic material. Moss species would provide such species introduced as either vegetative fragments or as population plugs (Daly et al. 2012).

Provide a suitable surface for future catotelm development. The development of a functioning two-part peat column is at present untried. A catotelm serves the purpose of providing an anoxic organic layer that protects the developing peat column from decomposition. As peat is initiated on either a mineral or an organic substrate, the stabilization on the newly developing organic layer is critical. Research in eastern Canada has revealed that after 10 years post-restoration on a cut-over peatland with a developing vegetated layer, water level fluctuations are not yet isolated within the newly accumulated peat (reviewed in Strack & Waddington 2012).

SALINE FENS (Minerotrophic wetlands with high Na^+ that may accumulate organic matter)

Developmental Characteristics

Saline fens occur at sites where sodium-rich ground water is or has been in the past discharged onto the landscape. These sites often contain layers of mineral deposits alternating with layers of organic material and over long periods of time may accumulate deep deposits of peat. Bryophytes are not present and the peaty material is composed of sedge and herb roots and stems. Salinity is highly variable and plant species able to tolerate these salinity amounts are few. Electrical conductivity is high, ranging from 500 to over 2000 µS cm^{-1} (S. Bayley, pers. comm.).

Reclamation strategies

Since saline fens are groundwater fed often with water discharging at the base of moderate slopes, early recognition for such landscape sites is important. Well sites that are flushed with local saline surface waters should be recognized at the onset of reclamation.

Site development should maintain a constant saline water source.

Establish a set of foundation plant species selected from among salt-tolerant species (see CEMA 2014).

From among these species, several germinate freely including *Triglochin maritima, T. palustris, Carex aquatilis*, and *Beckmannia syzigachne*. On the other hand. *C. atherodes* and *C. utriculata* have few seeds and are difficult to germinate. *Calamagrostis stricta* also is a species with tolerances to high salinity.

ALKALINE FENS (Minerotrophic wetlands having HCO_3^- and Ca^{2+} as dominant pore water ions and that accumulate organic matter)

Developmental Characteristics

Natural sites with surface and/or ground water sources high in $Ca(HCO_3)_2$ are often the first peatland communities evident in the historical record. Once established, these peatland plant communities can persist at individual sites for millennia (Yu et al. 2014). Although site chemistries can be somewhat variable, ranging from 30 mg L^{-1} of Ca^{2+} to over 100 or more mg/L Ca^{2+}, all contain a species-rich set of plant species. Sites have the ground layer dominated by true mosses (often 90-100 per cent cover) and a well-developed field layer of a variety of sedge species. Accumulated peat is either moss- or root-dominated, with well preserved seeds and plant parts. Peat depths range up to over 6 m and include some of Alberta's deepest peat deposits.

Reclamation strategies

In addition to the plans for fen reclamation (see above), the following are recommended.

Salinity must be reduced to less than 400-500 mg L^{-1} (Vitt 2013) either through hydrological removal, position on the landscape that provides insulation from Na-rich sediments, or flushing with fresh water.

A second strategy is to establish plant species that have some tolerance to high Na^+ and also tolerate Ca^{2+}-rich waters (Appendix D).

Both N and C cycle functions in alkaline fens are largely controlled by the moss layer, wherein both elements are sequestered in un-decomposed plant biomass resulting in peat accumulation (Vitt et al. 2009). Thus establishment of the moss layer is a key developmental characteristics that must be crossed. Two approaches are possible based on current knowledge, each best implemented under somewhat different initial conditions. Peat-based substrate: (See Gauthier 2014 for details and Rochefort & Lode 2006 for review of techniques). Mineral soil-based substrate: (See Vitt et al, 2011, and Hayes 2015 for details). There may be sites where exposed mineral soils as well as bare peat substrates are too severe for moss establishment at the out-set of reclamation and nurse plants may be needed to help with initial establishment. Here sedge species are selected from nursery stock and planted in clusters of 10-20 plants in year 1. After 2-3 years, a shallow organic layer of decaying sedge remains should be present and moss fragments can be introduced using techniques outlined in Quinty and Rochefort (2003). Additionally, indigenous moss species quickly colonize both mineral and organic substrates under a cover of a field layer (Vitt & House 2015). Water levels should be at to just below the soil surface in the spring and maintained close to soil surface throughout the first year. Lists of appropriate moss species and nurse plants are found in CEMA (2014).

CIRCUMNEUTRAL FENS (Minerotrophic wetlands having pH at neutral or slightly acid and have low concentrations of calcium and bicarbonate in the pore waters).

These mesotrophic fens are somewhat transitional between alkaline fens with high amounts of calcium and acid fens with little or no Calcium, thus they can be easily influenced by acid-producing species of Sphagnum.

Reclamation Strategies

This fen type is perhaps the easiest to establish. Waters need to have reduced amounts of salinity (including all base cations) and not be naturally acidic. Since natural circumneutral fens are often sedge-dominated and have ground layer species with broad tolerances, species introductions can be successful. Plantings of *Carex aquatilis, C. utriculata. Scirpus* spp, along with moss species such as *Drepanocladus aduncus, Campylium stellatum*, and *Ptychostomum pseudotriquetrum* are all tolerant of circumneutral chemical conditions.

ACID FENS (Minerotrophic wetlands that have H^+ as the major pore water ion and accumulate organic matter)

Developmental Characteristics

Acid fens are *Sphagnum*-dominated peatlands that often occupy watershed divides in elevationally high positions on the regional landscape. In other situations they are underlain with sandy deposits without contact to alkaline ground water. In these situations, they receive waters with few nutrients and minerals and are oligotrophic. Acid fens also most often occur in association with bogs and form large soligenous peatland complexes. The fen components of these complex peatlands have high water tables covered by carpet (e.g,. *S. majus*) and lawn (e.g., *S. angustifolium*) species of *Sphagnum*. Historically, acid fens have either remained relatively constant over time or rapidly developed from previous alkaline fens as they become more isolated from ground layer sources due to peat accumulation. In these cases, acidification by invading mesotrophic *Sphagnum* species (*S. teres, S. subsecundum*, and *S. obtusum*) appears to facilitate rapid succession.

Reclamation strategies

To our knowledge, no research has been carried out in reclamation of acid fen, although ditches and block harvesting of peat leaves areas within bogs that have many characteristics of acidic fens. The wet, oligotrophic nature of acid fens has made them difficult to utilize for peat harvesting or agriculture. Site selection would be of critical importance for initiation of acid fens. Sites with a natural (in situ) *Sphagnum* peat if maintained with water tables at the surface have naturally revegetated with species of *Sphagnum*, especially *S. fallax, S. angustifolium*, and *S. riparium*. This situation can be found naturally in areas subjected to permafrost thaw in bogs (Beilman et al. 2000). Using this natural disturbance as a surrogate the following would be appropriate.

- Introduce pure *Sphagnum* peat to the site
- Maintain water levels at or just beneath peat surface
- Ensure acidic nature of peat
- Reduce inputs of all base cations and nutrients
- Introduce *Sphagnum* fragments from locally available wet, oligotrophic *Sphagnum* species. *S. riparium* would be especially appropriate
- Introduce species of *Carex* (*C. limosa, C.magellanica* ssp. *irrigua, C. aquatilis*, and *C. canescens*) using either seeds or nursery stock
- Monitor pH and reduced electrical conductivity (pH 4.5-6.0, REC <50 μS cm^{-1}.

BOGS (Ombrotrophic wetlands that accumulate organic matter)

Developmental Characteristics

Bogs are ombrotrophic and result from long-term peat accumulation that isolated the growing moss surface above the local water table. Bogs thus are oligotrophic and have a well-developed acrotelm. This acrotelm consists of hummock species of *Sphagnum*, ericaceous shrubs, and in Alberta a tree layer of *Picea mariana*. The lack of minerogenous water inputs reduces base cations in the pore water and acidifying *Sphagnum* rapidly sequesters the ions that arrive from atmospheric fallout. The insulative properties of *Sphagnum* and the well-developed aerobic acrotelm reduce the temperatures in the upper peat layers (Vitt et al. 1995), thus bogs retain frost longer then fens. Historically, bogs in western Canada rarely develop directly on mineral soils, but are the end product of a long history of fen development succeeding to bogs - as a wetland climax plant community (Bauer et al. 2003).

Reclamation strategies

Bogs (sites that have an in situ acidic peat base) have been successfully restored in eastern Canada using methods clearly laid out in Quinty and Rochefort's (2003) peat restoration manual. Also, some minimally disturbed petroleum sites have been documented to return to *Sphagnum*/*Polytrichum* dominated sites with young *P. mariana* and ericaceous shrubs (House et al. 2013).

Bog reclamation on mineral soils is potentially feasible, albeit expensive. In 2008, at the U-cell research site at Syncrude, transplants of live bog peat were successfully transferred to research cells and continuously maintained. After five growing seasons, all transfers have maintained a living vegetative layer. No differences are evident in the flora from depth of transplanted material (10, 50, 100 cm) or in time of transfer (winter or summer) (Vitt 2013). From these results it appears that localized islands of bog peat could be successfully transferred to abandoned well sites.

Recommendations for success include:

- Maintain all base cation levels to an absolute minimum
- Maintain water level 15-20 cm below peat surface
- Isolate transfers from the surrounding inflowing water if rich in nutrients or base cations
- Place transfers on a substrate with good water holding capacity
- Make sure there is contact between the transferred blocks.
- Establish the water regime immediately
- Do not apply fertilizer or lime

The information provided above allows some general recommendations for peatland reclamation on mineral soils.

2. General Construction Considerations

Soil Quality and Construction
Soil assessments should be done on borrow material, whether reclaiming to peatland or forested communities. Clay materials in some regions of Alberta may have extreme pH, naturally occurring sulphates, elevated ECs and SARs. Sampling of borrow pit material to insure the chemistry is suitable for peatland or forested communities is critical to successful reclamation.

3. General reclamation recommendations

In principal, well sites should be engineered to provide suitable habitats for foundation plant species of fens, depending on the well site location and substrate/water chemistry. End-point design should carefully consider, up-front, the species selection for foundation plant species and their tolerances to water levels, nutrient supplies, and base cation concentrations.

Well site location
Reclamation of well sites located in alkaline fens should use a mineral soil base graded to surrounding water level. Well sites located in bogs or acid fens should use one of two methods: 1) mineral base graded to surrounding water level (Hayes 2015). In this case the influence of the mineral substrate will provide alkaline (or saline) fen conditions within a matrix of acidic fen or bog. 2) The peat inversion method that inverts the mineral pad and exposes the underlying peat, thus utilizing an initial organic substrate for reclamation (Gauthier 2014).

Selection of vegetation

Fens may have shrub or tree layers in addition to a moss-dominated ground layer and a sedge-dominated field layer. The addition of shrub and tree layers will be determined by site dryness; however, little information is available for recommending site dryness for shrub or tree layer development. All fens have abundant sedge and moss components; however, the historical record of fen initiation by primary peat formation or paludification often does not contain abundant moss macrofossils at the mineral/peat interface. Thus it is not clear at present whether mosses can be established directly on mineral soils without the protection of larger field layer species.

Selection of foundation species for fens

Tables in Appendix D provides lists of 'Characteristic Species' for each peatland type. Species should be chosen from among those listed. CEMA (2014) also provides lists of recommended species. Currently no information is available on community assembly and it is not known how fen species interact in the early stages of establishment. Current trials test two scenarios 1) The establishment of 1-2 foundation species will create an environment wherein additional species will colonize and form a structurally intact, functioning plant community or 2) structure and some component of the plant community should be established by nursery stock (i.e., three sedges, one shrub, two forbs, etc.) thus creating complex structure early on in community assembly. It would be appropriate for either or both of these designs to be attempted.

Avoidance of 'undesirable species'

The term undesirable species is a term used in the Alberta 2010 Reclamation Criteria for Wellsites and Associated facilities. As it applies to peatlands the presence of upland species, marsh species (species associated with non-peat forming wetlands), non-native or agronomic species are indicators of inappropriate trajectory and do not contribute to the percent canopy cover of desirable species. A successful reestablishment of the moisture regime, as referred to in each of the above Peatland types, is the primary tool to prevent these species. *Latifolia* spp. is a species that may establish in wetter areas. This species' high productivity, along with high decomposition leads to eutrophic conditions that limit peat buildup and establishment of peat-forming plants. Clay padded wellsites may have drainage along the edges that have allowed *Typha* spp to establish during operational phase from seed sources from surrounding areas and wildlife. The following may assist with prevention of *Typha* spp., 1) the removal of the seed source prior to initiating reclamation. 2) When working with clay pad material (e.g., removal, inversion), care taken not to spread surrounding seed source throughout the site. 3) If the hydrology is wetter in some areas, the quick establishment of *Carex* spp, to prevent invasion.

Selection of substrate

In theory, fens could establish on mineral substrates as well as on a variety of peat substrates. It is unknown whether the addition of a peat layer will enhance the development of a catotelm and currently there is no information on nitrogen cycle function, carbon cycle, or sulfur cycle in any of these artificially introduced substrates. Although no recommendation can be made, it appears that introduction of a peat layer to a site may not be necessary, although there is some evidence that an organic layer maintains moisture control better than a mineral substrate and may enhance indigenous moss introduction (Vitt & House 2015). In addition, it is unclear whether peat will act as a buffer for inherent sodium contents in underling well site sediments.

Salinity
Greenhouse trials for a number of key fen species (Vitt 2013, Koropchak & Vitt 2012) suggest that threshold values for sodium may be in the range of 300-600 mg L^{-1}. These species are all species characteristic of alkaline fens. Thus there appears to be a suite of species that can tolerate pore waters with relatively high concentrations of sodium and calcium as well as the associate anions of Cl^- and HCO_3-.

Nutrient supply
Fens and bogs are ecosystems that normally function under low nutrient regimes. There is no indication that either mineral soil or peat substrates have low concentrations of limiting nutrients, although there are few data. Research at Peace River (Vitt et al. 2011) where a well site with mineral substrate was treated with 10:10:10 fertilizer annually for 4 years and compared to an unfertilized pad yielded differences in introduced plant responses; however, the fertilized pad contained a significantly greater abundance of weedy species suggesting that increased invasibility is due to unused resources (Davis et al. 2000). Thus there is conflicting evidence that a fertilizer treatment is beneficial in early fen establishment.

Water levels
Fens naturally function with a water table close to, but somewhat lower than the substrate surface. Mature fens with hummock development have microtopographic drier areas where shrubs and trees are present. Water levels above the substrate surface favor marsh plants and the invasion by Typha, and appear to inhibit the establishment of indigenous plant species. Water levels too far beneath the substrate surface encourage upland weedy species, enhance decomposition, and disrupt the wetland N-cycle. Fluctuating water levels provide conditions favoring high rates of decomposition and also favor plant species with tissues that are easily decomposed. Thus water levels should be stabilized 2-8 cm beneath the substrate surface with annual fluctuation no greater then 30 cm.

4. Minimum disturbance

Development of an operational or exploration drilling frozen pad can include the removal of aboveground plant biomass (shrub & trees) and freezing-in of a working surface using locally sourced snow or external water. These sites may or may not return to natural conditions shortly after work is finished and two studies have explored how well these sites return to a potential peatland trajectory. (House et al. 2012) studied bogs while Caners and Lieffers (2014) worked in rich fens. Both found that return to pre-existing conditions was variable among the studied sites. Overall, both studies concluded that problems arose from 1) sites leveled to an elevation that removed too much of the ground layer, 2) the possibility that compaction from heavy equipment was a concern 3) areas of subsidence near the well site, and 4) insufficient information on records that detail the site predisturbance history and also insufficient records of site development. Points 2 and 3 can lead to the ground layer not returning, with the site overall increasing in wetness leading to peatland plant communities changing.

Recommendations from these studies include:

1. Site leveling should remove as little of the ground layer as possible, especially in hummocky terrain, only hummock tops should be removed.

2. Subsidence around the well site should be kept to a minimum.

3. Vascular plant debris, including black spruce tree tops, should be left whole on site and not mulched.

4. External water sources should be carefully documented – including source, chemistry, and amount.

5. Compaction from heavy equipment is a concern, and sites should be engineered to decrease this effect.

6. Microrelief of the surface should either be kept intact, or at a minimum the site should not be engineered to have a flat surface when operations are completed.

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appendix d: *water act* and riparian areas (wr)

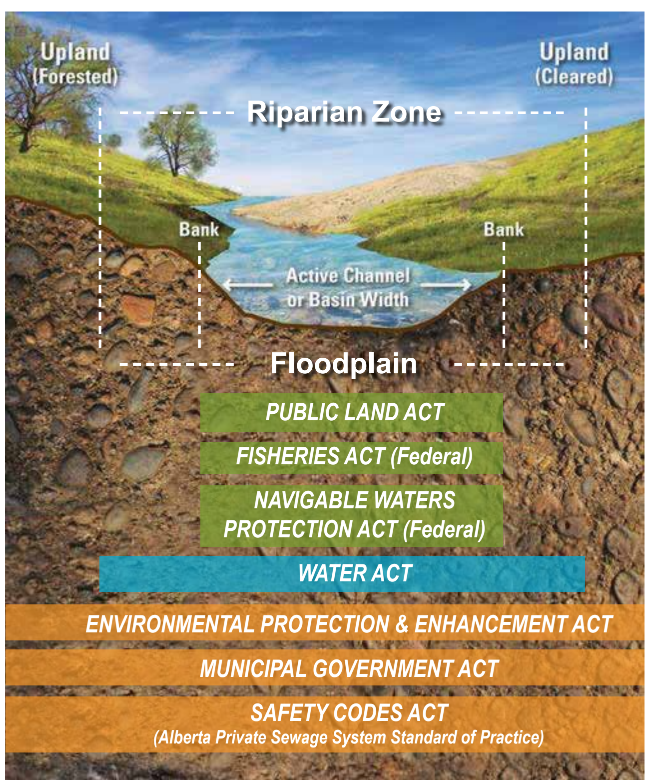
1.1. Landscape

The *Water Act* specifies that a water body is 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 (generally excluding irrigation works). There are, therefore, direct implications of the *Water Act* regarding riparian lands.

Riparian lands are transition zones between the land and the water and include any geographic area that adjoins or directly influences a water body (e.g., streams, lakes, ponds, wetlands including floodplains) and land that directly influences alluvial aquifers and may be subject to flooding. In west central Alberta, fens, bogs and marshlands represent a large proportion of riparian areas. Healthy, intact riparian lands deliver broad benefits to society including water quality improvement, flood control and water storage, reduced erosion and the maintenance of terrestrial and aquatic biodiversity.

The protection of riparian zones is therefore a key element of integrated land-water management and an important consideration in the development of these new reclamation policy and guidelines. The Wetlands Policy's goal to conserve, restore, protect and manage Albertans wetlands to sustain the benefits they provide to the environment, society and the economy (ESRD 2013) clearly outlines that avoidance is the most desired option.

Legislation Affecting Water Bodies in Alberta



The hierarchy of mitigation provided in the Wetland Policy include:

1. **Avoidance** - The primary and preferred response to avoid impacts on wetlands.
2. **Minimization** - Where avoidance is not possible, proponents are expected to minimize impacts on wetlands.
3. **Replacement** - As a last resort and when avoidance and minimization efforts are not feasible or prove ineffective wetland replacement is required.

1.2. Vegetation - Indicators of Riparian Areas

Riparian areas can be classified using hydrologic indicators as indicated by the types of vegetation and soils. Vegetation indicators are hydrophytic plants classified by their frequency of occurrence in wetlands including cattails, bulrushes, most sedges, some mosses, and many willows (SWCD, 2005). Hydrophytic vegetation occurs in distinct zones adjacent to streams and wetlands. Vegetation zones associated with riparian and aquatic areas include low prairie, wet meadow, shallow and deep marsh, and permanent open water (Stewart and Kantrud, 1971). Descriptions and photographs of the vegetation zones are provided in the City of Calgary's Wetland Conservation Plan (City of Calgary, 2004). Descriptions of plant community types in Alberta can be found in various sources (Thompson and Hansen, 2002; Thompson and Hansen, 2003) including helpful photographic and descriptive guide for key riparian plant species in Alberta (Hale et al., 2005).

1.3. Soils - Indicators of Riparian Areas

Riparian soils are typically hydric (i.e., usually saturated and subject to flooding or ponding during a portion of the growing season). Drainage classes found in riparian areas include: moderately well, imperfect, poor, and very poor. Imperfect and moderately-well drained soils can only indicate riparian areas at locations where hydrology and vegetation indicators are also consistent with riparian conditions as imperfect and moderately-well drained soils can also occur in uplands. For example, in central and northern Alberta these soils can also occur in fine-textured parent materials.

1.4. Riparian Function: Hydrology

Hydrology is the driving force that creates all wetlands. Hydrologic indicators include standing (lentic) or flowing (lotic) water during at least part of the growing season, water marks or drift lines of debris on trees or shrubs, or thin layers of sediment coating the ground or objects on the ground (SWCD, 2005). Riparian areas usually occur in depressional and toe-slope positions, but groundwater springs can occur in mid- and lower-slope positions.

1.5. Wellsites In or Near Riparian Areas

Reclamation criteria: The reclamation criteria for riparian lands are addressed in each Land use group. A framework for the health assessment of Alberta wetlands is provided by the Cows and Fish program's user's manual (Cows and Fish, 2004). Legislation that applies to wellsites in and/or near riparian areas:

1.5.1. *Water Act* (Government of Alberta, 2014)

No person may commence or continue an activity without approval unless it is otherwise authorized under the Act; Section 36(1) Subsection 2.

1.5.2. Directive 056 (AER, 2011)

Clause 45: The well centre must be sited a minimum of 100 m from a water body.

Clause 46: To submit a routine well licence application if the well centre is located on Freehold or Crown land but does not meet the 100 m setback requirement, the applicant must

a) have a Crown disposition if the well centre is located on Crown land;

b) maintain natural drainage if there is intermittent drainage or a spring/artesian flow across the well site or access road on Freehold and Crown land; and

c) have acceptable measures in place to protect the water body during drilling and future production operations and mitigate the consequences of a spill on Freehold and Crown land.

i) Acceptable measures must include one or more of the following as **required:**

- site and berms constructed using impermeable materials,
- synthetic liner,
- vacuum truck,
- absorption material,
- enclosed systems with tankage, and
- textile mat.

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appendix e: species list

Table 1. Peatland Type – Bog (pH 3.0-4.2)

Structural Layer	Species	Characteristic Species
Tree	*Picea mariana*	√
	*Larix laricina***	
Shrub	*Chamaedaphne calyculata*	
	Kalmia polifolia	
	Ledum groenlandicum	√
	Oxycoccus microcarpus	√
	Vaccinium uliginosum	
	Vaccinium vitis-idaea	√
Herb/Forb	*Carex pauciflora*	
	Eriophorum vaginatum	
	Rubus chamaemorus	√
	Smilacina trifolia	√
Bryophytes	*Aulacomnium palustre*	
	Calypogeia sphagnicola	
	Cephalozia connivens	
	Dicranum undulatum	
	Hylocomium splendens	
	Mylia anomala	√
	Pleurozium schreberi	
	Pohlia nutans	
	Polytrichum strictum	√
	Sphagnum angustifolium	
	Sphagnum balticum	
	Sphagnum capillifolium	
	Sphagnum fuscum	√
	Sphagnum magellanicum	√
	Stramiergon stramineum	
	Warnstorfia fluitans	

Structural Layer	Species	Characteristic Species
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

Table 2. Peatland Type – Acid Fen (4.0-5.5)

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*	
	*Pohlia nutans**	
	*Polytrichum strictum**	
	Sphagnum angustifolium	√
	Sphagnum fallax	
	Sphagnum jensenii	
	Sphagnum lindbergii	
	Sphagnum magellanicum	√
	Sphagnum majus	
	Sphagnum riparium	
	Sphagnum russowii	
	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.

Table 3. Peatland Type - Circumneutral fen (pH 5.5-7.0)

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 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	
	Smilacina trifolia	
	Stellaria longifolia	

Structural Layer	Species	Characteristic Species
	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	√
	Tomentypnum nitens	√

Table 4. Peatland Type - Alkaline fen (pH 7.0-8.5)

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 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	
	Tofieldia pusilla	
	Triglochin maritima	√
	Triglochin palustre	√
	Utricularia intermedia	

Structural Layer	Species	Characteristic Species
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	√

*Indicates a species that occurs in oligotrophic microsites

Table 5. Peatland Type – Saline Fen (pH 7.0-8.5)

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*	
	Bryum pseudotriquetrum	√
	Campylium polygamum	
	Drepanocladus aduncus	
	Campylium stellatum	√
	Tomenthypnum nitens	
Saline Pools	*Puccinellia nuttaliana*	
	Carex prairea	
	Plantago maritima	
	Potentilla anserina	
	Salicornia europa	
	Scirpus pungens	
	Suaeda calceoliformis	

Species lists are extracted and revised from regional literature sources including the following (see Literature cited for Appendix A): Vitt et al. 1975, Horton et al. 1979, Slack et al. 1980 Chee & Vitt 1989, Vitt & Chee 1990, Vitt and Belland 1995, Halsey 2007.

appendix f: a key and review of bryophytes common in north american peatlands

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Abstract. **Peatlands are ecosystems that have a ground layer dominated by bryophytes. Bryophytes act as foundational species in both bogs and fens and largely control many ecosystem functions as well as form the majority of organic matter sequestered in many of these systems. Here, a key is presented to 65 bryophyte species that represent most of the species that occur commonly in northern and oceanic North American peatlands. Also, taxonomic comments, brief morphological descriptions, and ecological preferences for each species are given.**

Keywords. **Peatland, fen, bog, boreal, mosses, hepatics**

Introduction

Peatlands are ecosystems that over millennia have accumulated organic matter as deposits of peat, due to inputs of carbon from photosynthesis being greater than losses from decomposition and outflow of dissolved organic carbon. Peatlands store about 33 per cent of the world's soil carbon and 16-28 per cent of the world's soil nitrogen while occupying only 3-4 per cent of the earth's surface.

Peatlands are rather unique in having a ground layer of bryophytes, often covering 80-100 per cent of the surface. The layer consists of either *Sphagnum* species in bogs and poor fens or true mosses (Bryopsida) in rich fens, although present hepatic species are never abundant. Due to differing cellular structural components, these bryophytes decompose at a slower rate than do vascular plants and thus bryophytes provide much of the organic material that remains as peat. These deposits of peat have, over the past 10,000 years or so, removed a substantial supply of CO_2 from the atmosphere and are important to climate change.

The bryophytes that occur in the ground layer are highly sensitive indicators of the varying conditions found in peatlands having sensitivity to pH, base cation content, water level, and nutrient supplies. They also have high fidelity and provide key indicators to the five peatland site types and a few can be considered foundational species of these habitats.

Peatlands can be classified into five fundamental site types. All of these have bryophytes as key indicators. Bogs, acidic ombrogenous site types, peat plateaus (bogs with permafrost), and poor fens (acidic, minerogenous site types) are dominated by species of *Sphagnum*. Rich fens (alkaline, minerogenous site types) are dominated mostly by true mosses - rich fens are often divided into moderate-rich fens (neutral to slightly alkaline site types) and extreme-rich fens (basic, strongly alkaline [calcareous] site types). Additionally non-peat forming site types – marshes (without trees) and swamps (forested) may have substantial bryophyte cover.

Peatlands are most common in the arctic and boreal regions of the northern hemisphere and any vegetation survey, environmental analysis, or EIA should provide a documentation of the ecologically important species of bryophytes. Although there are quite a few modern large scale or regional moss and hepatic floras available, including the 'Bryophyte Flora of North America' with considerable name revisions for species, no key and treatment of the common species of bryophytes found in North American peatlands exists. Here I provide a key, along with morphological and habitat notes for 65 of the common North American species. Also included are summary graphs for species occurrence along the microtopographic (pool, carpet, lawn, and hummock) gradient, the acidity (pH) gradient, the peatland site type occurrence, and the regional temperature/moisture gradients. Three graphics are given for each species providing representations of where the individual species are most frequent or abundant; they are not meant to represent the absolute range of the species. One graphic represents the regional occurrences of species across the continent. Across North America, peatlands change in structure and species composition along two gradients. A temperature gradient north to south, here viewed as Arctic, northern boreal (including the subarctic), and southern boreal (including areas such as northern Minnesota, and New England). Secondly, a precipitation gradient, here described as continental to oceanic, with the western boreal plain of Canada the most continental, Ontario and Quebec as variations of subcontinental, and the Maritime Provinces and Maine as (as well as coastal British Columbia and Alaska) as oceanic.

The second graphic illustrates for each species, habitat preferences at the site level. Two important gradients are the bog-rich fen gradient and height above water level, here represented as follows: pools are small bodies of open water filled with submerged vegetation, carpets are areas where the mosses have emergent upper parts and form unconsolidated substrates, lawns are low, relatively level, moist habitats of consolidated peat, while hummocks are relatively dry, elliptic to rounded mounds. Carpets have moss surfaces a few cm above water level, lawns have surfaces 10-15 cm above water level, while hummocks vary from 20-100 cm above water level. Bogs are wooded in continental climates, have only scattered trees in subcontinental climates, and are without trees in oceanic areas (or with scattered *Pinus contorta* along coastal

B.C. and Alaska). In oceanic areas, fens tend to be open, sedge-dominated habitats, but as continentality increases they become dominated by shrubs and trees. In the northern boreal zone, they may be patterned with elongate wet areas (flarks) and drier strings. Permafrost occurs in organic soils in northern boreal areas there restricted mostly to bogs, when these have a continuous layer of ice they are termed peat plateaus that contain small unfrozen areas (collapse scars or internal lawns) with carpet and lawn vegetation. Bogs without permafrost in continental areas have no pools and very limited carpet vegetation; however, these features become more evident as precipitation increases so that bog pools are common in oceanic areas. Arctic areas have few species of *Sphagnum* and thus bogs and poor fens are of limited occurrence. The third graphic provides the pH preferences for each species.

Photographs of most species are readily available by searching on the internet once a species is determined; however, one site is particularly valuable: The British Bryological Society's set of photographs and field notes is very useful, available at www.bbs.fieldguide.org.uk. Additionally, for *Sphagnum*, Kjell Ivor Flatberg's colored photographic guide is still available for download at www.ntnu.diva-portal.org. Photos and comments for many boreal peatland species are in Vitt et al. (1988) that is still available from the publisher.

Key to Species

1. Leaves with upper cells similar in size and shape, sometimes different from lower cells, but cells never having a reticulate network of alternating cell types; branches single or not branched 2

1. Leaves with alternating large, clear cells and small dense cells, forming a reticulate network; branches in fascicle .... ***(Sphagnum)*** 44

2. Leaves circular in outline, as wide as long, arranged in 2 or 3 ranks along stem 3

2. Leaves elliptic to lanceolate-ligulate, much longer than wide or with a border of elongate cells, not in ranks along stem.. ***(True mosses)*** 7

3. Leaves folded along postical edge to form two lobes, the upper smaller than the lower .... ***Scapania paludicola***

3. Leaves simple, not folded 4

4. Leaves incubous (lower margins hidden by upper margins of the leaf above) ....***Calypogeia sphagnicola***

4. Leaves overlapping and succubous (the upper margins hidden by lower margins of the leaf above) or not overlapping and obliquely inserted 5

5. Leaves rounded at apex; cells with distinct corner thickenings (trigones) .... ***Mylia anomala***

5. Leaves bilobed with two sharp points; cells thin-walled without trigones...6

6. Plants large; leaves with reflexed margins; occurring in rich fens ....***Mesoptychia (Lophozia) rutheana***

6. Plants tiny; leaves with erect margins; occurring among *Sphagnum* plants .... ***Cephalozia connivens***

7. Leaves with longitudinal folds 8
7. Leaves without longitudinal folds 10
8. Leaves straight, erect...T***omentypnum nitens***
8. Leaves curved (falcate)..9
9. Stems with reddish tomentum along one side .... ***Tomentypnum falcifolium***
9. Stems naked, without tomentum... ***Sanionia uncinata***
10. Leaves multi-stratose, consisting of broad costa, overlapping laminae encasing vertical lamellae; lower cells forming a clear, unistratose sheath ....***Polytrichum strictum***
10. Leaves unistratose, without lamellae; lower cells not forming clear sheath....................................... 11
11. Leaves curved (falcate) - all in one direction 12
11. Leaves erect, recurved, or wide-spreading..24
12. Leaves stiffly squarrose-recurved, margins broadly reflexed................................***Paludella squarrosa***
12. Leaves erect to wide-spreading, margins erect to narrowly reflexed...13
13. Costa very short and double, never extending beyond one-third of leaf length,.................................14
13. Costa long and single, extending at least to mid-leaf .... ***Drepanocladus sensu lato*** 16
14. Leaves complanate-secund. ....***Hypnum pratense***
14. Leaves falcate-secund 15
15. Leaves lanceolate, acuminate; alar cells numerous, forming an inflated group of cells .... ***Hypnum lindbergii***
15. Leaves broadly ovate-lanceolate, broadly acute to narrowly obtuse ....***Scorpidium scorpioides***
16. Upper leaf margins entire...17
16. Upper leaf margins serrulate, sometimes minutely so with only 1-3 apical teeth 21
17. Alar cells forming distinct marginal groups; stems with central strand and small epidermal cells 18
17. Alar cells not much different from basal cells, not forming distinct groups, at most 1-3 hyaline, inflated, fragile cells at basal margin; stems either without central strand or with epidermis of larger cells compared to outer cortical cells...19
18. Alar cells thin-walled, hyaline, inflated .... ***Drepanocladus aduncus***
18. Alar cells thick-walled, colored, enlarged .... Drepanocladus sordidus (Drepanocladus sendtneri in previous literature)
19. Leaves somewhat striate; alar cells not differentiated; stems without central strand .... ***Hamatocaulis vernicosus***
19. Leaves without any evidence of striations; alar cells 1-3, hyaline, inflated, fragile cells at basal margins; stems with central strand 21
20. Plants green; cells at mid-leaf 14-95 µm long, with square to short-fusiform cell ends ....***Scorpidium cossonii***

20. Plants reddish; cells at mid-leaf 61-140(-179) µm long, with short-tolong-fusiform ends .... ***Scorpidium revolvens***

21. Stems 4-5 angled in transverse section due to long leaf decurrencies; stem leaves acute, tips often bent downward .... ***Sarmenthypnum (Warnstorfia) tundrae***

21. Stems round in transverse section; leaves not to shortly decurrent; stem leaves acuminate, similar to branch leaves 23

22. Costa weak, ending one-half to two-thirds the distance up leaf length; alar cells gradually enlarged .... ***Warnstorfia fluitans***

22. Costa strong, ending in or just below apex; alar cells abruptly inflated .... ***Warnstorfia exannulata***

23. Upper leaf cells with very wavy and regularly nodulose walls; leaves ending in decurrent, papillose, hyaline point; occurring in coastal bogs .... ***Racomitrium lanuginosum***

23. Upper leaf cells with straight mostly evenly thickened walls to occasionally irregularly thickened walls; leaves ending in non-hyaline point; widespread in occurrence 25

24. Stems with abundant, green, filamentous paraphyllia .... ***Helodium blandowii***

24. Stems naked or with reddish tomentum of rhizoids 25

25. Upper leaf cells elongate-linear, mostly greater than (6)10:1 length:width ratio 26

25. Upper leaf cells rounded-quadrate to long-hexagonal, mostly (1)2-6:1 length:width ratio 36

26. Leaves blunt (rounded-obtuse), rarely with tiny apiculus 27

26. Leaves sharply pointed (acute to acuminate) 32

27. Costa long and single, ending in or just below apex of leaves 28

27. Costa short and more or less double and ending below mid leaf or single and ending about midleaf 29

28. Alar cells abruptly inflated, forming conspicuous groups of hyaline, thin-walled cells; costa ending at leaf apex .... ***Calliergon giganteum***

28. Alar cells gradually enlarged, forming inconspicuous groups of colored, thick-walled cells; costa ending below leaf apex .... ***Straminergon (Calliergon) stramineum***

29. Alar cells abruptly inflated to form groups of hyaline, thin-walled cells 30

29. Alar cells forming groups of firm-walled, often colored cells 31

30. Leaves lingulate; stems with conspicuous hyalodermis; rare in peatlands .. ***Calliergonella cuspidata***

30. Leaves triangular to ovate; stems without hyalodermis; sporadic but locally abundant in peatlands. .... ***Calliergon richardsonii***

31. Leaves ovate, about 1.0-1.5 times as long as wide; alar cells somewhat enlarged and oblong, firm-walled; stems clear to brownish; plants unbranched .... ***Pseudocalliergon (Calliergon) trifarium***

31. Leaves oblong-ovate, about 2.0 times as long as wide, with abruptly incurved upper margins; alar cells short-oblong with thick, orange walls, in concave marginal groups; stems reddish; plants abundantly branched .... ***Pleurozium schreberi***

32. Costa double, very short to ending about midleaf 33

32. Costa long and single, ending in upper part of leaf..34

33. Leaves channeled in upper portion, gradually narrowed to apex from broadly ovate base; leaf cells smooth; stems without paraphyllia..***Campylium stellatum***

33. Leaves abruptly acuminate, appearing almost blunt; leaf cells prorulose; stems with abundant paraphyllia..***Hylocomium splendens***

34. Leaf bases channeled; alar cells in a distinct group; occurring in eutrophic marshes and fens ....***Drepanocladus (Campylium) polygamus***

34. Leaf bases plane; alar cells gradually larger, grading to basal cells, occurring in rich fens................35

35. Plants large, unbranched or with a few branches; leaves 2.5-3.0 mm long; arctic and northern in occurrence ....***Brachythecium turgidum***

35. Plants medium-sized, irregularly branched, leaves 1.7-2.3 mm long; boreal, occurring in rich fens ....***Brachythecium acutum*** (formerly B. mildeanum in North American literature)

36. Upper leaf cells papillose (with one large papilla), often irregularly thick-walled, rounded-quadrate; stems with abundant reddish tomentum ....***Aulacomnium palustre***

36. Upper leaf cells smooth, mostly thin-walled, quadrate to long-hexagonal; stems without reddish tomentum 37

37. Leaves bordered by 1-several rows of elongate cells 38

37. Leaves without a border of differentiated cells 40

38. Leaves ovate to oblong-ovate; upper cells 1-4:1 length:width ratio 39

38. Leaves ovate-lanceolate to lanceolate; upper cells 3-6:1 length:width ratio ....***Ptychostomum (Bryum) pseudotriquetrum***

39. Leaves oblong-ovate; leaf cells 2-4:1 length width ratio, in oblique rows, with irregular walls ....***Pseudobryum cinclidioides***

39. Leaves ovate to elliptic; leaf cells 1-2:1 length width ratio, in irregular rows, with evenly thickened walls ....***Plagiomnium ellipticum***

40. Leaves ligulate, with recurved margins extending entire length of leaf ....***Meesia uliginosa***

40. Leaves lanceolate to lanceolate-ovate, with plane leaf margins..41

41. Alar cells enlarged and forming well-defined, colored groups; leaves transversely undulate, serrate near apex ....***Dicranum undulatum***

41. Alar cells not differentiated; leaves not undulate, entire to serrulate 42

42. Upper leaf cells long-hexagonal .... ***Pohlia nutans***

42. Upper leaf cells quadrate to oblong 43

43. Leaves decurrent, (1.5)2.5-4.0 mm long, margins serrulate; upper cells shortly rectangular ....***Meesia triquetra***

43. Leaves not decurrent, 0.8-1.5 mm long, margins entire; upper cells quadrate ....***Catoscopium nigritum***

44. Branch leaf apices blunt, hooded, cucullate; stem hyalodermis with fibrils 45

44. Branch leaf apices acuminate-truncate, open, concave, extreme apex appearing as if cut with a pinking shears; outer later of stem hyaline and enlarged or not, without fibrils 47

45. Green cell walls smooth .... *Sphagnum* ***magellanicum***

45. Green cell walls ornamented on adjacent hyaline walls 46

46. Green cell walls ornamented with papillae on walls adjacente to hyaline cells, green cells trapezoidal in transverse section .... *Sphagnum* ***papillosum***

46. Green cell walls ornamented with striae on walls adjacente to hyaline cells, green cells triangular in transverse section .... *Sphagnum* ***austinii***

47. Branch leaf hyaline cells with numerous (usually 1-2 between fibrils) pores arranged like two strings of beads along sides of hyaline cells in contact with green cells; branch leaves sometimes slightly curved 48

47. Branch leaf hyaline cells with 1-many pores arranged in a variety of patterns, but not chained along the cell sides; branch leaves straight ………………….............................……………………….....49

48. Branch leaf pores large, occupying full distance between fibrils; stem córtex unistratose .... *Sphagnum* ***subsecundum***

48. Branch leaf pores small, occupying about one-third to one-half of distance between fibrils; stem cortex bistratose .... *Sphagnum* ***contortum***

49. Green cells exposed on concave (dorsal) surface of leaves 50

49. Green cells exposed on convex (ventral) surface of leaves .... Section ***Acutifolium*** 60

50. Green cells very finely papillose on walls adjacent to hyaline cells .... *Sphagnum* ***teres***

50. Green cells smooth .... Section ***Cuspidatum*** 51

51. Most upper branch leaf cells with apical pore, additional pores restricted to cell corners or at most one additional central subapical pore 52

51. Most upper branch leaf cells without apical pore, additional pores few to numerous, not in contact with cell margins 59

52. Apical pores of branch leaves large, elliptic to elongate .... *Sphagnum* ***riparium***

52. Apical pores of branch leaves small, round to triangular 53

53. Green cells in transverse section extending to concave surface, forming isosceles triangles .... *Sphagnum* ***cuspidatum***

53. Green cells in transverse section enclosed by hyaline cells on concave side of leaf, not extending through to concave surface of leaf, forming equilateral triangles.. 54

54. Stems brown; stem leaves lacerate .... *Sphagnum* ***lindbergii***

54. Stems green or colorless; stem leaves entire or fringed only at apex 55

55. Branch leaves with almost no pores in apical part of leaf 56

55. Branch leaves with apical pores on most cells in upper part of leaf 57

56. Lower portion of branch leaves having numerous, tiny, elliptic wall thinnings (pseudopores), often in two indistinct rows .... *Sphagnum* ***obtusum***

56. Lower portion of branch leaves without pseudopores...................................... *Sphagnum* ***cuspidatum***

57. Stem leaves apiculate to acute .... *Sphagnum* ***fallax***

57. Stem leaves blunt .... *Sphagnum* ***angustifolium***

58. Stem leaves blunt ....*Sphagnum* ***balticum***

58. Stem leaves apiculate to acute .... *Sphagnum* ***pulchrum***

59. Branch leaf hyaline cells without pores on convex surface, with numerous (up to 10) large, unringed pores on concave surface .... *Sphagnum* ***majus***

59. Branch leaf hyaline cells with numerous pores on convex surface, with 7-15 small, usually ringed pores arranged in 1-2 rows .... *Sphagnum* ***jensenii***

60. Stem leaves fimbriate in upper two-thirds.. *Sphagnum* ***fimbriatum***

60. Stem leaves entire or with a apical notch 61

61. Branch leaf pores very small (one-half or less the width of the hyaline cell) and heavily ringed in upper one-third of leaf .... *Sphagnum* ***warnstorfii***

61. Branch leaf pores large (about one-half to two-thirds the width of the hyaline cell) and not ringed .... (oligotrophic ***Acutifolia***) 62

62. Stem and leaves brown ....*Sphagnum* ***fuscum***

62. Stems and leaves colorless, red, or green..63

63. Stem leaves triangular-lanceolate, usually with some porose and fibrillose cells .... *Sphagnum* ***capillifolium***

63. Stem leaves lingulate, without porose and fibrillose cells 64

64. Stem hyalodermis with some porose cells .... *Sphagnum* ***russowii***

64. Stem hyalodermis without porose cells .... *Sphagnum* ***rubellum***

Species Reviews

1. ***Aulacomnium palustre*** **(Hedw.) Schwaegr.**

Aulacomnium palustre is one of the very few peatland moss species with isodiametric, papillose leaf cells. The yellow-green leaf apices contrasted to the reddish stems, twisted leaves, and when present the gemmiferous shoots, also characterize this species. In arctic-alpine areas, *A. turgidum* and *A.acuminatum* occur – both are larger, more robust species without the covering of reddish tomentum of the stems. *Tomentypnum nitens* has reddish tomentum, but is distinguished by plicate leaves and pinnately branched stems.

Plants erect, unbranched, reddish below owing to dense tomentum of reddish rhizoids, yellow-green above. **Stems** covered with rhizoids, sometimes ending in attenuate shoots covered with triangular, red-brown brood-bodies that occur along upper portion of shoot. **Leaves** twisted and curled when dry, erect-spreading when moist, lanceolate to oblong-lanceolate, acute, serrate above; costa strong, ending just below apex; entire and recurved below. **Leaf Cells** isodiametric to rounded, thick-walled, with a single large papilla on each surface. **Alar Cells** not differentiated.

Growing on hummocks and on disturbed peat in all peatlands - limited by calcareous ground water in rich fens. This is a pioneer species in early succession of both fens and bogs. **Common Associates** - *Dicranum undulatum*, *Polytrichum strictum*, and *Tomentypnum nitens*; this is one of the most common peatland species.

Hummock	■	■	■	■	■
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH		■	■	■	■		
	3	4	5	6	7	8	

2. ***Brachythecium acutum*** **(Mitt.) Sull.**

This species is the only common *Brachythecium* that regularly occurs in boreal rich fens. *Brachythecium turgidum*, more common northward, is larger and mostly unbranched. The straight (non-falcate-secund), leaves with no plications, shortly acuminate leaf apices, lack of inflated alar cells, and presence of a single costa distinguish this species from all other mosses growing in fens. In general, other more upland species of the genus have narrower leaves, more branched plants, and most species have serrulate leaf margins. When these upland species occur in peatlands, they are found on rotting wood and tree bases, and do not occur directly in lawn habitats. *Drepanocladus polygamus* is somewhat similar, but has a u-shaped leaf insertion and more acuminate, somewhat channeled leaf apices - it occurs in more eutrophic habitats.

Plants rather large, erect to ascending, mostly with a few branches, light- to lime-green, sometimes with yellow-green tips. **Stems** naked, without enlarged epidermal cells. Leaves erect, sometimes loosely so, straight, broadly lanceolate to oblong-lanceolate, shortly acuminate, not plicate; costa weak, single, ending about 3/4 up leaf; margins entire. **Leaf Cells** elongate-linear, mostly with sharp ends, smooth, shorter below. **Alar Cells** gradually shorter and rectangular, rather dense and firm-walled, forming indistinct, angular groups.

Growing among other mosses in carpets and lawns of moderate-rich fens, occasionally found in pure patches. **Common Associates** - *Hamatocaulis vernicosus* and *Scorpidium revolvens*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

3. ***Brachythecium turgidum*** **(Hartm.) Kindb.**

The large, yellow-green, mostly unbranched plants growing erect in rich fens distinguish this species from *Brachythecium acutum*. Whereas *B. acutum* is common across the boreal zone, *B. turgidum* is more frequent in arctic and subarctic fens and meadows.

Plants robust, erect to ascending, mostly unbranched or with a few scattered branches. **Leaves** erect to spreading, straight, broadly lanceolate, acute; costa single, ending in upper portion; entire. **Leaf Cells** elongate, thin-walled, smooth. Alar Cells somewhat larger, rectangular-rounded, thin-walled and clear, forming a poorly defined group.

Growing intermixed with other mosses in rich fens and arctic meadows, not common in the boreal zone. **Common Associates** are species of *Campylium* and *Drepanocladus* (*sensu lato*).

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

4. ***Calliergon giganteum*** **(Schimp.) Kindb.**

Obtuse leaves with a very strong, single costa that continues to the leaf apex are key features of this species. Branch leaves are often much narrower and inrolled making them appear even more narrow than the stem leaves, but all of these leaves have the strong costa. All leaves also have abruptly differentiated alar cell groups. *Calliergon richardsonii* is similar, but has a short double costa; *Straminergon stramineum* has oblong leaves and alar cells with thickened walls; and *C. cordifolium* has gradually inflated alar cells and undifferentiated branch and stem leaves. *Calliergon cordifolium* is more common in eastern North America and occurs in more eutrophic habitats; *C. richardsonii* is more common in the northern boreal forest, often in shaded hollows, and *S. stramineum* is a species of bogs and poor fens, usually associated with *Sphagnum*.

Plants large, unbranched to regularly pinnately branched, brownish. **Stems** colorless, without tomentum. **Leaves** ovate, ovate-oblong to lanceolate-ovate, obtuse; with strong single costa ending at leaf apex; entire. **Leaf Cells** elongate-linear, smooth, most leaves having a few, clear, differentiated cells just below apex. **Alar Cells** inflated, hyaline, isodiametric to oval, cells forming abruptly differentiated, decurrent, concave auricles at leaf bases.

Emergent in pools, forming carpets, and intermixed with other brown mosses on lawns in rich fens. **Common Associates** - *Scorpidium cossonii, S. scorpioides*, and *H. vernicosus* are frequently found intermixed with this species.

Hummock					
Lawn					
Carpet				■	■
Pool				■	■
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH					■	■	■
	3	4	5	6	7	8	

5. ***Calliergon richardsonii*** **(Mitt.) Kindb.**

This is a species of the northern boreal forest. It is not completely clear how its habitat preferences differ from those of *C. giganteum*. These two species are similar in alar cell characters, but differ in strength of the costa and leaf shape. Both of these species differ from the eastern *C. cordifolium*, by the sharply differentiated alar cells, as compared to gradually differentiated ones of the latter species. *Calliergon richardsonii* has leaves that are shorter (1-2:1) and more ovate in shape then *C. giganteum*, wherein the stem leaves are oblong to oblong-ovate and about 2-3 times are long as wide. Also, *C. giganteum* is dioicous and seldom fruits, while *C. richardsonii* is autoicous and often has capsules.

Plants erect to ascending, lime-green, with few to rather numerous side branches. Stems flaccid and clear, without hyalodermis. **Leaves** ovate to ovate-oblong, obtuse, concave; with short, usually double costa ending 1/3 and 1/2 distance up leaf; margins erect, entire. **Leaf Cells** elongate to long rhombic, with blunt ends. **Alar Cells** hyaline, inflated, and forming an abruptly differentiated decurrent group.

Emergent from pools in rich fens, especially in wooded fens and forested swamps. **Common Associates** - species that also occur in wooded fen depressions are a variety of species of *Drepanocladus sensu lato*.

Hummock					
Lawn					
Carpet				■	■
Pool				■	■
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal				
	Cont	←	→	Oc

pH						■	■
	3	4	5	6	7	8	

6. *Calliergonella cuspidata* (Hedw.) Loeske

This large moss has erect to ascending, flattened stems that look like spear-heads. Whereas in Europe and along the western coast of North America the species is a common weed of ditches and yards, in continental Canada it occurs almost exclusively in moderate-rich fens. The leaves are complanate (flattened) and not at all secund, this feature separates this species from *Hypnum pratense* that has flattened leaves with secund tips and only a few moderate-sized alar cells. *Hypnum lindbergii* has inflated alar cells and a stem hyalodermis much like *C. cuspidata*, but has distinctly falcate-secund leaves. Both *H. pratense* and *H. lindbergii* occur characteristically in shrubby and wooded rich fens and forested swamps.

Plants robust, erect to ascending, shiny, yellow-green, occurring in mats or singly among other mosses. **Stems** irregularly to subpinnately branched, with a distinct hyalodermis and central strand. **Leaves** oblong to oblong-ovate, rounded and obtuse, concave; costa none or short and double; margins entire. **Leaf Cells** elongate and flexuose, smooth, those near insertion thicker-walled. **Alar Cells** oblong to oval, inflated, thin-walled, hyaline, forming conspicuous auricles.

Growing in fen lawns and carpets, floating mats, and wet meadows. **Common Associates** - When in peatlands, sometimes associated with *Brachythecium acutum, Sphagnum subsecundum, S. teres, Drepanocladus polygamus*, and *Hypnum pratense.*

Hummock					
Lawn				■	
Carpet				■	
Pool				■	
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH					■	■	
	3	4	5	6	7	8	

7. *Calypogeia sphagnicola* (H.Arnell et J.Perss.) Warnst. et Loeske

This small liverwort has incubous upper leaves along with bilobed underleaves. The upper leaves also have small apical notches in at least some leaves. The occurrence as individual stems within *Sphagnum* hummocks is shared with *C. suecica* - these two species differ in size of the leaf cells (25-30 µm in suecica and 30-35 µm in *sphagnicola*). All other *Calypogeia* species are rare in this habitat.

Plants slender, threadlike among *Sphagnum* plants. **Leaves** incubous, small and distant along stem, ovate, obtuse to notched, underleaves relatively large, bilobed, some with 1-2 obtuse, lateral teeth. **Leaf cells** rounded, 30-35 µm across.

Occurring on bog hummocks among *Sphagnum* stems, often not evident on the capitulum surface. More common in disturbed situations and occurring with *Cephalozia* spp.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

8. *Campylium stellatum* (Hedw.) C.Jens.

The widely-spreading stiff leaves are key field characters. The leaves have a concave, ovate base that quickly narrows to a long, channeled, acuminate apex. The channeled acumen is a key character. In the arctic, *C. arcticum* has even more concave leaves and a v-shaped insertion (compared to a more open u-shaped one for *C. stellatum*). *Drepanocladus polygamus* is a species that occurs in eutrophic marshes and fens, in carpets, and has less spreading and less concave leaves that have a stronger, usually single costa. Other *Campylium* species are smaller and more prostrate.

Plants golden-green, bristling, with erect to ascending, infrequently branched stems. **Leaves** wide-spreading to almost squarrose wet or dry, ovate-lanceolate, and sharply narrowed to a long acuminate, channeled apex; costa short and double; entire. **Leaf Cells** elongate to long rhombic with blunt ends, smooth. **Alar Cells** hyaline and enlarged, forming a well-marked angular group.

Found in lawns of rich fens, occurring above *Scorpidium* revolvens and *S. cossonii*, and below *Sphagnum warnstorfii* and *Tomentypnum nitens*. **Common Associates** - In extreme rich fens, rare associates may include *Catoscopium nigritum.*

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH							
	3	4	5	6	7	8	

9. ***Catoscopium nigritum*** **(Hedw.) Brid.**

When sterile, this moss has little character and except for the habitat could be mistaken for the ubiquitous *Ceratodon purpureus* – the latter has a few marginal notches just below the leaf ápices - however, *Ceratodon* never occurs in rich fen lawns. *Catoscopium* leaves are small (about 1.0-1.3 mm) and have smooth, quadrate cells. *Catoscopium* is usually fertile, with black, globose, nodding capsules that looks like golf clubs. These are distinctive and no other species has capsules like these.

Plants small, erect, forming dense, dark-green to reddish cushions. **Stems** unbranched, reddish, with scattered dark rhizoids. **Leaves** lanceolate, acute. **Leaf Cells** erect, quadrate, smooth, longer below. **Alar Cells** not differentiated.

Grows along the edges of flarks and carpets where it forms darkish cushions, sometimes in lawns with a variety of extreme rich fen species. **Common Associates** - often with *Scorpidium revolvens*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH							
	3	4	5	6	7	8	

10. ***Cephalozia connivens*** **(Dicks.) Lindb.**

The tiny, threadlike plants with sharply pointed, bilobed, obliquely succubous leaves are common on *Sphagnum* hummocks. This species, with relatively large leaf cells (45-60 µm across) and leaves with few cells (leaves 7-12 cells across), is frequent across the boreal. Although there are several other species of the genus that occur in this habitat, only *C. lunulifolia* is frequent. It differs by having leaf cells only 25-35 µm across. *Cladopodiella fluitans* and *Gymnocolea inflata* both occur is bog and poor fen pools - both of these species have blunt leaf lobes.

Plants threadlike, occurring singly among *Sphagnum* stems. **Leaves** round, bilobed to about half way, lobes incurved, tips often touching, sharply pointed, underleaves lacking. **Leaf cells** 45-60 µm across.

Scattered among *Sphagnum* stems in bog hummocks, more common in disturbed situations. **Common Associates** are *Calypogeia* species, sometimes among *Mylia anomala* stems.

	Peat Plat	Bog	Poor Fen	MRF	ERF
Hummock	■	■	■		
Lawn					
Carpet					
Pool					

Arctic				
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH		■	■				
	3	4	5	6	7	8	

11. *Dicranum undulatum* Brid.

The short, irregular leaf cells, strongly differentiated alar cells, and undulate, rather blunt leaves characterize this species. Two other species with undulate leaves are *Dicranum polysetum* that has strongly nodose, elongate upper leaf cells and *D. acutifolium* with slender, acute leaf apices. *Aulacomnium palustre* has leaf cells each with one well-developed, blunt, conical papilla.

Plants erect, unbranched, often with single sporophytes. **Stems** colorless, covered with orange-brown tomentum of rhizoids. **Leaves** lanceolate, obtuse to bluntly acute; with strong single costa; entire except just below apex where several course serrations are present, irregularly undulate above, loosely erect wet or dry. **Leaf Cells** irregularly isodiametric to oblong or quadrate, somewhat longer below, smooth or with an inconspicuous, low, single, papilla per cell. **Alar Cells** of well-differentiated groups of reddish, thick-walled, quadrate, enlarged cells.

Occurs as small clumps interspersed on hummocks in both bogs and fens, more common in bogs. This is one of the most commonly collected plants from boreal peatlands, but is less common in oceanic areas and northward. **Common Associates** - *Sphagnum fuscum, Tomentypnum nitens, Aulacomnium palustre*, and *Pleurozium schreberi*.

	Peat Plat	Bog	Poor Fen	MRF	ERF
Hummock	■	■	■	■	■
Lawn					
Carpet					
Pool					

Arctic		■		
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH		■	■	■	■		
	3	4	5	6	7	8	

12. ***Drepanocladus aduncus*** (Hedw.) Warnst.

Drepanocladus aduncus, in a broad sense, consists of plants that have stems with a central strand, but no enlarged epidermis; entire leaf margins; and a few enlarged and inflated alar cells. There is considerable morphological variation and several taxa have been recognized and occur in somewhat different habitats. These include the truly aquatic *Drepanocladus capillifolius* with a stout, long-excurrent costa; *D. polycarpus* with short leaf cells, branched erect-growing plants with short leaves; and *D. kneiffii*, a form with long leaf cells and slender, flaccid leaves. All of these variations appear to occur in mesotrophic to eutrophic fens and marshes. *Drepanocladus sordidus* has a strong costa, thick-walled and nodose lower leaf cells, and the alar cells are strongly porose, thick-walled, and brownish.

Plants highly variable, usually slender and irregularly branched. **Stems** naked, with a central strand, but without a hyalodermis or enlarged epidermis. **Leaves** falcate-secund, narrowly lanceolate, and gradually narrowed to a long acuminate apex, sometimes shorter; costa single, slender, ending ½ to ¾ up the leaf; margins entire. **Leaf Cells** elongate to long-rhombic, smooth, not decurrent. **Alar Cells** consisting of a few enlarged hyaline cells that merge gradually with the basal leaf cells.

Grows floating and stranded in water, emergent from fen pools, or forming dense carpets just above the water table. **Common Associates** - *Hamatocaulis vernicosus* sometimes occurs with this species, but is more common in less eutrophic habitats; *D. polygamus* co-occurs in more eutrophic situations.

Hummock					
Lawn				■	
Carpet				■	
Pool				■	
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH					■	■	
	3	4	5	6	7	8	

13. D***repanocladus polygamus*** (Schimp.) Hedenäs

The erect-spreading, broadly concave leaves are key features of this species. *Drepancladus aduncus*, which occurs in similar habitats, differs by having falcate-secund leaves (at least at the branch tips). *Campylium stellatum* differs by having no (or short and double) costa, and *Brachythecium acutum* has non-chaneled leaves, less-differentiated alar cells, and by habitat. In the past literature, this species has been placed in *Campylium*, close to *C. Stellatum*. This species has more similarity to *Drepanocladus*; however, it lacks the traditional falcate-secund leaves of species in that genus.

Plants simple to irregularly branched, usually ascending to erect, forming loose mats. **Stems** naked. **Leaves** lanceolate, shortly acuminate; costa single, ending in upper one-third of leaf, insertion u-shaped; entire, somewhat chanelled below. **Leaf cells** elongate, smooth. **Alar cells** oblong, somewhat inflated, darker and thick-walled with age.

Occuring in marshes and other eutrophic, open (sedge-dominated) fens. **Common Associate** is *Drepanocladus aduncus*. Although quite similar superficially to *Brachythecium acutum*, this latter species occurs in more mesotrophic habitats such as moderate-rich fens.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH	3	4	5	6	7	8

14. *Drepanocladus sordidus* (C.Muell.) Hedenäs

This rather rare species is robust, with long-acuminate, strongly falcate-secund leaves. The key feature that differentiates it from other species of *Drepancladus* (*sensu lato*) are the enlarged, oblong, colored, thick-walled (often nodose) alar cells. It shares entire leaf margins and stem transverse section features (central strand, no hyalodermis) with *Drepancladus aduncus*.

Plants dark- to brownish-green, erect to ascending, simple to irregularly branched. **Leaves** strongly falcate-secund, lanceolate, acuminate; costa strong, ending in upper portion of leaf; entire. **Leaf cells** elongate, with somewhat thickened walls in lower portion of leaf. **Alar cells**, oblong, colored, thick-walled and nodose, forming well-differentiated groups.

A species of rich fen pools and carpets.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH	3	4	5	6	7	8

15. *Hamatocaulis vernicosus* (Mitt.) Hedenäs

This is a characteristic species of moderate- and sometimes extreme-rich fens. The hooked and falcate leaves are good field characters, while under the microscope the lack of a central strand in the stem transverse section is definitive for the genus. Also, the faintly striate leaves with no differentiated alar cells and branched stems are helpful features. The stem apices have a characteristic fish-hook appearance that once recognized is useful for field identification.

Plants yellow-green to dirty-green in color, mostly ascending to erect, usually with numerous branches. **Stems** naked, with pronounced hooked upper portion, with no central strand and no enlarged epidermis cells in transverse section. **Leaves** falcate-secund, somewhat striate, especially when dry; costa single, ending about 2/3 up leaf; margins entire. **Leaf Cells** elongate with blunt ends, smooth. **Alar Cells** not much different from basal cells.

Forms lawns and small hummocks in rich fens, sometimes dominating areas and occurring in depressions and at the bases of shrubs. **Common Associates** - in more eutrophic habitats occurring with *Drepanocladus aduncus*, while in mesotrophic situations, occurring with *Scorpidium* revolvens and *S. cossonii*, but generally found in more nutrient rich places than are these two species. *Hamatocaulis lapponicus* is less branched, larger, has better developed alar cells, and occurs in depressions in similar habitats.

Hummock					
Lawn				■	■
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH					■	■	■
	3	4	5	6	7	8	

16. *Helodium blandowii* (F.Weber et D.Mohr) Warnst.

The densely pinnate fronds, stem leaves different from branch leaves, and abundant *filamentous paraphyllia* composed of long, smooth cells are key characters. *Thuidium* species are bipinnate, while *Haplocladium* occurs in uplands.

Plants robust, erect, regularly pinnately branched, in light-green, loose mats. **Stems** covered in filamentous, branched, green paraphyllia. **Leaves** - stem leaves ovate, shortly acuminate, serrulate, costa strong, single and ending below apex; branch leaves narrower, smaller; all leaves with ciliate basal margins due to presence of paraphyllia. **Leaf cells** oblong-rhombic, uni-papillose on ventral surface. **Alar cells** not differentiated, but basal cells somewhat enlarged.

A species of wooded and shrubby, moderate-rich fens, often with *Scapania paludicola, Hypnum pratense,* and *Hamatocaulis vernicosus*.

Hummock				■	
Lawn				■	
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	
S. Boreal		■	■	
	Cont	←	→	Oc

pH					■	■	
	3	4	5	6	7	8	

17. *Hylocomium splendens* (Hedw.) Schimp.

The bipinnate branching, presence of paraphyllia, and distinctive frondose growth form are characters of this species (however, arctic-alpine forms may lack the frondose growth form). Microscopically, the broadly acuminate leaves, short and double costa, and prorulose leaf cells are key features.

Plants complex, forming bipinnately branched wefts. **Stems** form annual increments visible as annual fronds having a stair-step arrangement, paraphyllia abundant. **Leaves** - stem leaves different from branch leaves, branch leaves with a short and double costa, ovate, abruptly acuminate often with tiny apiculus. **Leaf Cells** oblong to elongate, with small apical papillae on convex surface (prorulose). **Alar Cells** shorter and thicker-walled than upper cells.

Very abundant in upland coniferous boreal forests; occasionally found in dry peatlands, especially in peat plateaus and dry bogs where it occupies the highest and driest hummocks. **Common Associates** - in dry oligotrophic peatlands associated with *Pleurozium schreberi* and hummock-forming *Sphagna*, especially *S. fuscum*. In mesic situations, *Ptilium crista-castrensis* may occur. This species is easily told by its densely pinnate stems with non-costate, falcate-secund, plicate leaves.

Hummock	■	■			
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH			■	■	■		
	3	4	5	6	7	8	

18. ***Hypnum lindbergii*** **Mitt.**

The regularly falcate-secund, yellow-green leaves without a costa are distinctive features of this species. Although supericially similar to species of *Drepanocladus* (*sensu lato*) the lack of a costa readily differentiates this species.

Plants irregularly branched, yellow- to lime-green, forming loose mats. **Stems** naked, with unistratose outer layer of enlarged cells. **Leaves** falcate-second; costa lacking to short and double; entire. **Leaf cells** smooth, elongate. **Alar cells** hyaline, enlarged, forming distinctive inflated groups at insertion.

A species of wooded rich fens and swamps, but also common on mineral soils along stream banks, and occasionally forming mats in shrubby and drier open fens. **Common Associates** include P*lagiomnium elipticum, Bryum pseudotriquetrum*, and *Tomentypnum nitens*.

Hummock				■	
Lawn				■	
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH					■	■	
	3	4	5	6	7	8	

19. ***Hypnum pratense*** **(Rabenh.) Spruce**

Although seemingly similar to *H. lindbergii*, this species is easily distinguished by having complanate-secund leaves and a lack of inflated hyaline alar cells. The complanate-secund leaves that lack a costa differentiate this species from other species with falcate-secund leaves.

Plants simple to irregularly branched, yellow- to lime-green, forming loose mats or occurring as single stems. **Stems** naked with a unistratose outer later of enlarged cells. **Leaves** complanate-secund, entire or slightly serrulate at apex, contracted to insertion; costa lacking or short and double. **Leaf cells** smooth, elongate. **Alar cells** somewhat thin-walled, quadrate to oblong, enlarged but not forming an inflated distinctive group.

A species of swamps and moderate-rich fens, usually occurring scattered among other mosses on low hummocks and lawns. Not uncommon in sedge-dominated, shrubby, and wooded fens - more frequent in fens than *H. lindbergii*.

Hummock				■	■
Lawn				■	■
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH					■	■	
	3	4	5	6	7	8	

20. *Meesia triquetra* (Richt.) Aongstr.

The ovate-lanceolate leaves, with serrulate margins that occur in three spirals along the stem identify this species. *Meesia longiseta* is quite similar, but is differentiated by entire margins. In addition, *Meesia longiseta* is autoicous and frequently with capsules, while *M. triquetra* is dioicous and rarely has capsules.

Plants erect, unbranched, lime- to dark-green. **Stems** colorless and smooth. **Leaves** spreading when moist, twisted when dry, spirally three-ranked, ovate-lanceolate, acute; costa strong, single, ending in apex, decurrent; margins serrulate above. **Leaf Cells** rhombic, rectangular to quadrate, smooth, longer below. **Alar Cells** not differentiated.

Occurring singly or in small patches in rich fen lawns, often with species of *Scorpidium*.

Hummock					
Lawn				■	■
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH					■	■	■
	3	4	5	6	7	8	

21. *Meesia uliginosa* Hedw.

The strap-shaped leaves with strongly recurved margins nearly the whole length of the leaves are characteristic of this species. The short, smooth leaf cells and complete lack of differentiated alar cells are also features of this species. No other peatland species has such ligulate leaves. In addition, *M. uliginosa* is commonly found with sporophytes and the capsules with a long neck abruptly bent about ½ way up are characteristic of the genus *Meesia*. This species is one of several that inhabits wooded rich fen and swamp depressions, one of the richest habitats for uncommon bryophyte species. This species also occurs in peaty calcareous wet tundra and montane stream-side habitats.

Plants erect, unbranched. **Stems** short, naked. **Leaves** erect, ligulate, obtuse; costa very strong ending in apex; entire. **Leaf cells** rounded, smooth. **Alar cells** not differentiated.

This species is one of several that inhabit wooded rich fen and swamp depressions, one of the richest habitats for uncommon bryophyte species. This species also occurs in peaty calcareous wet tundra and montane stream-side habitats.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH	3	4	5	6	7	8

22. ***Mesoptychia rutheana*** **(Limpr.) L.Söderst. et Váňa**

This large, beautiful species is always a pleasure to find. The decurrent, succubous, bilobed leaves with broadly reflexed margins cannot be confused with any other boreal species. Historically this species has been placed in either the genus *Leiocolea* or *Lophozia*.

Plants robust, purple to copper-colored. **Stems** 4-5 mm across, prostrate to ascending. **Leaves** oblong-ovate, convex, bilobed, lobes acuminate; postical margin long-decurrent, underleaves large, bifid, and ciliate.

This infrequent indicator species of extreme-rich fens is the largest of the peatland liverwort species. It occurs with species of *Meesia, Paludella squarrosa* and other rich fen 'brown mosses'. It appears to occur on lawns and along the sides of small hummocks in open rich fens.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH	3	4	5	6	7	8

23. ***Mylia anomala*** **(Hook.) S.Gray**

This is the largest and most common species of liverwort in peatlands. In the field the conspicuous yellow gemmae, relatively large plants, and succubous entire leaves are characteristic. *Odontoschisma sphagni* also has round, entire leaves. It is oceanic in bog pools and has a strong leaf border and obvious stolons. Other liverworts in peatlands have incubous leaves or leaves that are bilobed. The thalloid hepatic, *Marchantia polymorpha* occasionally occurs in disturbed fens, especially after fire.

Plants prostrate with ascending stem tips, mostly unbranched (to 1-2 times branched), medium-sized. **Stems** rather turgid, with sporadic hyaline rhizoids. **Leaves** succubous, circular to oblong-ovate, rounded, usually with very conspicuous yellow gemmae produced at upper margins, concave. **Leaf Cells** rounded to stellate due to thickened corners (trigones), similar throughout.

Growing intermixed and sometimes covering *Sphagnum fuscum*, rarely intermixed with other Sphagna. **Common Associates** - Sometimes with the mosses *Polytrichum strictum and Pohlia nutans.* Also occurring with less common leafy hepatics on *Sphagnum* hummocks, including species of *Calypogeia* (incubous leaves) *Cephalozia* (bifid leaves on tiny plants), and *Lophozia* (*sensu lato*; large plants with bifid leaves).

Hummock	■	■			
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH		■	■				
	3	4	5	6	7	8	

24. *Paludella squarrosa* (Hedw.) Brid.

Perhaps the most distinctive moss found in peatlands. The erect plants, stiff, 5-ranked, strongly squarrose-recurved leaves, dense tomentum on the stems, and golden-green color are definitive. The strongly papillose upper leaf cells are also quite different from those of other species. When sporophytes are present, the capsules with long necks show its relationships with *Meesia*.

Plants erect, golden-green, with closely set leaves. **Stems** with dense orange tomentum of rhiziods. **Leaves** stiffly squarrose-recurved; costa strong, ending near apex; with margins reflexed. **Leaf cells** oblong-rounded, strongly unipapillose. **Alar cells** not differentiated.

A rare species of extreme-rich fens, where is occurs on open lawns and low hummocks.

Hummock					■
Lawn					■
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH						■	■
	3	4	5	6	7	8	

25. ***Plagiomnium ellipticum*** **(Brid.) T.Kop.**

Plagiomnium ellipticum could be confused with a number of species: A summary of these for peatland habitats follows with differentiating features noted (compared to those listed below for *P. ellipticum*). *Plagiomnium medium* has decurrent leaves on the fertile stems, is larger and darker in color, and is an upland and margin species; *Rhizomnium pseudopunctatum* (also *R. gracile*) has entire leaves; Pseudobryum cinclidioides has irregular leaf cells longer than wide with nodose walls and a very few inconspicuous marginal teeth – this is sometimes a common species of rich fen carpets in the northern boreal zone. *Plagiomnium cuspidatum* and *Mnium spinulosum* are upland species.

Plants prostrate to sometimes ascending, lime-green; when fertile with erect fertile branches and arching, spreading sterile runners. **Stems** naked or with a few rhizoids. **Leaves** obovate to ovate-rounded, blunt or with small apiculus, bordered by elongate cells; costa strong, ending just below or in apex; upper margins with a few to numerous small denticulations; leaves not or only very slightly decurrent. **Leaf Cells** hexagonal, somewhat longer near the costa, evenly thin-walled, marginal cells longer. **Alar Cells** not differentiated.

Occurring commonly in lawns and depressions in wooded fens, rich fens, and forested swamps; also in depressions in open fens. **Common Associates** - In open fens associated with species of *Hamatocaulis* and *Drepanocladus aduncus*.

Hummock					
Lawn				■	■
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH					■	■	
	3	4	5	6	7	8	

26. ***Pleurozium schreberi*** **(Brid.) Mitt.**

The pinnately branched, red stems without paraphyllia are characteristic. The leaves are relatively large, with a very short and double costa (or lacking), and well-differentiated alar cells. The very concave leaves with recurved leaf apices are useful characteristics. *Hylocomium splendens* has more acutely pointed leaves, is bipinnately branched, and has stems with paraphyllia.

Plants robust, coarse, sparsely to regularly pinnately branched, erect. **Stems** red, without hyalodermis or paraphyllia. **Leaves** ovate-oblong, with tiny, often recurved acute tip, concave; costa lacking; entire. **Leaf Cells** elongate-linear, smooth. **Alar Cells** composing a group of colored, quadrate-rectangular, thick-walled cells forming a distinct angular group.

Growing on hummocks of oligotrophic peatlands and dominating acidic, nutrient poor upland boreal forests, less common coastward, rare in tundra. **Common Associates** - Associated with *Hylocomium splendens* and *Ptilium crista-castrensis* in the continental boreal upland coniferous forest, and with species of *Rhytidiadelphus* in more mesic localities. Common in peat plateaus and continental bogs in association with *Sphagnum fuscum*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH							
	3	4	5	6	7	8	

27. *Pohlia nutans* (Hedw.) Lindb.

The very slender, unbranched stems; lanceolate leaves with serrulate margins; and rhombic cells are distinguishing features of this species. In rich fens, *Bryum pseudotriquetrum* is common - it is distinguished by decurrent leaves that are entire and bordered by elongate cells, and by shorter long-hexagonal leaf cells. The decurrencies easily differentiate this species from *Pohlia nutans*. *Pohlia wahlenbergii* is frequent in calcareous seeps, it is reddish in color, and has long-decurrent leaves; *P. cruda* is very shiny and golden-green in color with thin-walled leaf cells – it occurs on peaty calcareous ledges.

Plants slender, yellow- to Light-green, unbranched, occurring intermingled with other mosses. **Stems** reddish, naked, shiny. **Leaves** lanceolate, acute, erect wet or dry; costa single, ending just beneath apex; margins distinctly serrulate in upper part of leaf. **Leaf Cells** long rectangular to long rhombic, rather thick-walled, smooth. **Alar Cells** not differentiated, leaves not decurrent.

Occurring on rotting wood, this is one of the most common species of upland boreal forest habitats. It is also commonly intermingled with *Sphagnum* (and sometimes called *P. sphagnicola*) in oligotrophic peatlands. **Common Associates** - Most commonly intermingled in *Sphagnum fuscum* along with *Polytrichum strictum* and *Mylia anomala*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH							
	3	4	5	6	7	8	

28. *Polytrichum strictum* Brid.

This is the only common species of the *Polytrichaceae* that occurs in bogs and poor fens. A less frequent species in swamps and paludified woodlands is *P. commune*. It is larger, has recurved leaves when moist, no stem tomentum, and the lamellae are not covered by the lamina. The apical cells of the lamellae are u-shaped in transverse section. *Polytichum juniperinum*, a species of mineral soils, is similar to *P. strictum* in leaf morphology, but lacks abundant whitish stem tomentum. The complex leaf structure of lamellae and complex costa along with hyaline leaf sheaths is unique to this group of mosses.

Plants erect, unbranched, with a bluish-green hue, occurring gregariously or in loose mats. **Stems** covered with whitish tomentum of rhizoids. **Leaves** erect when dry, spreading when moist, lanceolate from a hyaline, unistratose, expanded, sheathing base, acuminate, ending in a short, reddish, toothed awn; upper portion of leaves consisting of an expanded costa, from which numerous, vertical, green, lamellae arise that are encased in the inflexed leaf lamina. **Leaf Cells** has upper cells irregularly quadrate to isodiametric, smooth, cells of sheath hyaline, long-rectangular, smooth. Apical cells of lamellae rounded in transverse section of leaf, smooth. **Alar Cells** not differentiated.

This species occurs intermixed with *Sphagnum* on high hummocks in oligotrophic habitats. The individual shoots are elevated 1 cm or so above the *Sphagnum* canopy. Also this species is one of the first bryophyte species to colonize disturbed bare peat surfaces, especially after fire where it forms large continuous mats. **Common Associates** - Most commonly associated with *Sphagnum fuscum,* but also with other hummock-forming species of *Sphagnum*; hummocks may also contain *Pohlia nutans* and *Mylia anomala*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

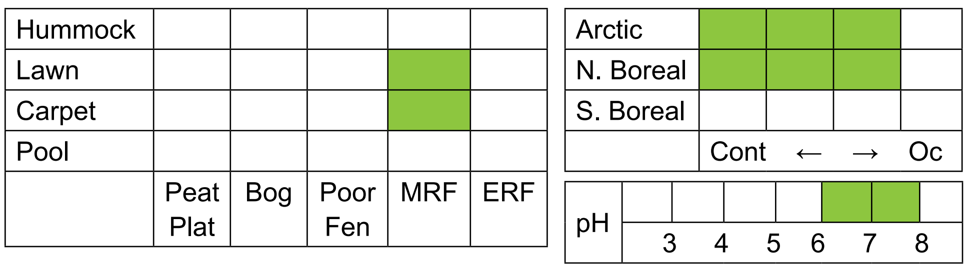
pH	3	4	5	6	7	8

29. *Pseudobryum cinclidioides* (Hueb.) T.Kop.

This species has a mysterious sheen to it that helps in identification. The sheen is due to the rather elongate, nodose leaf cells arranged in oblique rows. Also, the oblong, obtuse leaves with a poorly developed margin of longer cells and lack of a strong apiculus are key features. *Plagiomnium ellipticum* and *Rhizomnium pseudopunctatum* both have stronger leaf borders and thin-walled isodiametric leaf cells.

Plants robust, erect, with loosely arranged large leaves. **Stems** naked, but often with some rhizoids. **Leaves** oblong, obtuse, with satin luster, leaf border poorly developed, of 1-2 rows of unistratose, elongate cells; entire or with a few small teeth. **Leaf cells** rhombic to oblong, about 2-4 times as long as wide, with irregularly thickened walls, smooth. **Alar cells** not differentiated.

This uncommon species is found in swamps and eutrophic fens, usually in somewhat shaded or protected habitats, at the edges of small pools, or in wet lawns.



30. *Pseudocalliergon trifarium* (F.Weber et D.Mohr) Loeske

The slender string-like stems, ovate, imbricate, spirally seriate leaves that are not much longer than wide; indistinct, single costa; and gradually differentiated, but enlarged alar cells characterize this species. *Calliergon* species have longer leaves, Scorpidium species have falcate-secund leaves, and *Calliergonella* has abruptly differentiated, inflated alar cells. *Pseudocalliergon* (*Scorpidium*) turgescens is more robust, has more loosely arranged, imbricate leaves each with a tiny apiculus.

Plants single, mostly unbranched, terete, string-like, growing among other species. **Stems** without enlarged epidermis. **Leaves** ovate to oblong-ovate, obtuse, concave, imbricate and spirally seriate; costa single, extending 1/2 to 2/3 leaf length; margins entire,. **Leaf Cells** long-rhombic to elongate-oblong, with blunt ends, smooth. **Alar Cells** enlarged, hyaline to orange, forming large, decurrent, and gradually differentiated groups.

Usually found as individual stems among other mosses in extreme-rich fen carpets. Rarely found in pure patches in carpets of rich fens. **Common Associates** - usually found with *Scorpidium* species, especially *S. scorpioides* and *S. revolvens*, and in similar habitats as *Meesia triquetra*.

	Peat Plat	Bog	Poor Fen	MRF	ERF
Hummock					
Lawn					
Carpet					
Pool					

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH	3	4	5	6	7	8

31. *Ptychostomum pseudotriquetrum* (Hedw.) D.T.Holyoak et N.Pedersen

The slender, erect plants with reddish stems and contrasting greenish decurrencies are key characters. The leaf cells are short (3-4:1) and the upper leaf margins entire and bordered by long cells – these two features differentiate it from *Pohlia* nutans, a species of similar size, but having longer leaf cells (5-6:1) and serrulate upper leaf margins. The *Pohlia* occurs in bogs and poor fens within *Sphagnum*-dominated habitats whereas the *Ptychostomum* occurs in rich fens in true moss-dominated habitats.

Plants small, erect, reddish with dark, naked, unbranched stems. **Leaves** lanceolate, occasionally broadly so, acute to shortly acuminate; costa single, strong, ending at or just below leaf apex, occasionally shortly excurrent, distinctly decurrent; entire. **Leaf Cells** shortly hexagonal, longer at margin and there forming a border of long cells, longer below, smooth. **Alar Cells** not differentiated.

Growing intermixed among other mosses in rich fens, occurring not uncommonly in wooded fens and swamps as well as in open rich fens. Although this species is extremely common and variable in a number of non-peatland habitats (and hard to differentiate from numerous other *Bryum* (sensu lato) species), the form that occurs in rich fens is easily recognized by the decurrent leaf bases. **Common Associates** - A large number of typical rich fen species are often co-mingled with this species. Some examples are *Hamatocaulis vernicosus, Meesia triquetra, Scorpidium cossonii*, and *Plagiomnium ellipticum*.

	Peat Plat	Bog	Poor Fen	MRF	ERF
Hummock					
Lawn					
Carpet					
Pool					

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH	3	4	5	6	7	8

32. *Racomitrium lanuginosum* (Hedw.) Brid.

This species that is characteristic of dry, acidic rocks is also found in abundance in oceanic peatlands, where it is easily distinguished by the coarse, whitish plants. The unique leaves having cells with extremely wavy walls cannot be mistaken for any other species.

Plants erect, whitish-green to gray-green, pinnately branched, growing in dense, hoary hummocks. **Stems** naked with closely set leaves. **Leaves** erect-flexuose to somewhat falcate-secund, lanceolate, acuminate, ending in a broad, decurrent, hyaline point; costa single ending in hyaline tip; margins roughened due to projecting papillae. **Leaf Cells** long rectangular with wavy, nodulose walls; laminal cells smooth, those of the hyaline awn densely papillose. **Alar Cells** not differentiated.

Occuring on acidic rocks in montane, alpine, and arctic regions, and is commonly found forming hummocks in maritime bogs and poor fens. **Common Associates** - occurs in similar habitats as *Sphagnum rubellum, S. papillosum*, and *S. austinii*.

Hummock		■	■		
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				■
N. Boreal				■
S. Boreal				■
	Cont	←	→	Oc

pH		3	4	5	6	7	8
		■	■				

33. *Sanionia uncinata* (Hedw.) Loeske

The plicate, circinate, very long-acuminate, denticulate leaves are key features of this species. The presence of a costa (hard to see owing to the strong plications) and irregular branching differentiates it from *Ptilium crista-castrensis*, while the lack of tomentum separates it from *Tomentypnum falcifolium*.

Plants prostrate to ascending, irregularly branched, yellow-green, forming mats or sometimes as individuals among other mosses. **Stems** naked, with a large, hyaline outer layer of cells forming a hyalodermis and well-developed central strand. **Leaves** lanceolate, long-acuminate, circinate to falcate-secund, plicate; margins denticulate above; costa single ending in upper part of leaf. **Leaf cells** elongate, with blunt ends, smooth. **Alar cells** small, rectangular, hyaline and thin-walled, in small group.

Although generally considered an upland species, it can be frequent in wooded fens and swamps, usually occurring on logs and leaf liter.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

34. ***Sarmentypnum tundrae*** **(Arn.) Hedenäs**

This species has been placed variously in a number of genera, including *Calliergidium, Drepanocladus*, and *Warnstorfia*. Two features make it quite distinctive: The very long-decurrent leaves that are so decurrent that the stem becomes 5-angled; and the stem leaves that are erect with down-turned apices that contrast to the falcate-secund, smaller branch leaves. The stem leaves are rather short with acute apices while the branch leaves are longer and acuminate.

Plants large, erect, branched. **Stems** 5-angled, dark. Leaves – stem leaves loosely erect to somewhat curved, lanceolate, acute to shortly acuminate, apices bent, long decurrent; branch leaves falcate-secund, lanceolate, acuminate. **Leaf Cells** elongate, smooth. **Alar cells** oblong, colored, arranged as long decurrencies.

A rare species of pools and carpets of rich fens.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

35. ***Scapania paludicola*** **Loeske et K.Muell.**

One of two large species of *Scapania* that occurs in fens. *Scapania* is differentiated by the rounded, complicate-bilobed, succubous leaves, with the lower lobe larger than the upper lobe and with no underleaves. *Scapania paludicola* is a large showy species. Along with *S. paludosa*, it is distinguished by arched postical margins (where the two lobes are joined). *Scapania paludicola* has the dorsal lobe (smaller) not decurrent and the ventral (larger) lobe strongly decurrent, whereas *S. paludosa* has both the ventral and dorsal lobes long decurrent.

Plants large, erect to ascending, light-green, generally without gemmae. **Leaves** complicate-bilobed, entire, succubous, lobes heart-shaped, often acute, ventral lobe long decurrent.

A species of moderate-rich fens, usually along the sides of hollows in hummocky wooded or shrubby fens. Often associated with *Hypnum pratense* and *Helodium blandowi*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH							
	3	4	5	6	7	8	

36. ***Scorpidium cossonii*** **(Schimp.) Hedenäs**

Historically this species has been known by a number of names, most commonly as *Drepanocladus revolvens* var. *Intermedius*. It is identified by green, profusely branched plants with rather short leaves and shorter leaf cells and occurs in somewhat drier habitats than the type variety. This relationship is similar to that found in *Drepanocladus aduncus* and *D. polycarpus*. *Hedenäs* (1989) thoroughly reviewed the morphology of *D. revolvens* and *D. intermedius* and concluded that indeed intermedius was worthy of recognition as a species; however, the correct name for this species is not *intermedius*, but rather *cossonii* when placed in *Scorpidium*. He placed both '*revolvens*' and '*cossonii*' in the genus *Scorpidium*. *Scorpidium cossonii* differs from *S. revolvens* by brownish-green (not red) plant coloration, more profuse branching, smaller plants, and especially leaf cell shape and size (oblong 14-95 µm – Hedenäs 1989) with blunt ends in *S. cossonii* versus elongate (61-140 µm) with sharp ends in *S. revolvens*.

Plants ascending to erect, pinnately to irregularly branched, brownish-green. **Stems** in transverse section with a weak central strand and enlarged epidermal cells. **Leaves** concave, falcate-secund with spirally twisted, long acuminate apices; costa ending in upper 2/3rds of leaf; margins sparsely denticulate. **Leaf Cells** oblong-elongate, 14-95 µm long, with blunt ends, smooth. **Alar Cells** 2-10, hyaline and inflated, forming groups in leaf angles.

Found on dry lawns and low hummocks in open rich fens. **Common Associates** - *Campylium stellatum, Tomentypnum nitens*, and *Scorpidium revolvens*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

37. ***Scorpidium revolvens*** **(Sw.) Rubers**

The reddish plants with dark costa, precisely spirally twisted leaf apices, and differentiated alar cells serve to identify this species. *Scorpidium scorpioides* has broader and shorter leaves and a shorter, narrower costa; *Hamatocaulis vernicosus* has characteristically hooked leaves, a green color and no alar cells; while *S. cossonii* is brownish to green in color, shorter, more blunt leaf cells, and is usually more richly branched. In the arctic *Pseudocalliergon* (*Drepanocladus*) *brevifolius* can be superficially similar, but has shorter leaves and no enlarged stem cortex. Microscopically, the three species of Scorpidium all have enlarged stem epidermal cells and a central strand.

Plants prostrate to ascending, reddish to purplish. **Stems** irregularly to sparsely branched, in transverse section with enlarged epidermis and well-developed central strand. **Leaves** densely packed, strongly falcate-secund, with spirally twisted, long acuminate ápices; costa single, ending in upper 2/3rds of leaf, usually with some reddish color or at least darker then lâmina; margins faintly denticulate. **Leaf Cells** elongate-linear (14-95 µm long – Hedenäs 1989), with pointed ends, smooth, **Alar Cells** 5-20, hyaline, inflated, forming non-decurrent, angular groups.

Usually forming dense lawns and carpets in rich fens, especially characteristically occurring above Scorpidium scorpioides and below *Campylium stellatum* in extreme-rich fens.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

38. ***Scorpidium scorpioides*** **(Hedw.) Limpr.**

The large, turgid plants and blunt falcate-secund leaves that lack a costa are key features. All *Drepanocladus* (*sensu lato*) species have a strong single costa as do both *S. cossonii* and *S. revolvens*.

Plants large, turgid, black to reddish-green, floating in water or growing upright in loose carpets, mostly with a few irregular branches. **Stems** naked, without a hyalodermis. **Leaves** ovate-lanceolate to ovate, broadly acute to narrowly obtuse, falcate-secund, rather short and blunt overall; costa short and double; margins entire. **Leaf Cells** elongate to linear, with blunt ends, smooth. **Alar Cells** consisting of a few enlarged and hyaline cells at insertion.

Floats in pools of water, emergent from water, or forming dense, coarse carpets at the edges of pools. **Common Associates** - often intermingled with *Pseudocalliergon trifarium* and *Meesia triquetra*. *Scorpidium scorpioides* grows in the wettest areas of extreme-rich fens, with *Scorpidium cossonii* and *S. revolvens* occurring in somewhat drier habitats.

Hummock					
Lawn					
Carpet					■
Pool					■
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH					■	■	■
	3	4	5	6	7	8	

39. *Sphagnum* ***angustifolium*** **(Russ.) C.Jens.**

Stems without a hyalodermis, small triangular non-porose stem leaves, and branch leaf hyaline cells having a prominent rounded apical pore, along with green cells exposed on the convex surface are key features. Without stem leaves, this species cannot be distinguished from *S. fallax* (which is rare in the continental boreal region), nor *S. balticum*, which is northern in distribution.

Plants yellow-green, fluffy, with loose canopies, two pendent branches visible between capitulum arms. **Stems** clear, without hyalodernis, non-porose. **Leaves** ovate-lanceolate, minutely truncate at apex; stem leaves small, triangular, blunt to slightly erose at apex, without pores and fibrils. **Leaf Cells** with hyaline cells that have an apical rounded-elliptic pore at cell apex on convex surface, occasionally a second pore just beneath; additional pores restricted to hyaline cell corners, on concave surface and several rounded rather inconspicuous pores in central part of cells; green cells triangular, exposed on convex surface.

Perhaps the most common species across the continental boreal area, where it forms loose lawns in poor fens and bogs. It is also sometimes abundant in drier carpets in internal lawns and collapse scars. It is replaced in more mesotrophic situations and in less continental areas by *S. fallax*. Wetter oligotrophic carpets and pools have a number of other species including *S. cuspidatum, S. jensenii*, and *S. majus*; more mesotrophic carpets have *S. riparium*. *Sphagnum balticum* is more northern. **Common Associates** – in poor fens with *S. magellanicum* and occasionally associated with *Tomentypnum falcifolium*; in fens transitional to rich fens, sometimes with *S. teres* or *S. warnstorfii*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

40. *Sphagnum* ***austinii*** **Sull.**

This dominant species of oceanic bogs is easily distinguished by the presence of fine striations on the green cell walls where they contact the hyaline cells and by the equilateral-triangular green cells. Historically, *S. austinii* has been included in the concept of *S. imbricatum*; however, the latter species is a fen species not commonly found in northern North America. In coastal bogs *S. austinii* occurs with *S. papillosum* - the presence of threadlike, attenuate hanging branches in *S. austinii* is a neat field character.

Plants large, turgid, brownish, forming dense canopies, 0-1 inconspicuous pendent branches visible between capitulum arms. **Stems** dark, with porose and fibrose hyalodermis, spreading branches consisting of both short swollen branches and thread-like attenuate ones. **Leaves** ovate-ellipitc, hooded, and entire at apex, convex surface just below apex with denticulations due to resorption of apical portions of hyaline cells, stem leaves lingulate, without fibrils or pores, resorbed on convex surface. **Leaf Cells** with hyaline cells short, bulging on convex surface, numerous elliptic pores on convex surface, and inconspicuous rounded pores on concave surface; green cells equilateral-triangular, broadly exposed on concave surface, adjoining hyaline cell walls with fine striations (comb fibrils).

Forms hummocks and well-consolidated lawns in oceanic bogs where it is the major peat-forming species. **Common Associates** - *Sphagnum papillosum* also occurs in oceanic bogs, but generally closer to the water level.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

41. *Sphagnum* ***balticum*** **(Russ.) C.Jens.**

This species resembles *S. angustifolium*, but is differentiated by larger, more rounded, and more abundant stem leaves; also the spaces between capitulum arms have only one pendent branch evident. Microscopically, I find few differences between this species and *S. angustifolium* -- perhaps the apical pore is better defined in the latter species, but I am not convinced these two species can be identified by branch leaf features.

Plants forming loose mounds, soft, yellow-brown, with one pendent branch visible between capitulum arms and no evident apical bud. **Stems** clear, with hyalodermis not well differentiated. **Leaves** ovate-lanceolate and narrowed to narrowly truncate apex, often undulate in capitulum; stem leaves relatively large, shortly oblong to triangular-oblong, blunt and concave – appearing triangular, usually numerous and bent downward along stem, with fibrillose, hyaline cells having partially resorbed pores in upper portion. **Leaf Cells** - hyaline cells of convex surface of branch leaves with large apical pore and variable number of pores in cell corners, sometimes a few pores along cell edges, on concave surface with a few indistinct, unringed pores in cell corners, green cells triangular, and not reaching the concave surface, exposed only on convex surface.

In northern North America this species is infrequent on hummocks on peat plateaus and rare southward where it occurs intermixed with *S. fuscum* and *S. magellanicum*, and occurring in drier habitats than *S. angustifolium*; however, in Eurasia it also occurs in lawns in unfrozen peatlands.

Hummock	■	■			
Lawn	■				
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal				
	Cont	←	→	Oc

pH		■	■				
	3	4	5	6	7	8	

42. *Sphagnum* ***capillifolium*** **(Ehrh.) Hedw.**

Sphagnum capillifolium (= *S. nemoreum* Scop.) forms high, pinkish-red hummocks in oligotrophic habitats. The dense, rounded capitula and ovate-lanceolate stem leaves with some pores and fibrils identifies this species. Branch leaf features cannot be used to differentiate this species from *S. fuscum*, but *S. capillifolium* has clear (pinkish) stems compared to dark brown in *S. fuscum*.

Plants small, green to pinkish-red plants with dense canopies, one pendent branch visible between capitulum arms; individual capitula hemispheric. **Stems** clear, with non-porose hyalodermis. **Leaves** ovate-lanceolate, minutely truncate at apex; stem leaves broadly lanceolate, with at least some fibrils and pores. **Leaf Cells** hyaline cells with large elliptic pores along sides of the cell on convex surface, somewhat smaller, less conspicuous rounded pores in central part of cell on concave surface; green cells triangular, exposed on concave surface.

Forms hummocks in bogs and peat plateaus; rarely as isolated patches in both rich and poor fens. More abundant in eastern North America. **Common Associates** - usually few species occur intermixed with this species, but like *S. fuscum* occasionally mixed with *Polytrichum strictum*; while *Pohlia nutans*, and *Mylia anomala* occur as scattered individuals.

Hummock	■	■			
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH		■	■				
	3	4	5	6	7	8	

43. *Sphagnum* ***contortum*** **Schultz**

A species similar to *S. subsecundum, S. contortum* differs in having the stem hyalodermis in 2-3 layers and small branch leaf pores - the pores of *S. contortum* are less than half the distance between the fibrils, whereas in *S. subsecundum* the pores occupy about the entire distance between the fibrils.

Plants medium sized, in dense mounds on lawns, orange-green, with a dense capitulum and curved branches. **Stems** with a 2-3 layered hyalodermis. **Leaves** 1.2-2.0 mm long, ovate-lanceolate, tapering to truncate acute apex; stem leaves 0.7-1.4 mm long, triangular-lingulate. **Leaf cells** with numerous small pores arranged along sides of hyaline cells (as a string of beads), green cells trapezoidal, exposed more broadly on convex surface.

Found on wet lawns in site types transitional between rich and poor fens. More common in subcontinental and oceanic areas.

Hummock					
Lawn				■	
Carpet				■	
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic		■	■	■
N. Boreal	■	■	■	■
S. Boreal			■	■
	Cont	←	→	Oc

pH				■	■		
	3	4	5	6	7	8	

44. *Sphagnum* ***cuspidatum*** **Hoffm.**

The very slender, weak, yellow-green plants growing in oligotrophic habitats characterize this species. The very long, linear branch leaves have almost no pores and they never have medial pores. The stem leaves are relatively large and acute due to inflexed margins. *Sphagnum balticum* is more stout and has different green cell shape, whereas other species clearly have different pores patterns of the branch leaves or have distinctive stem leaves. *Sphagnum cuspidatum* is a subcontinental and temperate species and is rare in boreal continental bogs and poor fens.

Plants weak, slender; floating in water or sometimes forming loose carpets, yellow-green, one pendent branch visible between capitulum arms. **Stems** colorless, with poorly developed hyalodermis. **Leaves** elongate lanceolate, slender, gradually tapering to truncate, acuminate apex; stem leaves oblong-triangular, concave and appearing acute due to inflexed margins, somewhat fibrillose in upper portion, without pores, rather large and loosely erect. **Leaf Cells** very long, on convex surface with a few round pores in corners of cells, on concave surface without or with only 1-2 indistinct pores in corners, green cells triangular, exposed on convex surface and extending to concave surface.

Aquatic and emergent in oligotrophic habitats. **Common Associates** - occurs in poor fens along with *S. papillosum*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

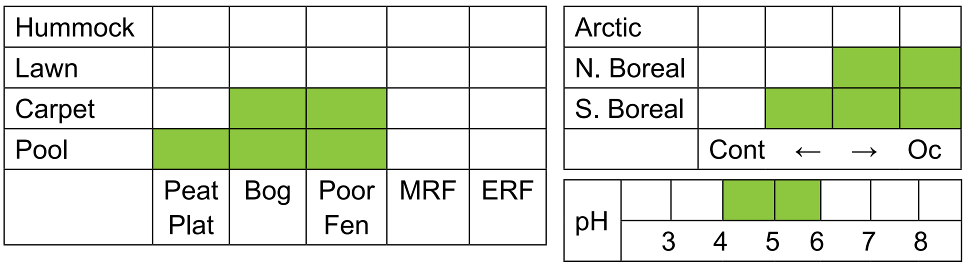
pH						
	3	4	5	6	7	8

45. *Sphagnum* ***fallax*** **(Klinggr.) Klinggr.**

The apiculate, entire stem leaves define this species. The branch leaf pore pattern is similar to that of *S. angustifolium* and *S. balticum* (the latter differentiated by green cell transverse section). *Sphagnum fallax* is subcontinental and temperate in distribution, and becomes rare in continental, boreal areas. Historically, and especially in North America, the name *S. recurvum* has been applied in a broad sense to include *S. angustifolium, S. fallax*, and *S. flexuosum* (as well as *S. recurvum sensu stricto*) – all differentiated by stem leaf features.

Plants large, but slender in yellow-green to green-brown, loose lawns, with small apical bud and two pendent branches visible between capitulum arms. **Stems** without enlarged hyalodermis, central core clear to green. **Leaves** ovate-lanceolate and narrowed to acuminate, narrowly truncate apex, often undulate when dry; stem leaves oblong-triangular and apiculate, not erose at tip, without fibrils and pores. **Leaf Cells** of convex surface of branch leaves few, consisting of one rather large rounded to elliptic apical pore and sometimes a few smaller pores restricted to cell corners, on concave surface several indistinct, unringed pores along cell edges, green cells triangular and reaching concave surface, exposed broadly on convex surface.

Found in wet lawns and carpets in poor fens and found in oceanic areas in bog hollows. This species appears to tolerate high nutrient levels and occupies more nutrient rich sites than others of the group.

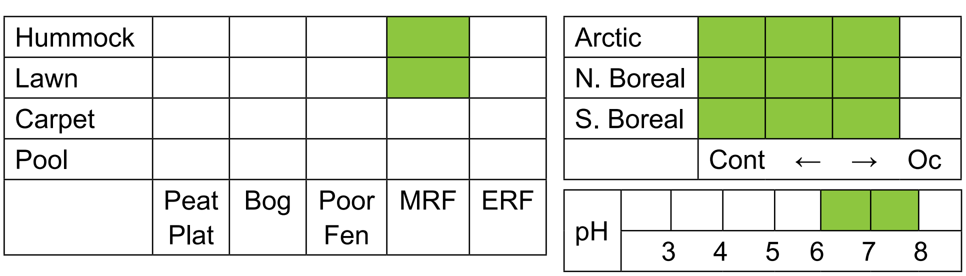


46. *Sphagnum* ***fimbriatum*** **Wils.**

This species has slender plants, capitula with a large apical bud, a pallid-green coloration, and stem leaves that are rounded and fimbriate along most of the margin. As a species of section *Acutifolium*, it has one-pendent branch shown between capitulum arms. *Sphagnum girgensohnii* is larger and has stem leaves fimbriate along a truncate apex. Two species in section *Cuspidatum* have lacerate stem leaf margins: *S. lenense* and *S. lindbergii* - both have dark brown stems.

Plants slender, dirty to pallid green, with dense canopies, one pendent branch visible between capitulum arms. **Stems** clear, with porose hyalodermis. **Leaves** ovate-lanceolate, minutely truncate at apex; stem leaves broadly obovate, obtuse, fimbriate across margin, without fibrils and pores. **Leaf cells** with large elliptic pores along sides of cells on convex surface, somewhat smaller, less conspicuous, rounded pores in central part of cell on concave surface; green cells triangular, exposed on concave surface.

Forming hummocks in transitional areas and in shrubby moderate-rich fens. The mesotrophic habitats often associated with marginal and transititonal areas are characteristic of this species. Also it sometimes forms quite large hummocks in rich fens.



47. *Sphagnum* ***fuscum*** (Schimp.) Klinggr.

Key features for the identification of *S. fuscum* include the lingulate, entire stem leaves, brown color, and the dark (brown) stems. The branch leaves with large elliptic pores that are arranged along the sides of the cells on the convex surface is a pore pattern similar to that in *S. capillifolium* as well as a number of more woodland species (e.g., *S. girgensohnii*); however, the brown stems are a key feature of S. fuscum that are not found in any other *Sphagnum* in the section *Acutifolium*. See *S. angustifolium* for additional comments.

Plants small, brownish with dense canopies, one pendent branch visible between capitulum arms. **Stems** brown, with non-porose hyalodermis. **Leaves** ovate-lanceolate, minutely truncate at apex; stem leaves lingulate, without fibrils and pores. **Leaf Cells** with large elliptic pores along sides of cells on convex surface, somewhat smaller, less conspicuous, rounded pores in central part of cell on concave surface; green cells triangular, exposed on concave surface.

Forming hummocks in bogs and peat plateaus; occasionally on isolated hummocks in both rich and poor fens. **Common Associates** - usually associated with *Polytrichum strictum, Pohlia nutans*, and *Mylia anomala*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH						
	3	4	5	6	7	8

48. *Sphagnum* ***jensenii*** H.Lindb.

Similar to *S. majus* in the field. When the two grow together, *S. jensenii* is slightly darker and a little larger - both differentiated from other species by dark color. The distinctive pore pattern (see below) of the branch leaf hyaline cells is the best identifying feature.

Plants forming loose mats, dark brown to reddish-green, with a moderate apical bud and one pendent branch visible between capitulum arms. **Stems** with clear core and poorly differentiated hyalodermis. **Leaves** ovate-lanceolate and gradually narrowed to narrowly truncate apex; stem leaves oblong and concave in upper portion – thus leaves appearing triangular, hyaline cells without pores and with few fibrils in upper part. **Leaf Cells** long, with numerous pores on both surfaces – convex surface with 7-20 small elliptic to rounded, ringed and unringed pores, usually in two medial rows and concave surface with 4-15 medium-sized, round, unringed pores, some near cell corners and most in 1-2 medial rows, green cells isosceles-triangular, exposed on convex surface.

Found in pools and emergent in poor fens and in permafrost collapse features. **Common Associates** - often with *S. majus, S. obtusum*, and *S. fallax*.

Hummock					
Lawn					
Carpet	■	■	■		
Pool	■		■		
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH			■	■			
	3	4	5	6	7	8	

49. *Sphagnum* ***lindbergii*** **Lindb.**

This beautiful species is easily differentiated by brownish plants that have a dark brown stem core, a conspicuous apical bud, and stem leaves that are fan-shaped and lacerate over the entire upper portion. This species is relatively large in stature and occurs in carpets in very wet poor fens and bogs. At least in North America, it is only abundant in the northern boreal zone and along both coasts. In comparison, *S. lenense* that also has brown stems, is much smaller (*S. fuscum* in size), has stem leaves that are fan-shaped and lacerate but also have a broad resorbed tear that is evident in the upper half of the leaves. It occurs on high hummocks in the subarctic and alpine zones. From *S. fuscum*, which it superficially resembles, it is distinguished by having a wonderful copper coloration, young pendent branches in pairs, and the lacerate stem leaves (also it is a member of the section *Cuspidatum* with green cells exposed on the convex surface).

Plants dark brown in firm carpets with conspicuous apical bud and shiny, 5-ranked leaves that are especially noticeable when wet, capitulum-indentations with one visible pendent branch. **Stems** with dark brown core and well-developed hyalodermis. **Leaves** ovate-lanceolate, narrowed to narrowly truncate apex, stem leaves fan-shaped, coarsely lacerate across upper ½ of leaf, hyaline cells noticeably resorbed on upper part of leaf. **Leaf Cells** of branch leaves with few small ringed pores in cell corners, concave surface with few marginal unringed, indistinct pores, no medial pores on either surface present, green cells triangular, exposed on convex surface, and extending to concave surface.

Emergent from oligotrophic waters and forming wet carpets in poor fens and bogs (in oceanic areas). Northern and coastal in distribution.

Hummock					
Lawn					
Carpet	■	■	■		
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal				
	Cont	←	→	Oc

pH		■	■				
	3	4	5	6	7	8	

50. *Sphagnum* ***magellanicum*** **Brid.**

The reddish, robust, and turgid plants are key features of *S. magellanicum*. Characteristics include clear to pinkish stems with fibrose and porose cells composing the hyalodermis, and very concave, entire branch leaves that have numerous pores on relatively short hyaline cells and totally enclosed green cells without wall ornamentation. Other robust and turgid species of the Section *Sphagnum* (all of these have hooded, entire branch leaves) are *S. palustre* and *S. henryense* with smooth, triangular green cells; *S. papillosum* with trapezoidal-triangular green cells with papillose adjacent walls; and *S. imbricatum* and *S. austinii* with broadly triangular green cells and adjacent walls with striations. Also, *S. centrale* has elliptic green cells with thickened walls exposed on both leaf surfaces. *Sphagnum magellanicum* is the only northern species with red color in the section *Sphagnum*.

Plants large, turgid, reddish, forming dense canopies, 0-1 pendent branches visible between capitulum arms. **Stems** pink to clear, with porose and fibrose hyalodermis. **Leaves** ovate-ellipitic, hooded, and entire at apex, convex surface just below apex with denticulations due to resorption of apical portions of hyaline cells; stem leaves lingulate, with hyaline cells not divided and mostly without fibrils or pores, resorbed on convex surface. **Leaf Cells** short, nearly plane or only slightly bulging on both surfaces, with numerous elliptic pores on convex surface and inconspicuous rounded pores on concave surface; green cells elliptic, completely enclosed by hyaline cells, adjoining hyaline cells walls smooth.

Forming small hummocks or occurring on the sides of high hummocks in bogs, sometimes on low hummocks and strings in poor fens. **Common Associates** - found in oligotrophic habitats with *S. fuscum* and *S. angustifolium*, or *S. fallax*.

Hummock					
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal				
S. Boreal				
	Cont	←	→	Oc

pH	3	4	5	6	7	8

51. *Sphagnum* ***majus*** **(Russ.) C.Jens.**

The lack of pores on the concave surface of branch leaf hyaline cells coupled with numerous, rather large medial pores on the convex surface and blunt, oblong stem leaves are identifying features. In the field, the dark color and habitat are helpful characters.

Plants medium-sized, floating or in loose carpets, dark brown to mottled reddish-green, with small apical bud and 1-(2) pendent branches visible between capitulum arms. **Stems** without dark core, hyalodermis not or poorly developed.

Leaves ovate-lanceolate, gradually acuminate and narrowly truncate at apex; stem leaves oblong, concave and inflexed, with leaves appearing triangular, blunt and rounded, hyaline cells with few fibrils in upper part, without pores. **Leaf Cells** long, with many unringed, large pores in 1-2 medial rows (not in contact with cell edges), without pores on concave surface (or occasionally with 1-3 small faint, pores at cell corners), green cells isosceles triangular, exposed on convex surface.

Floating and emergent in poor fens, in collapse scars, and in internal lawns. *Sphagnum majus* occurs in more minerotrophic habitats then does *S. cuspidatum*. **Common Associates** - often found with *S. jensenii*; also sometimes with *S. balticum* and *S. obtusum*.

Hummock					
Lawn					
Carpet	■	■	■		
Pool	■		■		
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH			■	■			
	3	4	5	6	7	8	

52. *Sphagnum* ***obtusum*** **Warnst.**

This species is troublesome, mainly because the definitive characters are hard to recognize. My approach is that when I have plants with rather large, blunt stem leaves (i.e., not *S. fallax* or *S. angustifolium)* and when I can find nearly no pores in the upper part of the leaves, then I heavily stain and look for the very small pseudopores in the lower part of the leaves, especially noticeable along the lower marginal areas. The other key character are the long (linear-elongate) lower hyaline cells. Additionally *S. obtusum* is a species of mesotrophic and rich fen habitats, rare in oligotrophic poor fens.

Plants brownish-green to shiny-green, robust and stout, branch ends obtuse, 1-2 pendent branches visible between capitulum arms. **Stems** hyalodermis not or only slightly enlarged, stem core colorless. **Leaves** ovate-lanceolate and gradually narrowed to a narrowly truncate apex, margins somewhat wavy; stem leaves oblong-triangular, obtuse and erose at apex, rather flat, without fibrils and pores. **Leaf Cells** very long, especially in basal leaf area, with almost no true pores or each with a small apical pore and 1-3 corner pores on both surfaces in upper portion of leaf, lower portion of leaves with numerous very small, pseudopores (membrane thinnings) in medial portion of cell and in 1-2 irregular rows - seen only with heavy staining.

This a species of mesotrophic habitats, seemingly present in transitional rich fens and the most minerotrophic poor fens. **Common Associates** - in wet fens with *S. teres* and *S. subsecundum*, along with true mosses.

Hummock					
Lawn				■	
Carpet				■	
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal			■	
	Cont	←	→	Oc

pH				■	■		
	3	4	5	6	7	8	

53. *Sphagnum* ***papillosum*** **Lindb.**

Sphagnum papillosum is one of several turgid, fat species of the genus. From other species that look somewhat similar, *S. papillosum* differs in brownish plants and the lack of thread-like spreading branches. Microscopically, it is easily distinguished by having numerous fine papillae on the green cell walls that are in contact with the hyaline cells.

Plants large, turgid, yellow-brown, forming dense, swollen canopies, 0-1 inconspicuous pendent branches visible between capitulum arms. **Stems** brownish, with porose and fibrose hyalodermis, spreading branches all short and stubby. **Leaves** ovate-elliptic, hooded, and entire at apex, convex surface just below apex with denticulations due to resorption of apical portions of hyaline cells; stem leaves lingulate; hyaline cells frequently 1-divided, without fibrils, largely resorbed on both surfaces. **Leaf Cells** short, somewhat bulging on convex surface, less so on concave surface, with numerous elliptic pores on convex surface and inconspicuous rounded pores on concave surface; green cells oval to trapezoidal-triangular, exposed equally or more so on concave surface, adjoining hyaline cell walls with minute papillae.

This oceanic to subcontinental species occurs in lawns in poor fens and rarely in bogs along with *S. cuspidatum, S. fallax, S. angustifolium*, and *S. magellancum*. **Common Associates** In poor fens, *S. papillosum* sometimes occurs intermixed with *S. magellanicum*, the latter at the extreme wet end of its habitat and *S. papillosum* at the extreme dry end of its tolerance for drought. In oceanic bogs and poor fens, it occurs with *S. pulchrum, S. tenellum*, and *S. austinii*.

Hummock					
Lawn		■	■		
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal			■	■
S. Boreal			■	■
	Cont	←	→	Oc

pH			■	■			
	3	4	5	6	7	8	

54. *Sphagnum* ***pulchrum*** **(Braithw.) Warnst.**

Temperate and oceanic in occurrence, this species has green cells of the branch leaves that do not reach the concave surface, a branch leaf pore pattern similar to that of *S. fallax*, and concave stem leaves with fibrils in their upper portion. The branch leaves are distinctly 5-ranked.

Plants large, yellow-green, forming loose carpets, capitulum rounded and with 1-2 pendent branches visible between capitulum arms. **Stems** colorless to green, hyalodermis not enlarged. **Leaves** shortly ovate-lanceolate and narrow to truncate, acuminate apex, distinctly 5-ranked on branches; stem leaves triangular-ovate, apiculate, concave, spreading outward from stem with some fibrils in upper portion. **Leaf Cells** long on convex surface with few, small pores restricted to corners and margins, concave surface with few larger round pores along sides of cell, green cells, rounded, triangular, not exposed on concave surface and broadly exposed on convex surface.

Found in mounds and carpets in poor fens, sometimes forming carpets in oceanic bogs. **Common Associates** - Occurring with *Sphagnum papillosum* and *S. tenellum*.

Hummock					
Lawn		■	■		
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal			■	■
S. Boreal			■	■
	Cont	←	→	Oc

pH			■	■			
	3	4	5	6	7	8	

55. *Sphagnum* ***riparium*** **Ångstr.**

The stem leaves with an obvious tear and the irregular to elliptic, large apical pore of the branch leaf hyaline cells are characteristics of this species. Living plants are easily identified by the large apical bud. Branch fascicles are usually sparsely positioned along the stem, thus the characteristic stem laves are easily seen with a hand lens.

Plants large, yellow-green, forming loose canopies, apical bud very conspicuous, 1-2 pendent branches visible between capitulum arms. **Stems** clear, without hyalodernis. **Leaves** ovate-lanceolate, minutely truncate at apex; stem leaves large, broadly lanceolate, with single longitudinal resorption-tear to about mid leaf. **Leaf Cells** with conspicuous, oval, irregularly-shaped pore at apex on convex surface, additional pores either none, a second central pore just beneath apical one, or with some rounded pores only in cell corners, several very inconspicuous rounded central pores on concave surface; green cells triangular, exposed on convex surface.

Forms carpets in mesotrophic pools, especially prevalent in internal lawns and recent collapse scars, and patterned poor fens where local nutrient inputs are evident. *Sphagnum riparium* is an early colonizer of wet, disturbed sites across the boreal, but becomes infrequent farther north. **Common Associates** - often found with *S. majus, S. jensenii, S. fallax*, and *S. angustifolium*.

Hummock					
Lawn					
Carpet	■	■	■		
Pool	■		■		
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal		■	■	■
S. Boreal			■	■
	Cont	←	→	Oc

pH			■	■	■		
	3	4	5	6	7	8	

56. *Sphagnum* ***rubellum*** **Wils.**

Closely related to *S. capillifolium* and sometimes considered synonymous with it. The features of the two species appear to intergrade in some specimens. When distinct, *S. rubellum* has oblong stem leaves without pores and fibrils, a flat capitulum, and occurs in wetter habitats (lawns). *Sphagnum capillifolium* has triangular-oblong stem leaves with at least some pores and fibrils and a rounded capitulum; it is a hummock species of bogs. Although there are no differences between the branch leaf pore patterns between these species and also those of *S. fuscum*, color easily differentiates them.

Plants small, slender, reddish-green to pinkish with flattened capitulum and one pendent branch visible between capitulum arms. **Stems** with pinkish core and well-developed hyalodermis of 2-3 layers of enlarged cells, outermost hyalodermis layer without pores. **Leaves** ovate-lanceolate and narrowed to a narrowly truncate apex; stem leaves oblong, obtuse, entire, somewhat concave, without (or nearly so) fibrils and pores in upper portion; many hyaline cells subdivided. **Leaf Cells** on convex surface with several large, elliptic, ringed pores arranged along sides of bulging cells, on concave surface several large, unringed, round pores positioned in medial portion of cell; green cells triangular, exposed on concave surface of leaf.

Forms lawns and low hummocks in bogs and poor fens. *Sphagnum rubellum* is not found in continental boreal areas. **Common Associates** - *S. papillosum, S. fuscum*, and *S. capillifolium*.

Hummock		■	■		
Lawn		■	■		
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic			■	■
N. Boreal		■	■	■
S. Boreal		■	■	■
	Cont	←	→	Oc

pH		■	■				
	3	4	5	6	7	8	

57. *Sphagnum* ***russowii*** **Warnst.**

The reddish coloration; oblong, blunt stem leaves with a resorbed apical notch; and porose stem hyalodermis are the key characters of this species. The branch leaves are quite similar to those of other Section *Acutifolium* species; however, the ringed, elliptic, rather small pores in the upper part of young leaves are about half way in size between those of *S. warnstorfii* and those of *S. capillifolium* and *S. fuscum*.

Plants slender reddish-green with loose canopies, capitulum flat and clearly star-shaped, sometimes mottled in red to greenish bands, one pendent branch visible between capitulum arms. **Stems** with pale-reddish core and 2-3 layered, well-developed hyalodermis; some cells of outermost stem layer with pores. **Leaves** ovate-lanceolate and gradually tapered to truncate acuminate apex; stem leaves oblong, obtuse, flat, with small resorbed notch at apex, without fibrils and pores. **Leaf Cells** with 6-10 elliptic, ringed, medium-sized pores arranged along sides of bulging hyaline cells, concave surface flat, with several larger, unringed pores positioned medially; green cells triangular, exposed on concave surface.

Found on low hummocks and drier lawns at the edges of oligotrophic habitats and in marginal swampy woods. **Common Associates** - sometimes with *S. girgensohnii* and other woodland mosses or with *S. fallax* in marginal habitats.

Hummock			■		
Lawn			■		
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic		■		
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH			■	■			
	3	4	5	6	7	8	

58. *Sphagnum* ***subsecundum*** **Sturm**

This species has subsecund capitulum branches, often a dirty orange tint; one-layered hyalodermis; and branch leaf hyaline cell pores arranged as strings of beads along both sides of the cell - the pores large and covering the distance between the fibrils. Several closely related species have been recognized and form a difficult complex of seemingly intergrading taxa. Two are key northern species worth mentioning. *Sphagnum contortum* has a 2-3 layered hyalodermis and small pores that are less than ½ the distance between the fibrils. *Sphagnum orientale*, a truly arctic species has tiny pores in 2-3 rows, the medial row is sometimes not well-organized, but there is at least 1-3 tiny medial pores in some upper leaf cells. It is shiny blackish purple color calling to mind 'Darth Vadar'.

Plants orange-green to yellow-brown in soft cushions and lawns; branches slightly curved (subsecund); and one pendent branch somewhat visible between capitulum arms. **Stems** with brownish central core and 1-layered, well-developed hyalodermis. **Leaves** 1.0-1.2 mm long, curved, ovate, acute and narrowly truncate, very concave; stem leaves small 0.5-0.8 mm long, oblong to ovate-oblong, blunt, concave, with some fibrils in upper portion and also few irregular areas of resorption present. **Leaf Cells** on convex surface with two rows of numerous, rounded to elliptic pores arranged along green cell contact, pores about width of fibril spacing; on concave surface with few small pores at ends and corners; green cells trapezoidal, exposed more broadly on convex surface.

In wet minerotrophic habitats, sometimes in transitional rich/poor fens. **Common Associates** - *S. teres, S warnstorfii, S fimbriatum*, and *S. obtusum* can all occur in similar habitats

Hummock					
Lawn			■	■	
Carpet			■	■	
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH				■	■		
	3	4	5	6	7	8	

59. *Sphagnum* ***teres*** **(Schimp.) C.Hartm.**

The distinctive stem leaves (see below), are dark, often dirty stems with a hyalodermis, and faintly papillose walls between the hyaline and green cells of the branch leaves are differentiating characters. Also the large apical bud and minerotrophic habitat are field characters.

Plants forming loose mats, greenish to brownish, rather slender, with large apical bud and one pendent branch visible between capitulum arms. **Stems** with 2-3 layered hyalodermis, without fibrils and pores, usually with dark core. **Leaves** ovate-lanceolate, apex narrowly truncate, erect or sometimes with recurved apices; stem leaves long-lingulate; hyaline cells in body of leaf undivided and without pores, in upper part leaf, marginal hyaline cells divided and resorbed, forming delicate marginal fringe. **Leaf Cells** with 1-3, large, irregular pores or gaps on convex surface, with distinct elliptic pores on concave surfasse; green cells oval-trapezoidal to triangular, exposed more so on convex surface, adjacent walls to hyaline cells very finely papillose.

Found in minerotrophic habitats such as floating mats around lakes, carpets, and lawns of rich fens, and marginal fen laggs. **Common Associates** - sometimes intermixed with *S. angustifolium* in transitional poor fens. It occurs in wetter habitats then does *S. warnstorfii*; however, in similar chemical conditions.

Hummock					
Lawn				■	
Carpet				■	
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH				■	■		
	3	4	5	6	7	8	

60. *Sphagnum* ***warnstorfii*** **Russ.**

Branch leaves of *Sphagnum warnstorfii* are distinguished by the very small, strongly ringed pores on the convex surface of the upper hyaline cells of the branch leaves. This character is best seen in branches of the capitulum; however, hanging branches lower down the stem may not have these small pores, and thus are not distinguishable from those of other species of the section *Acutifolium*. Association with *Tomentypnum nitens* can be used to suggest the identity of this species.

Plants slender, green to purplish-red, usually with flat-topped capitulum, and one conspicuous pendent branch visible between capitulum arms. **Stems** with non-porose hyalodermis, uncolored to pinkish. **Leaves** - branch leaves ovate-acuminate, fimbriate at apex, clearly ranked and seriate; stem leaves long-lingulate, without pores or fibrils. **Leaf Cells** - green cells triangular, exposed on convex surface, pores on convex surface along sides of cells, small and strongly ringed in upper 1/3, larger below; on concave surface with few, large, indistinct pores in center of cell.

Occurring in lawns and on low hummocks in rich fens of the boreal forest, becoming less frequent northward and coastward. **Common Associates** - often associated with *Tomentypnum nitens* and *Aulacomnium palustre*. In rich fens, as pH decreases above the water table, low hummocks and hummock sides are often dominated by *S. warnstorfii*; however, high hummocks may have *S. fuscum*.

Hummock				■	
Lawn				■	
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■		
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont ←		→	Oc

pH				■	■		
	3	4	5	6	7	8	

61. ***Stramiergon stramineum*** **(Brid.) Hedanäs**

The straw-colored, slender, unbranched plants with oblong, obtuse, straight leaves distinguish this species. *Calliergon* and *Calliergonella* species (all with similar leaf cells) have inflated, hyaline alar cells and generally broader leaves. Formerly known as *Calliergon stramineum*.

Plants erect to ascending, yellow-green, slender, forming loose mats or occurring singly in *Sphagnum* mats. **Stems** mostly unbranched, without hyalodermis. **Leaves** narrowly oblong to oblong, ending in obtuse, cucullate apex, straight; costa single, ending about 2/3 up the leaf. **Leaf Cells** elongate to narrowly rhombic, with blunt ends, smooth and thin-walled. **Alar Cells** forming a conspicuous group of thick-walled, rectangular, colored cells; somewhat decurrent.

Mostly occurring on a variety of organic substrates, most common in oligotrophic habitats where it is found intermingled with *Sphagnum*, but also occurring in carpets and lawns of rich fens. **Common Associates** - intermingled with peat-forming *Sphagna* such as *S. fuscum, S. angustifolium*, and *S. magellancium*, but also with carpet/lawn species of *Drepanocladus* (*sensu lato*).

Hummock	■	■	■		
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal		■	■	■
	Cont	←	→	Oc

pH			■	■			
	3	4	5	6	7	8	

62. ***Tomentypnum falcifolium*** **(Nichols) Tuom.**

This species differs from *Tomentypnum nitens* in having falcate-secund leaves with tomentum restricted to one side of the stem. The falcate-secund, plicate leaves are reminiscent of *Sanionia uncinata*, but differs in having abundant tomentum.

Plants erect to ascending, pinnately branched. **Stems** covered on one side with tomentum of reddish rhizoids. **Leaves** long lanceolate, falcate-secund, acuminate to narrowly acute, strongly plicate; costa strong and single, ending just below apex; margins entire. **Leaf cells** elongate-linear, thin-walled, smooth. **Alar cells** not much different, shorter, with thicker nodose walls.

A species of hummocks and drier habitats in poor fens, often associated with *Sphagnum angustifolium*.

Hummock			■		
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic				
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH			■	■			
	3	4	5	6	7	8	

63. ***Tomentypnum nitens*** **(Hedw.) Loeske**

The costate, plicate, straight leaves with linear cells are diagnostic for this common species of rich fens. *Tomentypnum falcifolium* is similar, but has falcate-secund leaves; it occurs in poor fens. In arctic meadows *Orthothecium chryseum* occurs, but is distinguished by ecostate leaves.

Plants erect, pinnately branched. **Stems** covered with tomentum of reddish rhizoids. **Leaves** long-lanceolate, straight, acuminate to narrowly acute, strongly plicate; costa strong and single, ending just below apex; margins entire.

Leaf Cells elongate-linear, thin-walled, smooth. **Alar Cells** not much different, shorter, with thicker, nodose walls.

Grows on hummocks and raised areas in wooded to open rich fens and calcareous tundra. **Common Associates** - *Sphagnum warnstorfii, Aulacomnium palustre*, and *Campylium stellatum*. Occasionally associated with less frequent species such as *Paludella squarrosa* and *Helodium blandowii*.

Hummock				■	■
Lawn					
Carpet					
Pool					
	Peat Plat	Bog	Poor Fen	MRF	ERF

Arctic	■	■	■	
N. Boreal	■	■	■	
S. Boreal	■	■	■	
	Cont	←	→	Oc

pH					■	■	■
	3	4	5	6	7	8	

64. *Warnstorfia exannulata* (Schimp.) Loeske

Distinguished from *W. fluitans* by having a stronger costa, reddish coloration, and abruptly inflated groups of hyaline alar cells. In general, the plants are larger and more robust then those of *W. fluitans*. The denticulate leaf margins, often seen best in the apical tufts of young leaves, distinguish this species and *W. fluitans* from species in the *Drepanocladus aduncus* group. Scorpidium species have shorter leaves and enlarged epidermal cells of the stem, while *Hamatocaulis* species have no central strand of the stem, and lack differentiated alar cells. Somewhat similar species include *W. trichophylla* with a long excurrent costa and *W.* (*Calliergidium or Sarmentypnum*) tundrae with 5-angled stem and long decurrent leaves.

Plants slender to large, reddish-green. **Stems** sporadically to irregularly pinnately branched, in transverse section with central strand and no enlarged epidermal cells. **Leaves** narrowly lanceolate, gradually acuminate; costa strong, ending 2/3 up leaf to just below apex, excurrent in closely related aquatic species. **Leaf Cells** elongate-linear with rather blunt ends, smooth; with denticulate margins, sometimes with teeth only near apex and sometimes teeth continuing to mid leaf and conspicuous on lower shoulders. **Alar Cells** abruptly inflated and hyaline, forming conspicuous groups of one row of enlarged, rectangular cells along with a few smaller, hyaline cells.

Floating in water or forming emergent mats in pools or on unconsolidated peat. Characteristic of poor fens. **Common Associates** - in boreal regions found with *Sphagnum majus, S. fallax*, and *S. jensenii*, occasionally with the rare *S. lindbergii* and farther north with *S. balticum*.

	Peat Plat	Bog	Poor Fen	MRF	ERF
Hummock					
Lawn					
Carpet	■		■		
Pool	■		■		

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH							
			■	■			
	3	4	5	6	7	8	

65. ***Warnstorfia fluitans*** **(Hedw.) Loeske**

Differentiated from other species with costate, falcate-secund leaves by denticulate margins (best seen just below the apex), gradually differentiated alar cells that do not form conspicuous inflated groups, and a stem transverse section with a central strand. *Drepanocladus aduncus* has completely entire leaf margins; *Warnstorfia exannulata* has abruptly differentiated and inflated alar cells and a much stronger costa; while species of *Hamatocaulis* have no central strand in the stem. Species of *Scorpidium* have shorter leaves and a hyalodermis of enlarged cells. Also see comments under *W. exannulata.*

Plants floating to emergent, rather slender, green. **Stems** generally with few branches, occasionally with numerous branches, with central strand and no differentiated hyalodermis. **Leaves** narrowly lanceolate, gradually acuminate, falcate-secund; costa single, weak, ending about 1/2-2/3 up leaf, somewhat narrowed to insertion; margins denticulate in upper portion of leaves. **Leaf Cells** elongate-linear, with blunt ends, smooth. **Alar Cells** indistinct, gradually enlarged and forming small groups of hyaline, rectangular cells at leaf angles.

Found floating in shallow pools to emergent and forming carpets in shallow water in oligotrophic habitats and characteristic of bogs and extreme poor fens. **Common Associates** - in oceanic areas found with wet-growing species of *Sphagnum*, especially *S. cuspidatum*, while in continental areas associated with permafrost melt often found with *S. majus* and *S. jensenii*.

	Peat Plat	Bog	Poor Fen	MRF	ERF
Hummock					
Lawn					
Carpet	■	■			
Pool	■	■			

Arctic	■	■	■	■
N. Boreal	■	■	■	■
S. Boreal	■	■	■	■
	Cont	←	→	Oc

pH							
		■	■				
	3	4	5	6	7	8	

Acknowledgments

I would like to dedicate this publication to Dr. Raymond Stotler, whose dedication and service to the study of hepatics has been of utmost value to the field of bryology. The bryological community will miss Ray, but his legacy will be long remembered in his publications and presentations. Funding for this publication was from NSF RCN Grant 0443447, through support from the Research Coordination Network Program "PEATNET". I would like to thank Sandi Vitt for her assistance and to all of my colleagues and students who have helped along the way.

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appendix g: glossary

Acid Fen
Minerotrophic wetlands that have H+ as the major pore water ion and accumulate organic matter. pH of pore waters range from 4.0-5.5 (5.9). The ground layer is *Sphagnum*-dominated. Similar to poor fens in previous literature.

Acrotelm
The upper, aerobic portion of the peat column, including the region of fluctuating water levels.

Alkaline Fen: Fens with pH 7.0-8.5 or higher
Minerotrophic wetlands having high amounts of HCO_3^- and Ca^{2+} as dominant pore water ions and that accumulate organic matter. The ground layer is true moss-dominated. Similar to extreme rich fens in previous literature.

Assessment Grid
An approximately 40 m x 40 m grid, established on the lease to provide a systematic method for collecting soils (and vegetation) data.

Assessment Point
The point that is positioned at a location within a grid (or access) that is representative of the entire grid (or mapped section of the access) where the soil (and vegetation) is to be assessed.

Bare Areas
Areas devoid of vegetation, but are not permanently water filled areas

Bog
Ombrotrophic wetlands that accumulate organic matter. Bog pore waters are acid (pH 3.0-4.2). Bogs in continental boreal Canada have scattered (wooded) cover of *Picea mariana* (black spruce), The ground layer is *Sphagnum*-dominated.

Bryophytes
A group of plants with similar ecological and life history traits found in the ground layer. Phylogenetically, consisting of three distantly related green plant groups. Bryophyta (mosses) – with long-lived sporophytes; Marchantiophyta (liverworts) with short-lived sporophytes; and Anthocerotophyta (hornworts) with cylindrical capsules. Mosses, in particular, are important parts of northern hemisphere peatland vegetation.

Canopy Cover
The area of within a sampling unit that is occupied by the above-ground parts of plants (live or dead) when viewed from above but multiple layers of vegetation often result in cover values over 100 per cent.

Carbon Sequestration
Movement of carbon as gas (CO_2) from the atmosphere to organic material (CHO) through the process of photosynthesis. Net balance within an ecosystem is controlled by decompositional losses to the atmosphere from aerobic (as CO_2) or anaerobic areas (as CH_4) of the peat column.

Cation Exchange Capacity (C.E.C.)
A measure of the total amount of exchangeable cations that can be held by the soil; it is expressed in terms of mols per kg of soil (formerly meq/100g); CEC is largely controlled by the amount of clay and organic matter in the soil.

Catotelm
The lower, anaerobic portion of the peat column, below the region of fluctuating water levels.

Circumneutral Fen: pH 5.5-7.0
Minerotrophic wetlands with small amounts of bicarbonate and calcium ions in the pore water and that accumulate organic matter. The ground layer is true moss-dominated, but some *Sphagnum* species can be present. Similar to moderate-rich or transitional rich fens in previous literature.

Clay pads
Built-up wellsite or access road.

Compaction
The result of bearing equipment and drilling activity onsite that exceeds the soil strength, increasing the density of the topsoil and/or subsoil, limiting root penetration and water infiltration.

Construction
Preparation of the site for exploration and/or extraction.

Contour
Topographic features measured in centimeters (micro), meters (meso) and tens of meters (macro). Such can be lost due to cut and fill wellsite construction activities and need to be restored during reclamation.

Control
Refers to information collected offsite against which collected information from a reclaimed site will be compared. The control information is collected offsite from adjacent undisturbed or representative undisturbed land.

Detailed Site Assessment (DSA)

The report that must be attached to the Wellsite Reclamation Certificate Application form that provides all the data collected on the site. The report will also contain the justification used to explain why a site should get a certificate if some of the criteria have not be met.

Dissolved Inorganic Nitrogen

Nitrogen in the form of NH_4^+, $NO_2^=$, and NO_3^- present in the pore waters.

Dissolved Organic Nitrogen

Nitrogen in the form of short organic molecules (including amino acids) dissolved in pore waters.

Disturbed Assessment

For the Peatland Criteria, a disturbed assessment evaluates criteria components, landscape and vegetation in areas of a lease where the ground layer has been disturbed. The purpose is to evaluate reclamation success.

Disturbed Areas

Sites that are considered disturbed for the purpose of the Peatland reclamation criteria will include clay padded sites and any minimal disturbance sites that do not pass the undisturbed vegetation assessment. In some cases, even though padding was not conducted, traffic may have caused compaction, pulverized organic soil, rutting or clodding to the extent that the native plant community (i.e., species and/or layers) has been altered or removed (e.g., organic soils that were not frozen during later winter access).

Drainage

The removal of excess surface water or groundwater from land by natural runoff and percolation.

Ecological (or ecosystem) goods and services and services (EGS)

EGS are categorized as:

1. **Regulating Services** - benefits obtained from an ecosystem's control of natural processes: air quality regulation, climate regulation, natural hazard regulation, water regulation, erosion control and sediment retention, waste treatment, pest regulation, pollination;

2. **Supporting Services** - underlying processes that are necessary for the production of all other ecosystem services: soil formation, primary production, nutrient cycling, photosynthesis, water cycling;

3. **Cultural Services** - nonmaterial benefits people obtain from ecosystem services: ethical values, existence values, recreation and ecotourism; and,

4. **Provisioning Services** - the goods or products obtained from ecosystems: water supply, fiber, food production, genetic resources, biomass fuel, biochemicals, natural medicines, and pharmaceuticals.

Ecological site
A distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation. In a grassland environment, range site refers to a broader description of soil landscape (e.g., loamy, clayey, sandy, choppy sand hills) that might be further subdivided into ecological sites due owing to differences in plant community potential.

Erosion
The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

Evapotranspiration
The combined loss of water from a given area and during a specific period of time, by evaporation from the soil surface and bryophytes and by transpiration from vascular plants.

Facilities or Features Left in Place
In some cases, the landowner may wish to have roads or pads left in place. In these cases, the soil or vegetation criteria are not necessarily applied. In other cases, roads or pads may be left in place but will be expected to be vegetated (e.g., peat lands in agricultural areas, roads in Green Area). In these cases, some form of root zone must be established and the vegetation portions of the landscape criteria have to be met.

Fen
Minerotrophic wetlands that accumulate organic matter. Fen pore waters are variable in pH (4.5-8.5). Fens in continental boreal Canada may have moss, sedge, shrub, and tree vegetation components. The ground layer is moss-dominated.

Fine texture
Consisting of, or containing large quantities of the fine fractions, particularly of silt and clay.

Full Disturbance
Full disturbance sites are sites that have had soil disturbances across the entire site.

Flark
An elongated wet area that alternates with elongate dry ridges (strings) in patterned fens; always positioned perpendicular to direction of water flow.

Green Area
Public Lands General Land Classification. Forest lands not available for agricultural development other than grazing.

Groundwater
That portion of the hydrosphere which at any particular time is either passing through or standing in the soil and the underlying strata and is free to move under the influence of gravity.

Gullying
Erosion of soil or soft rock material by running water that forms distinct, narrow channels that are larger and deeper than rills and that usually carry water only during and immediately after heavy rains or following the melting of ice or snow.

Justification
Explanation of why a site should get a certificate if some of the criteria have not been met. This information must be included in the Detailed Site Assessment Report. It will require a more vigorous review by the Regulator before acceptance.

Land Manager
For Public Lands, this includes staff from from Alberta Environment and Parks or the Alberta Energy Regulator responsible for stewarding public/crown lands. For Provincial Parks and Protected Areas this will include staff from Parks in AEP. For Special Areas this will include the Special Areas Board. For Private Lands, this includes the landowner, their designate, or occupant.

Landowner
Person(s) holding the deed to the property.

Microhabitat
A locality at a small scale (generally < 1 m in size) distinguished by a particular set of environmental factors. In boreal peatlands, height above water level is a key environmental factor influencing individual microhabitats. This height above water level can be described as follows: Pools - permanently water-filled basins with some vascular plant vegetation. Carpets - areas with emergent populations of bryophytes generally from 5 cm below to 5 cm above water table, usually with sparse graminoid cover and a dominance of bryophytes. Lawns – areas from 5-20 cm above water table with graminoids and firm moss cover. Hummocks – are raised above water table 20-50 cm or more and characterized by shrubs and herbs along with hummock-forming bryophytes.

Minerogenous
Peatlands that are influenced by surface and ground water including waters in lakes, streams, and runoff.

Mire
A mire is a wet area dominated by living peat-forming plants.

Moisture Regime
For peatlands, it is the relative amount of wetness in the upper peat column, often designated by microtopographic levels, namely: pools (permanently water-filled basins with little vegetation); carpets (mosses floating and emergent from water, often forming unconsolidated mats -5 to + 5 cm from water level); lawn (moss surfaces from 5-20 cm above water level forming consolidated mats with sedges and forbs); and hummocks (moss surfaces raised 20-50 cm above water level as variable elliptic mounds dominated by dwarf shrubs).

Native species
A plant species that is indigenous to the Eco-site.

Offsite
See definition for “control”. Refers to information collected offsite against which collected information from a reclaimed site will be compared. The control information is collected offsite from adjacent or representative land.

Ombrogenous
Peatlands that are influenced solely from precipitation.

Onsite
Refers to information collected on the reclaimed site against which collected information from the control (i.e., offsite) will be compared. The control information is collected offsite from adjacent or representative land. See also definitions for “Lease” and “Access Road”.

Open Water and Ponding
Permanently water-filled areas without living, peat-forming vegetation (both vascular plants and bryophytes). When assessing the size of the open water/ponded area, the non-peat forming vegetation (such as submerged vascular plants), and surrounding non-peat-forming vegetation (such as cattails) are included in the area documented as open water/ponding.

Organic soil
An order of soils that have developed dominantly from organic deposits. The majority of organic soils are saturated for most of the year, unless artificially drained. The great groups include Fibrisol, Mesisol, Humisol and Folisol.

Organic Matter
The non-mineral fraction of soil, composed of plant and animal remains.

Paramater Point System
A grid failure calculation for the disturbed assessment based on five possible quantative paramater point components; Open water/ponding and Upland Eco-sites, desirable species cover, undesirable species cover, species richness, and if applicable the woody structural layer. Combined with the qualitative landscape assessment, determines a site pass/fail.

Parent material
The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil is developed by pedogenic processes.

Peat
The remains of plant and animal constituents accumulating under water-saturated conditions owing to incomplete decomposition.

Peatlands
Areas covered by peat to a minimum depth of 40 cm.

Pits
For the purposes of these criteria, the term Pits refers to a borrow pit from which earth was removed for constructing the Lease and/or the access.

Public Lands
Land of the Crown in right of Alberta.

Reclamation certification
A reclamation certificate indicates that the reclaimed site has met equivalent land capability as defined by the reclamation criteria.

Reclamation
The process of returning disturbed land to equivalent land capability.

Reduced Electrical Conductivity
A measure of total ions in a water solution minus the contribution resulting from H+, calculated following Sjors (1952).

Regulator
For the purposes of the Reclamation Criteria for Wellsites and Associated Facilites, this refers to Alberta Energy Regulator.

Remote sump
Constructed pit, used for temporary storage and/or containment of liquids and solids produced from the site.

Rilling
A rill is a narrow, very shallow, intermittent watercourse having steep sides.

SAR (Sodium Adsorption Ratio)
The proportion of sodium on the soil exchange complex in relation to the proportion of calcium and magnesium.

Saline Fens
Minerotrophic wetlands having high amounts of Na+ as the dominant pore water ion and that may accumulate organic matter. No moss-dominated ground layer is present.

Site
Means the wellsite, pipeline, access road and any other associated facility (e.g., campsite, borrow pit, offsite sump, log deck).

Sodicity
A measure of the amount of sodium on the exchange complex (often estimated by sodium adsorption ratio – SAR).

Soil pH
The degree of acidity or alkalinity of soil, expressed as a pH value.

***Sphagnum*-dominated ground layer**
A ground layer with greater than 80 per cent cover of *Sphagnum* (peat moss).

Species Composition
The different kinds, amounts, and proportions of plants present on a revegetated disturbed area. These can be bryophytes, graminoids, forbs, shrubs, or trees.

Specified Land
For the purposes of these criteria, the term Specified Land, means land that is being or has been used or held for or in connection with the construction, operation or reclamation of a well, battery or pipeline (excerpt from the Conservation and Reclamation Regulation (115/93))

Structural Layers
The vegetation of peat-forming wetlands is organized into 1 or more structural layers: These structural layers are: Ground layer: The layer of vegetation at ground elevation consisting of bryophytes and lichens. Field layer: The layer of vegetation consisting of herbs, forbs, and graminoids (in peatlands graminoids are mostly Cyperaceous plants (sedges and rushes). Shrub layer: The layer of vegetation consisting of woody multi-stemmed plants, in peatlands these are often dwarf Ericaceous shrubs. Tree layer: The layer of vegetation consisting of woody plants with one central stem, in boreal peatlands usually either *Larix laricina* (Larch) or *Picea mariana* (black spruce).

Third-party impacts
Non-operator activities such as recreational or industrial use, trails, bale storage, or wildlife.

Trajectory
The probable course of plant community development through a series of dynamic changes in ecosystem structure, function, and species composition over time (adapted from Dictionary of Natural Resource Management, UBC Press, 1996)

True mosses
A generic term for peristomate mosses, excluding mosses in the genus *Sphagnum* (peat-mosses). Many of these species of true mosses that occur in peatlands are brown in color and have been called ‘brown mosses’ in some literature.

Undesirable species
Upland species, marsh species (species associated with non-peat forming wetlands), non-native or agronomic species are indicators of an inappropriate trajectory.

Undisturbed Assessment
A Peatland reclamation assessment that is designed to determine if the original ground cover layer is intact. The purpose is to evaluate reclamation success or to identify any anomalies requiring more in-depth assessment (more detailed landscape and vegetation parameters).

Undisturbed Areas
Activities that utilize minimal disturbance techniques, such as construction in frozen conditions, may result in a site that for the purpose of these reclamation criteria is classified as undisturbed. Undisturbed is defined as a peatland with the original ground cover layer intact. The undisturbed vegetation assessment is designed to determine intactness.

Water table
The upper surface of groundwater or that level below which the soil is saturated with water.

Weed
An undesirable or unwanted plant. Prohibited noxious and noxious weeds must be managed as per the Alberta *Weed Control Act* and/or the local authority.

Wetland
Land that has the water table at, near, or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment.

White Area
The white zone is the settled areas of Alberta. This includes privately owned lands as well as public lands in this area, which are suitable for the proposed use and are not required for conservation, recreational, wildlife habitat, forestry and other purposes, may be applied for pursuant to the *Public Lands Act* and associated regulations.