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Final Report for AUPRF Project

Assessing Peatland Restoration Success to Meet Alberta's Peatland Reclamation Criteria

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ABSTRACT

We conducted a full peatland assessment using the new criteria on a restored well pad near Peace River, Alberta. In 2012, mineral overburden was removed along with geo-textile and the buried peat was fluffed and gently packed to the surrounding peatland elevation, followed by donor moss transfer. We found that after three years post revegetation, the average peatland species cover is close to 60% for all grids surveyed. Landscape assessment showed no presence of open water or upland features although areas near the main entrance are seasonally flooded and remained wetter than the remainder of the pad throughout the seasons. Vegetation assessment found greater undesirable species cover in these wetter areas where no donor moss material was transferred, leaving the site open to invasion by undesirable species such as cattail. These areas also failed the woody species criterion without tree establishment due to wetness. However, only 1 out of the 9 grids failed the undesirable cover criterion (27%; where 20% = fail). Out of a possible 45 parameter points, our site scored 40 points, exceeding the 36 required to pass.

We will discuss the process for the site evaluation based on the methods outlined in the criteria and our assessment of the methodology in terms of clarity, scientific rigor, and most importantly, ease of use. Three new peatland reclamation trials have been initiated since 2015 using modified approaches from the first trial. We will discuss how we developed our reclamation approaches to address key areas in the criteria to meet the certification requirements in the future. Survey templates and technical notes for practitioners are also included as part of this final report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The present study assesses peatland restoration success in the Peace River area using the newly released "Reclamation Criteria for Wellsites and Associated Facilities for Peatlands". The primary goal was to evaluate the applicability of the newly released criteria and to use the criteria as a guiding document for future peatland reclamation trials. Key deliverables include: 1) operational scale demonstration of successful well site restored to functional peatlands; 2) assessment of the newly released criteria and provision of feedback; 3) cost-benefit analysis of reclamation practices and key factors contributing to meeting the criteria; 4) provision of knowledge and technologies to SMEs and industry partners; and 5) development of HQPs specializing in peatland restoration.

We received the award letter in August 2015 with an end date of December 15, 2015. Given the short duration of the funded project in 2015, the key objectives of the 2015 project were to: **1) assess the criteria in terms of practicality and scientific rigor (Appendix I), and 2) adopt the criteria in the planning and operation stages of future well site reclamation trials (Appendix II, III, and IV)**.

Study 1: Assessing Well Site Restoration and Evaluating Criteria: Inversion Trial #1 (IPAD)

Site Background:

The NAIT Inversion Pad trial #1 (IPAD) is located 50 km northeast of the Town of Peace River. Prior to disturbance, the site was a treed, poor fen. Shell Canada built the 1.27 ha site in 2006 with borrow clay material (Figure 1 left). Civil earth work of the reclamation project started in November 2011 with the removal of a clay pad using a combination of six different clay removal and peat inversion techniques, followed by moss donor transfer in the summer of 2012 (Figure 1 right). A detailed step by step site preparation and moss transfer method can be found in **Appendix II** of this report. Partnered with university researchers, NAIT Boreal Research Institute has been closely monitoring the vegetation establishment, hydrological connectivity, and overall restoration success on the site since 2012.

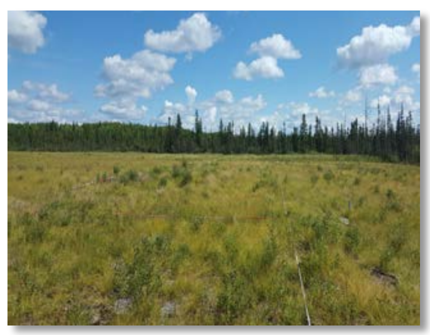

Figure 1. Inversion Pad (IPAD) trial #1: Pre-restoration in 2011 (left) and three years (summer 2015) after donor transfer (right).

The ultimate goal of this research trial is to restore the well pad to a functional peatland with connected hydrology and sustainable peatland vegetation. This trial provides a perfect opportunity to test the newly released criteria since there are not many reclaimed and ready to certify well pads in northern Alberta.

Site assessment using the new criteria on IPAD originally started with a test run in September 2015. The full pad assessment was completed in October, when most vegetation had senesced but was still identifiable. Ideally, vegetation surveys such as this should be conducted during the peak growing season of around mid- to late summer (in July/August).

Site Assessment:

A summary of the assessment process and a datasheet template is included in **Appendix I** of this report.

Disturbed vs. Undisturbed:

Once it is determined that the reclaimed site should be assessed as a peatland, the first decision to make is whether a disturbed or undisturbed assessment should be completed. Undisturbed is defined as a site that has experienced minimal impact and still has the original, intact ground layer. An example would be winter oil sands exploration (OSE) wells without significant stripping/compaction. Disturbed sites usually apply to clay pads and minimally disturbed sites with significant compaction/rutting etc. The original ground layer is perturbed and no longer considered intact even though no padding was used during construction. Our clay pad falls under the disturbed category.

The criteria provide a decision tree for choosing the correct assessment for each site (Figure 2), particularly for sites that were not padded but considered disturbed. In our case, the surrounding area does have woody species present and is dominated by *Sphagnum* spp. (over 80% canopy). There are more than 1 stem/grid woody plants (or 25% of canopy cover) onsite but *Sphagnum* spp. cover is significantly less than the 60% required to be considered undisturbed. Therefore, the disturbed assessment is the appropriate method to use.

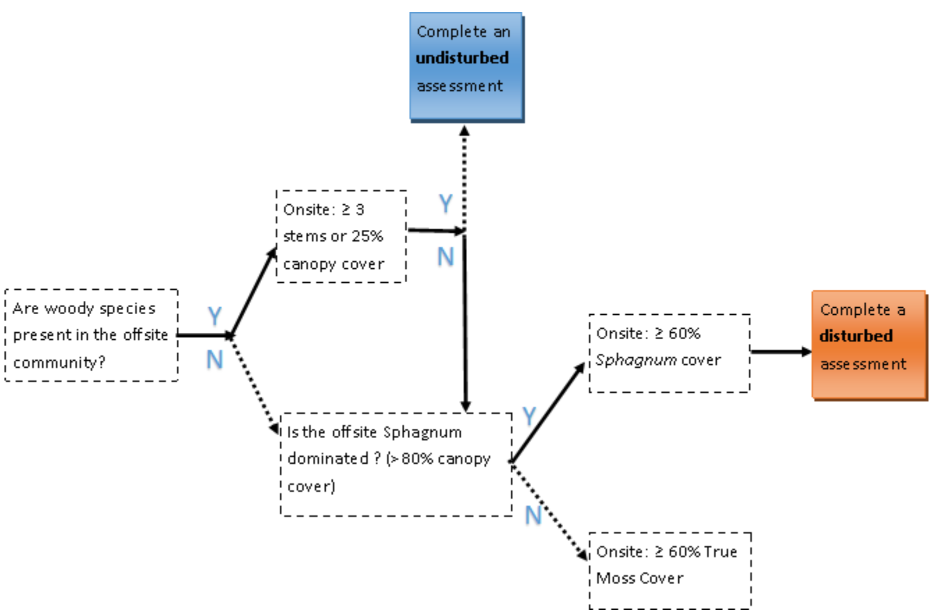

Figure 2. Decision tree for an undisturbed assessment. We used the same process and determined that a disturbed assessment is needed. Solid arrows indicate the selection process. From the Criteria.

Landscape Assessment:

The 120 m by 120 m site was delineated into 9 grids (Figure 3 right and Figure 4 left) according to the criteria (Figure 3 left) (Alberta Environment and Parks 2015). Landscape level assessments were conducted both on site within each grid and off site in four locations in the surrounding peatlands. This entailed determining whether general hydrological conditions promoted peatland species establishment, and that the area was neither a dry upland nor a cattail pond. The presence of erosion, industrial debris, and gravel/rock were also noted in the survey.

Disturbed Assessment		
Maximum disturbance size (m)	**Minimum number of onsite grids**	**Offsite Assessment**
Up to: 40 m x 40 m (1600 m²)	1	Landscape Overview
80 m x 80 m (6400 m²)	4	
120 m x 120 m (14, 400 m²)	9	
>120 m (>14, 000 m²)	9 (+1 more for each additional 1600 m²)	
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 m²)	

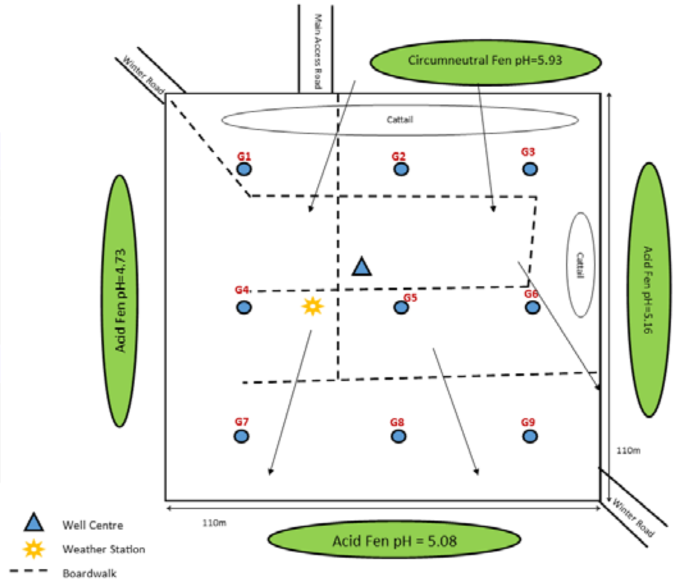

Figure 3. (Left) Sample intensity based on the type and size of the site. From the Criteria; (Right) Site sketch of inversion trial #1: IPAD.

Peatland Type and Desirable Species Lists:

Within each grid, the site characteristics, such as moisture regime, pH and EC are used to determine the peatland types on site. Our site soil is organic (peat) and moist with periodic flooding in the spring and with vegetation overall indicates a wetland/peatland environment.

A characteristic species list for each peatland type is provided to decide if a species is a desirable peatland species or an undesirable species. When conducting a disturbed assessment, there is no requirement to use a species list for a specific peatland type. It is recommended that the best fit species list, by peatland type, should be used for the site. **Our interpretation is that when conducting a disturbed assessment, any species found in the desirable species lists, regardless of peatland type, will be considered a desirable species.** More on this topic in the discussion and comments sections.

The criteria did not specify the methods that should be used to measure EC and pH onsite. In practice, both pore water and peat can be used to measure EC and pH. Even though we have surface water wells installed across the site, we chose to use surface peat samples as most sites will not have wells on site at the time of assessment. Samples were collected across the site at the end of August and analyzed in our lab to determine the average EC and pH of each grid. Onsite pH ranged greatly between grids and among sampling points within each grid (Table 1). Therefore, we chose to combine the range of measured pH within each grid to determine the peatland type and the corresponding species list to use (see discussion section).

Table 1. Five peatland types identified in the Criteria. From the Criteria.

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)		

Vegetation Assessment:

Both species richness and species percent cover (desirable and undesirable species) were surveyed for each grid. The species richness assessment was completed using a timed (15 min) meandering assessment to record species encountered from all strata.

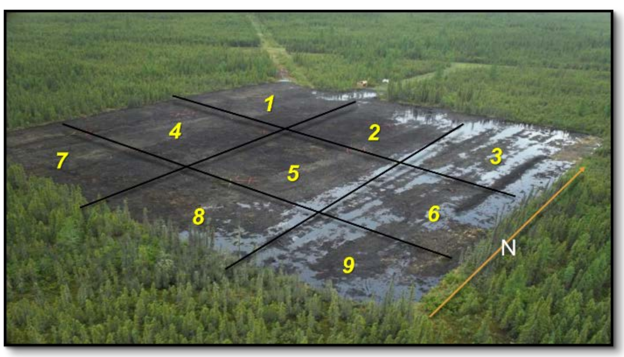

Figure 4. Aerial view of the nine survey grids (left). Assessment of ground layer vegetation using the recommended 1 m quadrat (right).

For the field, shrub and tree layers, a 10 m^2 vascular plant plot was centered on a representative area of each grid, and both desirable and undesirable vascular species percent coverage were recorded. Tree stem count for desirable species (black spruce and larch) within the plot was also recorded. Undesirable species such as balsam poplar were not included in the stem count, and were instead recorded as percent coverage in the undesirable species coverage. Shrubs (including willows) were captured using percent coverage.

For the ground layer vegetation, primarily peat forming bryophytes, five 50 cm quadrats were assessed for percent coverage (all species considered desirable). We chose the 50 cm quadrat instead of the recommended 1 m × 1 m quadrats because the smaller quadrats allowed easier and more accurate assessment of small vegetation that would otherwise be masked by vascular plants at the larger scale (Figure 4 right).

A timed species richness assessment (5 min) was also conducted on each side of the site in the natural areas to gain a sense of the natural setting's vegetation.

Site Monitoring:

In addition to the proposed project to assess site progress using the methods outlined in the criteria, we also aimed to understand the driving factors contributing to early success/failure on site. Specifically, we have been studying and monitoring hydrological connectivity, site chemistry, and carbon fluxes since the initial donor transfer in 2012.

Water table level (WTL) and water pH, electrical conductivity and temperature were monitored in surface water wells across the pad and the surrounding peatland. Wells were categorized by the distance from the pad, with wells on the pad being represented by distance 0, and distances 2, 50 and 100 m for wells away from the edge of the restored pad in the natural area.

Examples of the monitoring results are shown below. Site chemistry (pH, EC) and moisture regime varied significantly over the growing season (Figure 5 left). Moss cover increases with decreasing EC while *Carex* prefers high EC environments (Figure 5 right).

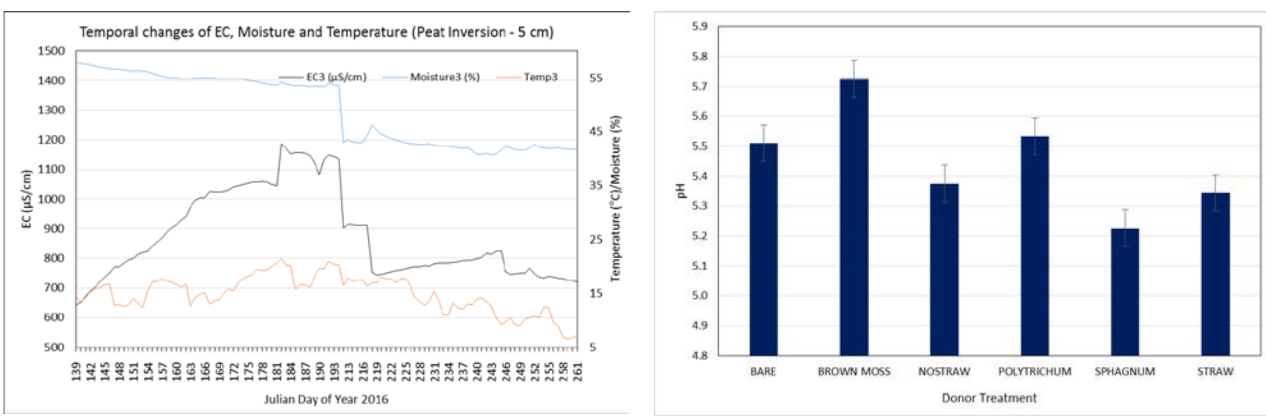

Figure 5. (Left) Temporal fluctuation of EC, moisture content, and temperature 5 cm below the surface in the Peat Inversion treatment. (Right) Spatial variation of pH among different donor treatments.

Study 2: Using the Criteria as a Guide for New Peatland Reclamation Trials: Pads 13-29 and 8-22 (Inversion Trials #2 and #3) and Woody Chip Road (Inversion Trial #4)

Beyond assessing the criteria, the information provided within the criteria can be used as a guideline to plan and design reclamation trials to meet the target results. For example, peatland types and the associated desirable peatland species list can be used when choosing revegetation strategies after site preparation is completed.

In this study we developed site preparation and revegetation plans based on refined pad removal and moss transfer methods tested on the first inversion trial (IPAD). Refer to **Appendices III** and **IV** for more details on field operation.

Figure 6. (Left) Inversion trial #2 as the pad is being removed and peat being inverted. (Middle) the chip winter road before reclamation; (Right) The chip winter road after the peat inversion.

Inversion Trial #2: Pad 13-29

Site civil earth work was completed by Shell contractors in February, 2015 (Figure 6 left). The clay pad and geo-textile were removed off site to the original borrow pit. The upper layer of the clay was removed and buried beneath peat in areas where the peat was greater than 1 m deep. The surface peat was fluffed and the entire site contoured to an elevation equal to the hollows of the surrounding natural area (see **Appendix III** for more information). Donor moss was collected from an adjacent cutline and spread in April, 2015. The moss was then covered by straw mulch.

Fertilizer will be applied by NAIT to the site in spring, 2016, with small experimental plots to assess the effect of two fertilizer types. Black spruce trees will also be planted on the site by Shell contractors. Water table measurements, chemistry and annual vegetation assessments will be completed by NAIT to monitor the establishment of the ground layer and assess the success of the planted trees.

Inversion Trial #3: Pad 8-22

The site civil earth work for Pad 8-22 was partially completed by Shell contractors in March, 2015 and finalized in November, 2015. 70% of the pad was removed to the original borrow pit in February, 2016, until warm weather conditions made the site further inoperable. The remaining 30% of the pad and geo-textile were removed in November of 2015. The underlying peat surface was inverted and fluffed. The peat surface was then bladed to achieve a contoured elevation roughly 5–10 cm lower than the surrounding natural hollows. An additional 50 m of the access road opening up to the pad and crossing through the surrounding natural peatland was also restored to a peat surface. Donor moss material was collected from a nearby cutline and spread across the site, including the restored road section, followed by straw mulch.

Fertilizer will be applied by NAIT to the site in spring, 2016, with small experimental plots to assess the effect of two fertilizer compositions. Black spruce trees will also be planted on the site by Shell contractors. Water table measurements, chemistry and annual vegetation assessments will be completed by NAIT to monitor the establishment of the ground layer and assess the success of the planted trees.

Inversion Trial #4: Chip Road 13-29

The chip road civil earth work was completed over two days in February, 2015 (Figure 6 middle and right). The wood chips were stripped off the surface and inverted with the underlying peat (**Appendix IV**). The surface was contoured to be about 30 cm higher than the surrounding natural area as it was expected the road would settle with rain and the flow through hydrology perpendicular to the road. Drought conditions in 2015 led to the road not settling as much as anticipated, so a dozer was brought in August, 2015 to further compact the surface elevation to match the surrounding area.

The site will be planted by Shell contractors with black spruce and larch in 2016 and compared to control plots to assess the necessity of planting. Annual vegetation assessments will monitor the natural ingression of the field layer and assess the success of the planted trees.

BACKGROUND

Boreal peatlands are some of the world's most valuable and unique ecosystems by virtue of their diverse functions and services. Over one third of the global soil carbon is stored in boreal peatlands in the form of peat (Tarnocai et al. 2009, Vitt and Bhatti 2012). The mean atmospheric CO_2 concentration could double if all the stored C in peatlands was released as CO_2 (Turetsky et al. 2002, Vasander and Kettunen 2006). At the landscape and watershed level, peatlands play a critical role in regulating water flow and supplying clean water, protecting against heavy floods and erosion, providing habitats to unique fauna and flora, and sequestering atmospheric CO_2 (Wieder et al. 2006).

In Alberta, wetlands (mainly peatlands) account for 17% of the total land area. In the boreal region of northern Alberta, peatlands dominate the landscape with coverage as high as 70% (Halsey et al. 1998, 2000, 2003). Alberta's boreal peatlands are facing increasing pressure with the rapid development and expansion of the energy sector. Industrial activities in the boreal region include the construction of well pads, roads, pipelines, and seismic lines (Vitt and Bhatti 2012).

Research efforts on restoring peatlands disturbed by resource exploration, particularly oil and gas extraction, in Alberta are mainly focused on the open pit-mining area near Ft. McMurray (Cumulative Environmental Management Association (CEMA) 2014). However, the majority (90%) of Alberta's oil and gas deposits are too deep for open pit mining (surface mineable) (Alberta Energy Regulator 2015). These deep deposits will have to be extracted by in-situ enhanced development methods such as cyclic steam stimulation (CSS) and steam assisted gravity drainage (SAGD). In-situ bitumen production has increased dramatically over the last few years. In 2014, crude bitumen production (daily output) by in-situ extraction (201.2×10^3 m^3/day) has exceeded that produced by open pit mining (165.1×10^3 m^3/day) (Alberta Energy Regulator 2015) (Figure 7). There are currently 11,500 well pads in production across Alberta, with many more added every year. More importantly, Alberta has 52,831 unreclaimed oil and gas wells as of 2012, 68% of which were abandoned in the last decade (Alberta Energy Regulator 2015). As the number of abandoned wells continues to outpace those that are reclaimed, new management targets and restoration technologies are essential, not only for industry growth, but for the health of the boreal region in Alberta. The alarming trend of increasing in-situ bitumen production highlights the urgent need for better planning, management, and mitigation measures to meet the reclamation obligations. Without proper foresight and long term planning, exponential growth in the energy sector and industrial activities will take a significant toll on the environmental health of Alberta's northern boreal forests and the long-term economic growth of Alberta and Canada.

Oil and gas and forestry companies are liable for reclaiming the disturbed lands and their associated linear features, but it is the small- and medium-sized enterprises (SMEs) that carry out most of the reclamation work. The industry's need for efficient, cost-effective reclamation methods and techniques has never been greater to meet government regulatory requirements. In recent years, energy and forestry sectors have been actively developing best management practices to lessen the impact of industrial activities on wetlands. However, research on restoring disturbed peatlands has just begun and development of practical and effective techniques and methods specific to peatland restoration remains in the early stages. Significant gaps remain in our understanding of peatland ecology and the restoration of disturbed peatlands to be naturally appearing and self-sustaining over time (Graf 2009, Vitt and Bhatti 2012, Cumulative Environmental Management Association (CEMA) 2014). More importantly, there is an urgent need for dialogue between restoration ecologists and policy makers to narrow gaps between the expectations set by offset policies and offsetting practice carried out by practitioners and SMEs (Maron et al. 2012). The changing regulatory environment, e.g. newly released Alberta Wetland Policy 2013, represents a significant shift from returning land to equivalent land capabilities towards the restoration of ecosystem functions and services. The energy sector is faced with even greater challenges to develop and employ innovative peatland restoration techniques to meet the regulatory requirements.

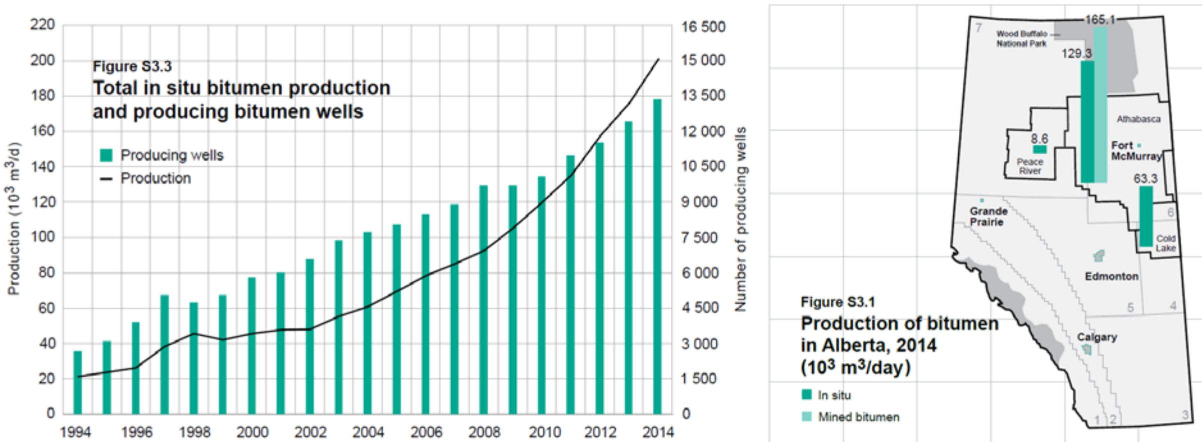

Figure 7. (Left) Total in situ bitumen production and the number of producing wells as of end of 2014. (Right) Daily production of bitumen by oil sands regions. The combined production by in-situ is 201.2 10^3 m^3/day. From AER Report ST98 2015.

The main effects on peatlands caused by resource extraction activities, including in-situ well pads and associated linear features, are: 1) fragmentation of the landscape and destruction of habitat, 2) altered hydrology by compaction and drainage, 3) physical and chemical changes in soil and water properties, 4) ultimate loss of ecosystem function and service. However, the cumulative impacts of industrial development on boreal peatlands are difficult to assess given the transient and interconnected nature of wetlands to both upland forests and major water bodies on the boreal landscape (Wieder and Vitt 2006, Vitt and Bhatti 2012).

Restoring peatlands in the in-situ oil sands region of northern Alberta presents a set of challenges that have yet to be properly addressed. The lack of proven, cost-effective methods for restoring peatlands, coupled with a tightening regulatory environment suggests that peatland restoration will likely result in substantial long-term liability, possibly even limiting further development for the oil sands resource. Expanding the array of restoration methods and technologies for peatland management and restoration is of utmost urgency given the importance of energy sector to Canada's overall economic wellbeing.

The Peatland Restoration program at NAIT BRI is adopting an innovative approach towards peatland restoration based on the North American Peatland Restoration protocols developed for the peat industry in Eastern Canada. This comprehensive approach includes multiple steps with the ultimate goal of recreating a suitable peat surface hydrologically connected with the surrounding peatland that is biologically inductive to re-establishment of peatland vegetation. Our first full pad-scale pilot project, the Inversion Pad Trial 1, was initiated in the winter of 2011. The clay pad was completely removed and back filled into the original borrow pit, followed by re-contouring of the peat surface, donor material transfer and monitoring (Figure 8). A detailed step by step site preparation and moss transfer method can be found in **Appendix II** of this report.

In this peatland research trial, we tested the feasibility of establishing a vegetation community characteristic of natural peatlands by removing clay fill and restoring a peat surface followed by donor material transfer. Several different operational techniques were used to remove the clay pad and to create a suitable peat surface for re-vegetation. We've simplified these different methods into three main treatments: **Peat Inversion**, **Clay Inversion**, and **Mixed Inversion**, based on the inversion process and the presence/absence of clay under the peat (Figure 8).

The inversion process involved the removal of the clay pad (along with geo-textile) and the re-profiling of the exposed peat, either with (Clay Inversion) or without the addition of clay (Peat Inversion) underneath the 40 cm of peat to raise the surface to the desired elevation. The Mixed Inversion, on the other hand, only removed the majority of the clay pad. The remaining clay (~20 cm) along with the underlying geo-textile and buried peat (40 cm) was ripped up and flipped to expose the peat on top (Figure 8).

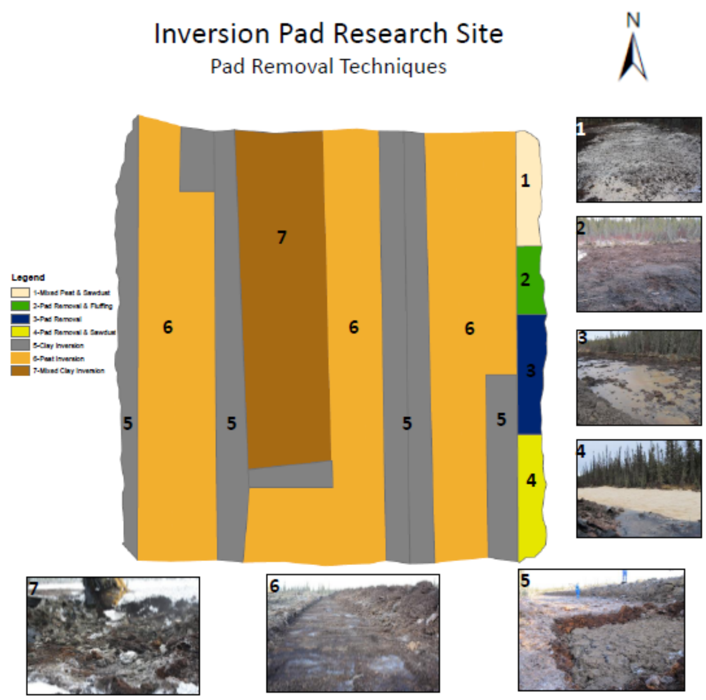

Figure 8. Sketch of the pad removal and peat inversion processes. Methods 1-4 were testing strips. The pad was mostly removed using three methods: Clay Inversion (5), Peat Inversion (6), and Mixed Inversion (7).

Moss fragments, along with roots, rhizomes, seeds, and spores were collected from three distinctive communities (*Sphagnum* dominated, Brown moss dominated, and *Polytrichum* dominated) from the surrounding cutlines and winter roads (Figure 9). The *Sphagnum* dominated community and Brown moss dominated community were mixed with fragments of *Polytrichum strictum* in a 1:1 ratio. *Polytrichum* is an early successional species known to improve soil conditions that favour the establishment of a peat-forming moss carpet. The *Polytrichum* dominated community was also tested as a stand-alone treatment, without mixing in any other donor materials. The top 10 cm of the moss carpet from each donor site was harvested and collected and spread across the restored site. Two areas with no moss introduction (bare peat and straw covered peat) serve as controls to quantify the differences between the transfer of donor materials and the lack of donor materials on the re-vegetation success, particularly for moss species establishment.

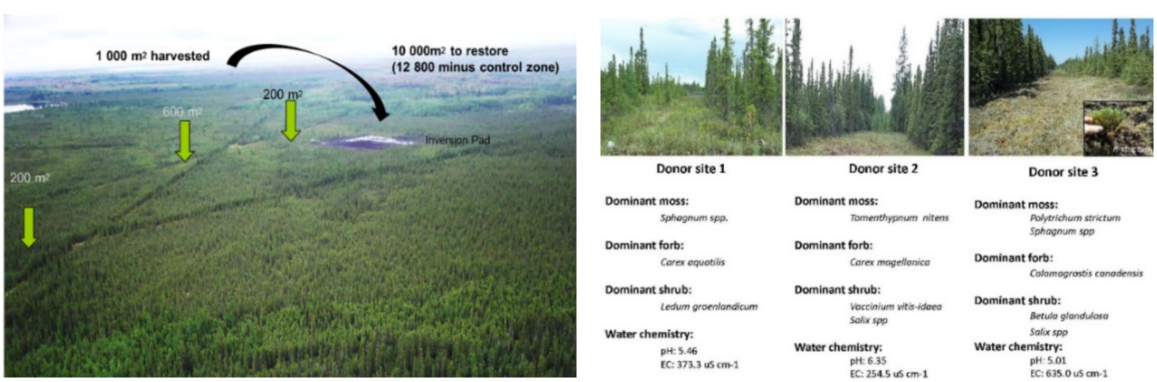

Figure 9. (Left) Aerial view of the cutlines from where donor materials were collected. (Right) Three types of communities were targeted in the collection process.

METHODOLOGY – SITE ASSESSMENT AND ADDITIONAL RECLAMATION TRIALS

Methods used in the two proposed studies are presented here in a consistent format corresponding to the criteria. Each study has two main foci, **landscape and vegetation**, and within each there are several additional key considerations. In study I, we present the assessment process on landscape and vegetation components to evaluate the criteria. In study II, we focus on how we developed reclamation strategies to meet the requirements and address the landscape and vegetation considerations to facilitate site recovery towards a certifiable state in the future.

Study 1: Assessing Well Site Restoration and Evaluating Criteria: Inversion Trial #1 (IPAD)

Detailed pad removal and donor transfer process information is presented as a technical note (**Appendix II**). Here we focus on how we assessed the landscape and vegetation components on site as required by the criteria.

Inversion Trial #1: IPAD

Landscape Parameters

1. **Moisture Regime**
   Onsite soil is hydric/sub-hydric peat with periodically flooding during the spring. Average water table is 48 cm below surface at the time of survey.
2. **Open Water/Upland**
   There was no open water or upland ecosites present onsite at the time of survey. However, there were dense stands of cattails near the main entrance and at the southeast outlet (Figure 3), indicating periodic flooding and ephemeral ponding during some part of the growing season. Since cattail is included in the vegetation assessment as an undesirable species, we do not consider areas with high cattail as open water.
3. **Offsite Drainage**
   There was good cross-site drainage and connectivity with the surrounding peatlands. The general flow direction is from north to south (Figure 3).
4. **Riparian Areas**
   There was no riparian areas present on site.
5. **Erosion**
   There was no erosion onsite.
6. **Bare Areas**
   The entire pad is covered by vegetation, either vascular or ground layer bryophytes.
7. **Gravel & Rock**
   There was no gravel or rock or any other types of mineral materials onsite.
8. **Industrial Debris**
   There was a weather station and other approved research equipment onsite. No other industrial debris is present.

Vegetation Component

Onsite pH ranged from 4.66 to 6.05 and EC ranged from 581 to 1898 µs/cm. All survey grids except one are identified as acid fen according to the criteria. However, the species list used to determine the desirable/undesirable species is not peatland type specific. Any species found in the species lists for bog, acid fen, circumneutral fen, alkaline fen and saline fen were considered desirable.

1. **Species Richness**
   Species richness ranged from 12 to 17 during the timed meandering survey in 9 grids. A list of identified species is included in this report (Table 1).
2. **Desirable Species**
   Desirable species coverage is the combined estimate of all species in the ground and field layers, excluding trees. Total desirable species coverage ranges from 80% to 136% with all grids passing the required threshold of 50%. Bryophyte coverage is not required to be estimated by species.
3. **Non-Desirable Species**
   Undesirable species coverage varied between 1 to 27%. Only one grid failed the criterion (20%). Major undesirable species are *Typha latifolia* in low-lying areas and *Deschampsia cespitosa* in the dryer areas.
4. **Stem Count**
   Number of woody stems ranged from 0 to 12. Four of the 9 grids did not meet the minimum threshold (1 stem).

Study 2: Using the Criteria as a Guide for New Peatland Reclamation Trials: Inversion Trials #2 & #3 and Inversion Trial #4

These two additional well pads were reclaimed in 2015 using modified approaches based on Inversion Trial #1 (IPAD), though the exact procedures differ and the site reclamation was completed at different times due to weather delays on Pad 8-22. However, the approaches we took to address the landscape and vegetation considerations in the criteria were similar for both sites. A detailed description of the reclamation process can be found in the technical note (**Appendices III and IV**).

Inversion Trials #2 & #3: Pad 13-29 and 8-22

Landscape Parameters

All of the landscape parameters were addressed by the civil earth work site prep for Pad 13-29 completed in February of 2015 and November 2015 for Pad 8-22.

As replicates of the IPAD, the clay pad and geo-textile on both pads were fully removed off site and buried in a borrow pit (gravel and rock, industrial debris).

Under Pad 13-29, about one third of the site was found to be an upland ridge. In the areas with deep peat, dirt exchange was completed. The upper layer of the clay was removed and buried beneath peat in areas where the peat was greater than 1 m deep. Peat 10–15 cm deep replaced the skimmed off clay material, creating a shallow peat surface where the ridge was located. This was to create a uniform peat surface that would supposedly support peatland vegetation. This is not a recommended practice but was completed at the consultant’s request. This information is not included in our technical notes for practitioners to adopt.

The surface peat of the deep areas was fluffed to ensure lateral subsurface flow and the entire site contoured to an elevation equal to the hollows of the surrounding natural area, with the expectation that the site would settle about 5 cm (moisture regime, open water/upland, erosion). Careful attention was paid to ensure no clay remained along the edges that would block surface offsite drainage.

Deep peat was found under Pad 8-22, so the peat surface of the entire site was fluffed and smoothed to a flat surface contoured and feathered into the natural surrounding (erosion, offsite drainage). Based on the dry conditions of 2015 along with further drought expected in 2016, the target elevation of the surface was at least 10 cm below that of the natural hollows (moisture regime, open water/upland) to ensure wet enough conditions for moss establishment in the first growing season.

No pits were left open on either site preventing the formation of riparian zones, and vegetation was reintroduced to both sites to prevent bare areas from remaining.

1. **Moisture Regime**
   Peat surface was decompacted/fluffed to restore lateral subsurface flow with the natural area and target elevation relative to the surrounding area was to create saturated, but not inundated surface.
2. **Open Water/Upland**
   For Pad 13-29 (completed in Feb 2015), target surface elevation was identical to those of the hollows of the natural area as we expected to see about 5cm of settling (which did not occur due to drought conditions in 2015).
   For Pad 8-22 (completed Nov 2015), target elevation about 10cm lower than the hollows of the natural as we were concerned about extra dry conditions due to drought effecting the successful establishment of the donor moss, based on the performance of the donor moss of Pad 13-29 in the summer of 2015, a severe drought year.
3. **Offsite Drainage**
   Clay was completely removed from pad and edges were feathered to remove any potential barriers. The overall site was contoured into the natural area.
4. **Riparian Areas**
   Buried, compacted peat was fluffed and elevated, sometimes with buried clay when necessary to reduce significant depression areas onsite.
5. **Erosion**
   The recreated peat surface is flat and at target elevation gently contoured into the natural areas. There shouldn't be any erosion.
6. **Bare Areas**
   Vegetation was introduced as donor materials evenly across the entire site, leaving no bare areas.
7. **Gravel & Rock**
   Clay and any other mineral materials were removed off site and buried. There is no gravel or rock onsite.
8. **Industrial Debris**
   Geo-textile was completely removed off site and buried.

Vegetation Component

Identical revegetation strategies were used on Pad 13-29 (April 2015) and Pad 8-22 (November 2015) as the IPAD. The strategy targeted establishing the bryophyte and field layer of desirable species in a single approach. A donor moss transfer was utilized from cutlines in the surrounding areas of each pad to introduce live moss fragments as well as vascular plant diaspores (rhizomes, seeds, roots) across the site (species richness). The target communities chosen were representative of peatland communities present in the local landscape and included on the criteria's desirable species list.

The planned undesirable species management is minimal, and is mostly ensured by restoring appropriate hydrological function and moisture levels on site combined with introducing desirable vegetation to limit the available space for undesirable invasion. Both sites will be monitored closely in the 2016 season to ensure vegetation establishment under the expected drought conditions, and undesirable species will be hand pulled to limit their establishment and possible early dominance on site.

As a tree layer (stem count) is present in the surrounding natural areas around each pad, trees will be planted on each site in 2016 to ensure their early establishment on the site.

1. **Species Richness**
   Species rich donor materials (moss fragments and plant diaspores) were spread across site to restore the bryophyte and vascular layers.
2. **Desirable Species**
   Donor material was collected from nearby cut-lines in the same peatland complex.
3. **Non-Desirable Species**
   Correct site preparation combined with early introduction of target peatland donors should out-compete undesirable species. Any undesirable species will be hand pulled.
4. **Stem Count**
   Black spruce seedlings will be planted in 2016.

Inversion Trial #4: Chip Road 13-27

Landscape Parameters

The construction of the chip road did not introduce any gravel and rock or industrial debris onto the site and, therefore, did not need to be addressed.

The wood chips were inverted under the buried peat in February 2015. The presence of the chips at the surface did not impede drainage on the surface and will not impede it at depth. The peat surface was smoothed and tapped down to an elevation 30 cm higher than the adjacent natural area with the expectation of settling in the spring. This did not occur due to severe drought conditions leaving the surface unsuitably dry; therefore, in August of 2015, the road was track packed to an identical elevation as the adjacent road to promote a saturated surface (moisture regime, open water/upland). The surface was left smooth and flat to promote offsite drainage and prevent erosion and because no differences in surface grade were introduced, there is no formation of riparian zones.

Vegetation was not initially planned to be introduced to the site as the road is narrow with highly available seed sources on both sides (bare areas).

1. **Moisture Regime**
   Chips were buried beneath inverted peat to create a moist peat surface appropriate for vegetation.
2. **Open Water/Upland**
   The reclaimed site elevation was originally 30–40 cm higher than adjacent area due to lack of precipitation in summer 2015. It was track packed in late summer to compensate for lack of settling. The lowered surface was hydrologically connected with the natural area and suitably saturated without creating a pond.
3. **Offsite Drainage**
   Buried chips do not impede drainage.
4. **Riparian Areas**
   No grade was created that would create a riparian area and no pits were excavated.
5. **Erosion**
   A flat surface at identical elevation as the adjacent area will illuminate possible erosion.
6. **Bare Areas**
   Due to the close proximity of nearby fen, natural ingress of sedges and seed rains of larch and birch should be enough to re-vegetate the reclaimed areas. Additional trees will be planted in rows to speed up woody establishment.
7. **Gravel & Rock**
   None introduced on site - N/A.
8. **Industrial Debris**
   None introduced on site - N/A.

Vegetation Component

Vegetation was not initially planned to be introduced to the site as the road is narrow with highly diverse available seed sources along both sides (species richness, desirable species). It was also expected that sedges and marsh cinquefoil will naturally ingress through rhizomes from the road edges. Correct site prep combined with the high availability of desirable species from the adjacent area should prevent non-desirable species from establishing. The consultant has decided to plant black spruce and larch along the road in 2016 to ensure a stem count will be present at time of reclamation certification, even though we believe that trees will seed-in quickly on their own. Black spruce is not present in the natural area, but is listed on the criteria's desirable species list, though we expect that conditions may be too wet for it to survive.

1. **Species Richness**
   The road is narrow with a diverse peatland community on either side, providing an abundant, species rich seed source which should restore the vascular and tree layer without manual revegetation. Moss should be able to grow once the surface is shaded with growing vascular plants and the site chemistry stabilizes.
2. **Desirable Species**
   The natural seed source is a typical fen community that will provide desirable species.
3. **Non-Desirable Species**
   Correct site prep combined with the high availability of desirable species from the adjacent area should prevent non-desirable species from taking over the area.
4. **Stem Count**
   Black spruce and larch will be planted in 2016, but we expect to see natural regeneration of larch on the site (black spruce not present in the surrounding area).

DATA AND RESULTS – SITE ASSESSMENT (STUDY 1)

Reclamation trials #2, 3, and 4 were completely by the end of 2015 and are not ready for site assessment and certification using the criteria. Therefore, only results from study 1, site assessment using the criteria on inversion trial #1, are presented here.

Overall the onsite soil is hydric to sub-hydric peat. Periodic flooding can occur in the spring but it does not result in prolonged inundation throughout the growing season. There are no open water or upland ecosites (Figure 3). The entire site is contoured with the natural gradient of the surrounding peatland with the west side slightly higher than the east side. There is no steep sloping or barriers between the restored pad and the natural areas. Water flows freely from north-east to south. Aside from research equipment (a weather station, boardwalks, and collars), there are no industrial debris or rock and gravel onsite. There are also no signs of erosion.

We recorded 44 species/genera in the meandering survey and a list of all the survey species are listed in table 2 Roughly half of the total species are desirables (22) peatland species and the other half (20 spp.) are not on any of the desirable species lists by peatland types. *Carex canescens* and *Carex paupercula* (Table 2) are counted as desirable species because they are discussed in the criteria but not included in any of the species lists (see discussion). The average ground layer bryophyte coverage ranged from 11 to 53%. The combined percent coverage of ground layer and field layer (excluding trees) ranged from 80 to 136%. Four of the nine grids did not have any woody stems while the rest of grids had up to 12 stems.

Table 2. List of all species counted in the 15 min meandering survey. Red are undesirable species and black are desirable species found on the Appendix E of the criteria. Two extra *Carex* spp. are included as desirable. See discussions.

Undesirable	Desirable
Agrostis scabra	*Beckmannia syzigachne*
Alopecurus aequalis	*Campylium stellatum*
Calamagrostis canadensis	*Carex aquatilis*
Carex bebbii	*Carex canescens*
Carex praticola	*Carex disperma*
Deschampsia cespitosa	*Carex paupercula*
Epilobium angustifolium	*Carex tenuiflora*
Hordeum jubatum	*Cladina spp.*
Juncus bufonius	*Equisetum spp.*
Moneses uniflora	*Juncus balticus*
Pedicularis parviflora	*Larix laricina*
Petasites sagittatus	*Oxycoccus microcarpus*
Populus balsamifera	*Pedicularis labradorica*
Ranunculus sceleratus	*Picea mariana*
Rhinanthus borealis	*Pohlia nutans*
Spiranthes romanzoffiana	*Polytrichum spp.*
Stellaria longifolia	*Rhododendron groenlandicum*
Taraxicum officiale	*Salix spp.*
Typha latifolia	*Sphagnum angustifolium*
	Sphagnum warnstorfii
	Tomenthypnum nitens
	Vaccinium vitis-idaea

Overall our assessment scored 40 of the total 45 possible points, exceeding the required 36 points to pass. Our site did not fail any of the landscape parameters. It is worth noting that although the entrance areas likely had prolonged flooding in the spring and have abundant cattail year round, these areas (grid #1, #2, and #3) did not have standing water at the time of survey. Therefore, they are not considered as open water/ponding. See the discussion section for more information on this particular point.

Four of the nine grids failed the stem count parameter and one grid also failed in undesirable species coverage (Table 3, Figure 10).

Table 3. Landscape assessment of the Inversion Trial #1 IPAD. At the time of survey there was no standing water present on site. Cattails were assessed in the vascular plot, not part of the open water criterion.

LANDSCAPE ASSESSMENT											
Section in Criteria	**Grid**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Comments**
10.1	**Moisture Regime**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	
	Moisture Regime (hydric, sub-hydric, hygric, sub-hygric, mesic)	hygric	sub-hydric	sub-hydric	hygric	hygric	sub-hydric	hygric	hygric	hygric	
	Average depth to water table (cm)	-35	-53	-47	-55	-62	-42	-41	-58.5	-45	cm below surface
10.2	**Open Water /Upland Ecosite**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	no actual ponding present, so did not capture it. The high presence of cattails is recorded in the undesirable species list
	Permanent Open Water Present % of grid (≤15 = pass)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	have separated open water from ponding with vegetation present
	Permanent water + associated vegetation % of grid	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Desirable species %	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Undesirable species %	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Open water passes no matter the size if desirables >50% and undesirables <20%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
10.3	**Offsite Drainage**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	
	Offsite Drainage (well, moderately well, imperfect, poor, very poor)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	elevation is lowest at G2, so it is a bit wetter, but the drainage is not impeded, so designated poor rather than imperfect
	Surface flow direction/volume (see sketch as well)	north	north	north	north	north	north	north	north	north	
	Micro-contour	level	level	level	level	level	level	level	level	level	
	Macro-contour	level	level	level	level	level	level	level	level	level	
	Elevation	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	general site elevation decreases from south to north
10.4	**Riparian Areas**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	
	Riparian areas (present Y/N)	no	no	no	no	no	no	no	no	no	
	Bank and shore stable (slumping, erosion) Y/N	yes	yes	yes	yes	yes	yes	yes	yes	yes	
10.5	**Erosion**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	
	Water erosion (rill, gully, pedestaling, sediment fans) (present Y/N) degree, extent, rate, severity (see sketch)	no	no	no	no	no	no	no	no	no	
	Wind erosion same off site (Y/N)	yes	yes	yes	yes	yes	yes	yes	yes	yes	
10.6	**Bare Areas**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	
	Bare areas (present Y/N)	no	no	no	no	no	no	no	no	no	
10.7	**Gravel and Rock**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	
	Gravel and rock (present with detrimental effects Y/N)	no	no	no	no	no	no	no	no	no	
10.8	**Industrial Debris**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	**PASS**	
	Industrial debris (present Y/N)	no	no	no	no	no	no	no	no	no	have approved research related equipment present; weather station
11.1	**Peatland Type**										
	Peat pH	5.19	4.87	5.46	5.15	5.41	5.18	5.31	4.66	6.26	
	Peat EC	583	1898	671	672	568	581	1691	967	612	
	Peat salinity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	Bog										
	Acid Fen	x	x	x	x	x	x	x	x		
	Circumneutral Fen									x	
	Alkaline Fen										
	Saline Fen										

Table 4. Vegetation assessment of the Inversion Trial #1 IPAD and the overall parameter scores. *Carex canesencs* and *Carex paupercula* are not in any of the species lists but included. See discussion.

VEGETATION ASSESSMENT																		
Grid	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**	
Landscape Parameter Points	n/a	P	n/a	P	n/a	P	n/a	P	n/a	P	n/a	P	n/a	P	n/a	P	n/a	P
Species Richness	12	P	13	P	12	P	12	P	13	P	12	P	17	P	17	P	16	P
Peatland Type	Acid Fen		Acid Fen		Acid Fen		Acid Fen		Acid Fen		Acid Fen		Acid Fen		Acid Fen		Circumneutral Fen	
Minimum no. of Peatland Species	6		6		6		6		6		6		6		6		9	
	Beckmannia syzigachne Carex aquatilis Carex canescens Juncus balticus Larix laricina Pedicularis labradorica Picea mariana Pohlia nutans Polytrichum spp. Rhododendron groenlandicum Salix spp. Sphagnum angustifolium		Beckmannia syzigachne Campylium stellatum Carex aquatilis Carex canescens Juncus balticus Larix laricina Pedicularis labradorica Picea mariana Pohlia nutans Polytrichum spp. Rhododendron groenlandicum Salix spp. Sphagnum angustifolium		Beckmannia syzigachne Campylium stellatum Carex aquatilis Carex canescens Juncus balticus Larix laricina Pedicularis labradorica Picea mariana Pohlia nutans Polytrichum spp. Salix spp. Sphagnum angustifolium Tomenthypnum nitens		Carex aquatilis Carex canescens Equisetum spp. (arvense) Larix laricina Oxycoccus microcarpus Picea mariana Pohlia nutans Polytrichum spp. Rhododendron groenlandicum Salix spp. Sphagnum angustifolium		Beckmannia syzigachne Carex aquatilis Carex canescens Carex tenuiflora Larix laricina Oxycoccus microcarpus Pedicularis labradorica Picea mariana Pohlia nutans Polytrichum spp. Rhododendron groenlandicum Salix spp. Sphagnum angustifolium		Campylium stellatum Carex aquatilis Carex canescens Carex paupercula Larix laricina Pedicularis labradorica Picea mariana Pohlia nutans Polytrichum spp. Rhododendron groenlandicum Salix spp. Sphagnum angustifolium		Carex aquatilis Carex canescens Carex disperma Cladina spp. Equisetum spp. (arvense) Juncus balticus Larix laricina Oxycoccus microcarpus Pedicularis labradorica Picea mariana Pohlia nutans Polytrichum spp. Rhododendron groenlandicum Salix spp. Sphagnum angustifolium Tomenthypnum nitens Vaccinium vitis-idaea		Beckmannia syzigachne Carex aquatilis Carex canescens Carex tenuiflora Equisetum spp. (arvense) Juncus balticus Larix laricina Oxycoccus microcarpus Pedicularis labradorica Picea mariana Pohlia nutans Polytrichum spp. Rhododendron groenlandicum Salix spp. Sphagnum angustifolium Tomenthypnum nitens Vaccinium vitis-idaea		Beckmannia syzigachne Campylium stellatum Carex aquatilis Carex canescens Juncus balticus Larix laricina Oxycoccus microcarpus Pedicularis labradorica Picea mariana Pohlia nutans Polytrichum spp. Rhododendron groenlandicum Salix spp. Sphagnum angustifolium Sphagnum warnstorfii Tomenthypnum nitens	
Total Undesirable % Coverage	15%	P	27%	F	16%	P	6%	P	5%	P	18%	P	1%	P	4%	P	8%	P
	Agrostis scabra Calamagrostis canadensis Deschampsia cesppitosa Hordeum jubatum Pedicularis parviflora Populus balsamifera Ranunculus sceleratus Rhinanthus borealis Typha latifolia		Agrostis scabra Calamagrostis canadensis Carex bebbii Deschampsia cesppitosa Hordeum jubatum Pedicularis parviflora Populus balsamifera Ranunculus sceleratus Rhinanthus borealis Typha latifolia		Agrostis scabra Calamagrostis canadensis Carex bebbii Deschampsia cesppitosa Juncus bufonius Populus balsamifera Rhinanthus borealis Typha latifolia		Agrostis scabra Calamagrostis canadensis Deschampsia cesppitosa Juncus bufonius Typha latifolia		Agrostis scabra Calamagrostis canadensis Deschampsia cesppitosa Epilobium angustifolium Pedicularis parviflora Populus balsamifera Rhinanthus borealis Taraxicum officiale		Agrostis scabra Calamagrostis canadensis Epilobium angustifolium Juncus bufonius Pedicularis parviflora Populus balsamifera Spiranthes romanzoffiana Typha latifolia		Agrostis scabra Calamagrostis canadensis Carex praticola Deschampsia cesppitosa Epilobium angustifolium Moneses uniflora Petasites sagittatus Populus balsamifera Ranunculus sceleratus Rhinanthus borealis Spiranthes romanzoffiana		Agrostis scabra Calamagrostis canadensis Carex bebbii Deschampsia cesppitosa Epilobium angustifolium Moneses uniflora Ranunculus sceleratus Stellaria longifolia		Agrostis scabra Alopecurus aequalis Calamagrostis canadensis Deschampsia cesppitosa Populus balsamifera Typha latifolia	
Total Desirable % Coverage	91%	P	80%	P	95%	P	105%	P	103%	P	119%	P	114%	P	110%	P	136%	P
Desirable Vascular Species % Coverage	80%	-	46%	-	81%	-	81%	-	75%	-	78%	-	65%	-	57%	-	110%	-
Bryophyte Average % Coverage	11%	-	34%	-	14%	-	24%	-	28%	-	41%	-	49%	-	53%	-	26%	-
#1 % Cover	35%	-	0%	-	20%	-	10%	-	20%	-	15%	-	17%	-	95%	-	15%	-
#2 % Cover	15%	-	5%	-	5%	-	30%	-	30%	-	60%	-	15%	-	90%	-	25%	-
#3 % Cover	0%	-	90%	-	5%	-	35%	-	55%	-	6%	-	50%	-	30%	-	5%	-
#4 % Cover	5%	-	15%	-	20%	-	27%	-	25%	-	90%	-	85%	-	20%	-	5%	-
#5 % Cover	2%	-	60%	-	20%	-	20%	-	10%	-	35%	-	80%	-	30%	-	80%	-
Number of Woody Stems	0	F	0	F	0	F	11	P	2	P	4	P	5	P	12	P	0	F
Actual Points	4		3		4		5		5		5		5		5		4	
Possible Points	5		5		5		5		5		5		5		5		5	

Max number grids can fail for same parameter	4	**Site Pass/Fail: PASS**
Number that do fail for same parameter	4	
Total Possible Points	45	
Points to Pass	36	
Total Scored Points	40	

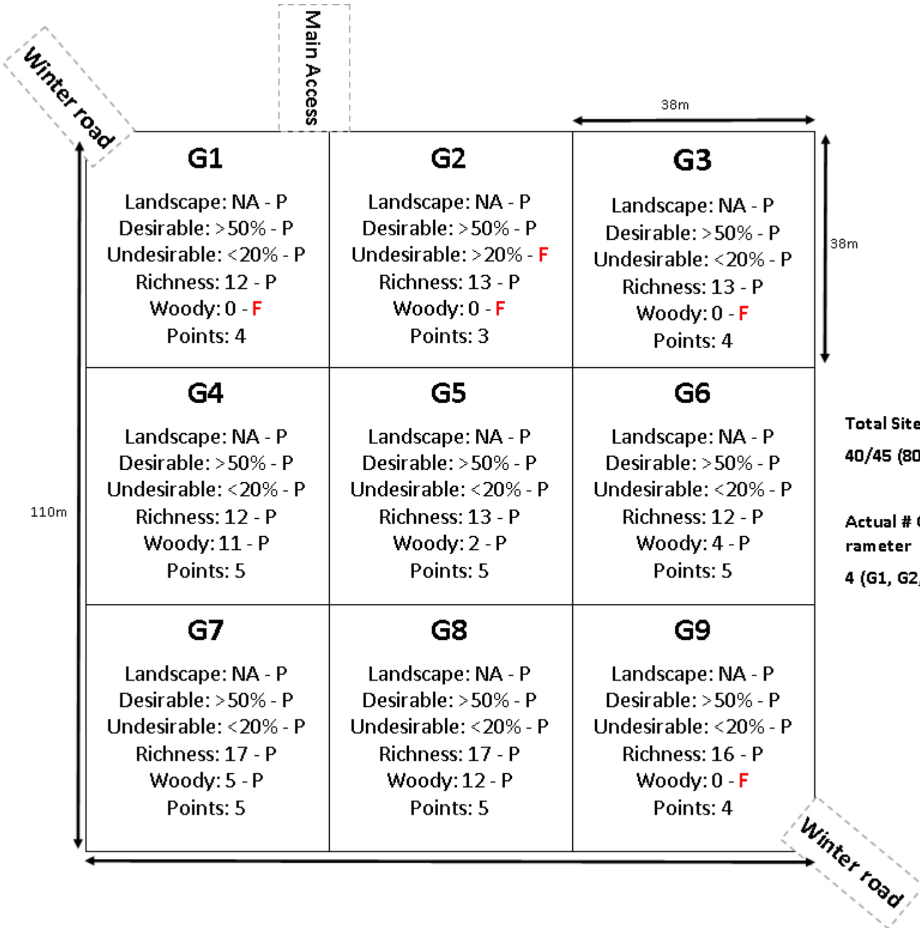

Figure 10. Summary of assessment by parameter and by each sample grid. Our site passes the assessment with 40 points out of the possible 45 points.

DISCUSSION

Peatland reclamation/restoration in Alberta is still in its early stages and faces many challenges, one of which is the lack of clear policy directive and a standard for site assessment and certification. The "Reclamation Criteria for Well Sites and Associated Facilities for Peatlands" is a much needed addition to the 2010 Reclamation Criteria. It provides the reclamation certification criteria for wellsites, access roads, and associated facilities reclaimed to peatlands on both Private and Crown lands in Alberta. It applies to both minimal disturbance, winter access and all season padded sites. This document is not intended as a construction guide, but could be used in planning reclamation projects to minimize disturbance and to increase reclamation success.

Currently, there are not many reclaimed peatland well sites that are ready for potential certification. NBRI's first full pad reclamation trial (inversion pad #1) has shown promising progress towards a functional peatland since the civil earth work in 2011 and the re-vegetation using donor moss materials in 2012. This reclaimed site provides a unique opportunity to evaluate the criteria and the methods outlined within it. We set out to test the criteria by assessing the reclaimed well pad and using the key parameters in the criteria to guide reclamation practices on three new research trials, two well pads and one linear feature, all adopting updated reclamation techniques used on the first trial.

Overall we found the criteria logical, relatively simple to understand and follow with a strong scientific basis. Boreal peatlands are complex ecosystems with unique hydrology, vegetation, and chemistry and their formation on the landscape takes a long time under specific climatic conditions (Vitt et al. 1994, Halsey et al. 1998, Wieder et al. 2006). Well sites reclaimed to peatland usually cannot be considered peatlands by definition as they often lack the required minimum 40 cm depth of peat. Instead, the criteria refer to reclaimed "early successional peatlands" as **mires**, which are young, developing natural wetlands that are actively accumulating peat through the action of living, peat-forming plants. Therefore, the reclamation of a well site to peatland should aim to re-establish the landscape and the vegetation components that will set the system on a trajectory towards a future peatland. As such, the criteria is intended to be used to evaluate whether a site has met or is on a trajectory to support the production of goods and services consistent in quality and quantity with the surrounding landscape (equivalent land capability).

There are two key components to assess: **landscape** and **vegetation**. The landscape assessment is primarily to ensure that any potential impacts of the features (either well site or access roads) are mitigated in reclamation and that the reclaimed site does not interfere with peatland vegetation development and shows no negative impact on or offsite. A self-sustaining, peat forming vegetation community is a primary indicator of the desired reclamation outcome, a mire on track to becoming a true peatland over time. Therefore, the landscape assessment is conducted at the site overview scale (except for open-water/ponding and upland ecosites) and the vegetation assessment is conducted at variable scales.

We believe the methods to be (mostly) well explained and appropriate for the assessments. Off-site conditions are commonly not directly compared to onsite conditions as it is acknowledged that a reclaimed site will differ greatly from the natural/surrounding peatland. Offsite assessment is required, however, to determine if certain parameters should be included, such as the woody stem count.

We generally agree with the rationale for recommended methods to assess both landscape and vegetation components. In practice, we did find several areas of potential confusion because of the conflicting wording of certain sections of the criteria. Interpretation of these sections varied greatly among our field staff and between our assessment and an independent third-party assessment of this site. Such variation in understanding the criteria can affect how data are collected and results are interpreted, leading to vastly different conclusions. The following discussion will focus on three main areas**: overall clarity and consistency**, **field methodology**, and **professional judgment and training**.

Clarity and Consistency

Open Water/Ponding and Cattails:

Cattails are a non-peat forming species, and therefore considered an undesirable species in the criteria. Cattails can grow in both very wet and relatively dry conditions. When assessing the open water/ponding parameter, there is room for confusion regarding the treatment of cattails. On page 19, the criteria specifically stated that cattails surrounding open-water should be included in the open-water/ponding parameter, NOT in the vegetation assessment (Figure 11). It also defines open-water/ponding as permanently water filled areas (criteria page 18). However, there is a tendency to associate abundant cattails with periodic flooding and seasonal ponding. When there is no ponding/open water present at the time of survey, the presence of cattails should be assessed as part of the vascular percent coverage assessment. However, this scenario was not clearly stated in the criteria, leaving room for varied interpretation.

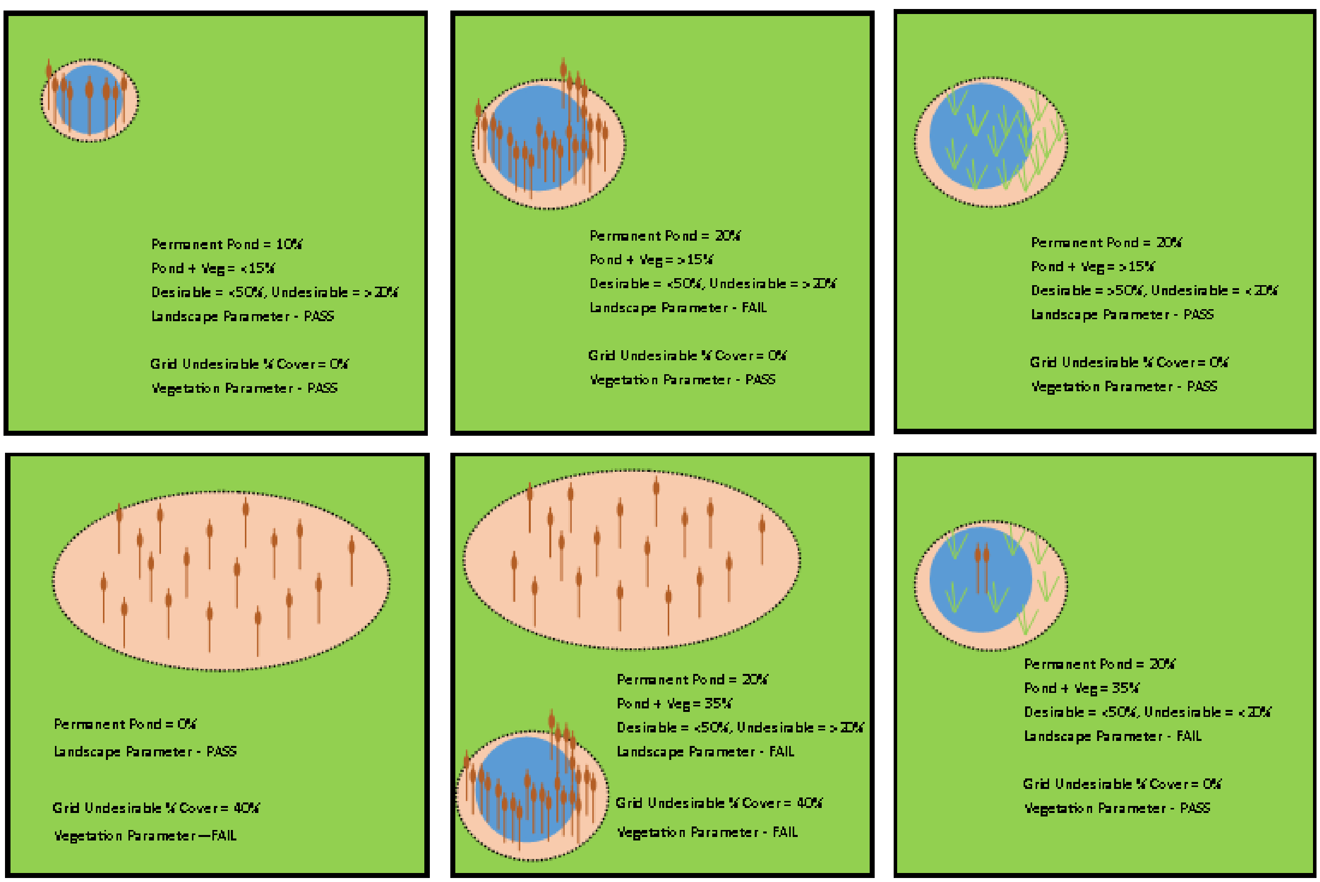

Figure 11. Six scenarios of open-water/ponds and cattails, each with pass/fail assessment for landscape and vegetation parameters.

Case in Point:

Here are six scenarios with both open-water/ponding and peat-forming or non-peat forming plants growing in a survey grid (Figure 11).

Suggestions:

- We strongly recommend adding a specific statement to exclude cattails not growing around open water from the open water/ponding assessment and have them assessed only as part of the $10m^2$ plot survey.
- An example statement could be "Cattails growing on site without permanent water should be assessed as part of the undesirable species parameter in a vascular plant plot".
- This would also apply to any non-peat forming species other than cattails.

Peatland Type:

Peatland type is a key component in determining if a site can be considered undisturbed. A large shift in community, such as a *Sphagnum* dominated bog community to a sedge dominated alkaline fen, would be considered a disturbed scenario. Our understanding is that **if the onsite peatland type is shifted by more than one class, it would require a disturbed assessment even if the site is technically a young peatland**.

Identifying onsite peatland type is required for a disturbed assessment while offsite peatland type should be recorded, though a detailed offsite community list is not required. There are five basic types of peatlands in the criteria: 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).

The criteria recommend the use of site characteristics, such as moisture regime, water chemistry (pH, EC and salinity) and species lists by peatland type to determine the peatland type (Table 5). As we have shown, on-site chemistry varies greatly temporally and spatially. pH may be a better indicator than EC as our site had mineral materials buried in certain locations.

Case in Point:

Our measured EC (all over 500 µs/cm) fall under the Alkaline Fen or Saline Fen categories (Table 5). All pH measurements were between 4.66 and 6.26, within the range of Acid Fen and Circumneutral Fen. EC and pH will not be useful when separating Alkaline Fen and Saline Fen, both with pH 7.0–8.5 and EC 250–2000 µs/cm. Vegetation will have to be used in this case although we did not encounter such conditions on site.

Suggestions:

- For typical sites, characteristic species and pH should be sufficient to determine the most appropriate peatland types.
- For disturbed and reclaimed sites, especially where mineral fill was introduced during construction, EC can vary greatly and thus less useful to determine peatland types

Associated Desirable/Undesirable Species Lists and Species Richness:

Aside from the uncertainties determining peatland types (both onsite and offsite), the greatest potential for confusion arises from deciding which species are undesirable. On page 26 of the criteria, it specifically states that “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” (Alberta Environment and Parks 2015). This has implications for all three vegetation parameters: **desirable species cover, undesirable species cover, and species richness**. In the tables on pages 28 and 29, for both disturbed and undisturbed assessment, minimum species richness required to pass the parameter is listed by peatland type (Table 5). This can cause confusion as each peatland type is associated with a specific species list in Appendix E of the criteria. Our understanding is that the number of species (species richness) refers to ALL peat-forming species even if that species does not match the list associated with that peatland type.

After consultation with Susan McGillivray at AEP, it is confirmed that when conducting assessments, any species found onsite that match species on ANY of the lists in Appendix E of the criteria will be counted as a desirable species, REGARDLESS of the peatland type and the species list they are found in. However, it can be viewed that the number of species required to pass is peatland type specific, meaning only the species found on a bog list can be counted towards the species richness for a bog grid (Table 5).

Table 5. The vegetation assessment measure, method, and criteria for disturbed site assessment. From the Peatland Criteria. Note that the species richness criteria are listed by peatland type even though the species can come from any of the lists in Appendix E of the criteria.

Vegetation Assessment Component	Measure	Method	Criteria
Desirable Species Cover	Percent canopy cover	**Bryophyte plot** *(Moss and liverwort species)* Average a minimum of four 1m² assessment points per grid **Vascular plant plot** *(Sedges, Herbs, Woody Species)* 10m² representation plot	≥50% canopy cover (Combine data from 1m² and 10m² plots)
Undesirable Species	Percent canopy cover	**Vascular plant plot** *(Non-peat forming species)* 10m² representation plot	≤20% canopy cover (10m² 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)* 10m² representative plot	≥1 stem **or** 25% canopy cover

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

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

Case in Point:

- There are abundant willow (*Salix* spp.) plants across the site, including areas with pH below 4.0–5.5 (acid fen). *Salix* spp. are not included in the species list of acid fen (Page 76 of the criteria) but are included in the lists for circumneutral, alkaline and saline fens. Although we could not identify the species of *Salix* on site, we did include them as a desirable species in our assessment, even for acid fen (Grid 1,2,3,4,5,6,7 and 8).
- Willow species tend to hybridize and young willows are very difficult to identify by species. There are 3 *Salix* spp. listed in Appendix E of the criteria. We are not confident that we could identify the willow plants by species on a newly reclaimed site.
- **Species discussed in the text of the Criteria but not on any of the species list**: *Carex canescens* and *Carex paupercula*. Both were found on site and counted as desirable species.

Suggestions:

- Include a clear and strong statement that "**Any peat-forming species found onsite that match ANY species lists regardless of peatland type will be counted in the total species richness for an identified grid**".
- We have compiled all species in Appendix E of the criteria and produced **a master list of all peatland species** for practitioners to use (Appendix V) in this report. *Carex canescens* and *Carex paupercula* are both included even though they are not included in any of the lists in the criteria.
- We would also recommend a **mechanism to include regional/local species** that are not in Appendix E of the criteria to be counted as desirable species if there is sound justification.
- Use of professional judgment when identifying *Salix*, either by species or just as a genus.

Field Methods

The criteria does not specify how to measure site chemistry. Both pore water and peat samples have been used in various studies. Depending on the timing of assessment, the site EC and pH could vary significantly, resulting in different peatland type identification, which can in turn affect the parameter criteria to pass or fail.

Secondly in terms of ease of use, while we did use the circular 10 m^2 plot for the vascular plant species percent coverage, we found it difficult to work with. We felt that while the size and shape worked well for stem count, it was difficult to estimate percent coverage without having a visually delineated plot, so we marked out the circular plot boundaries. Many of the vascular species accounted for are naturally small sized plants and sometimes difficult to assess in such a large area (e.g. small bog cranberry). As well, instead of using four 1 × 1 m quadrats to determine bryophyte coverage, we used five 50 × 50 cm plots. We found the 1 × 1 m quadrat very difficult to accurately estimate percent coverage, especially in areas with dense sedges. To offset the reduced quadrat size, we increased the number of replicates as they were averaged together within each grid.

Case in point:

- Porewater pH can vary greatly over the growing season. In some grids, we measured pH as low as 4.5 (acid fen) in the summer and pH as high as 7 (circumneutral fen) in the fall in the same water wells. If we survey the site when pH is 4.5, we will need only 6 peat forming species to pass the criteria for that grid. However if the site is surveyed in the fall when pH is close to 7, we will need 9 species to pass (Table 4).
- We think the 1 m × 1 m quadrat is too large for ground layer bryophyte assessment and the 10 m^2 vascular plot is also too large.

Suggestions:

- The AEP should include more detailed information on survey methods and timing of sampling and measurements.
- The assessor should specify and justify the methods and timing of field survey and include detailed data in the application.
- Reduce the circular plot size to a more manageable and reasonable size, maybe 2 m by 2 m?
- Allow smaller sized quadrats for ground layer measurements: 0.5 m by 0.5 m.

Professional Judgment and Training

The peatland criteria is a new directive for field practitioners who might not have appropriate peatland related knowledge and training. Proper training on peatland ecology and the use of the peatland criteria is urgently needed as the criteria is expected to take effect as of April 15, 2016.

Case in point:

- *Calamagrostis stricta* is listed as a desirable species under saline fen. It can be overlooked or counted as undesirable by practitioners more familiar with agriculture or forestry assessment.
- Other species on the list that could be overlooked or mistaken are: *Beckmannia syzigachne, Epilobium palustre*, and *Drepanocladus revolvens.*
- Additional **peatland species** (as designated by habitat in "Plants of the Western Boreal Forest & Aspen Parkland") were **identified on site but are absent from the criteria**'s desirable species lists (*Pedicularis parviflora, Spiranthes romanzoffiana*). These additional species could be the difference between pass or fail for a grid in the species richness and desirable percent coverage parameter. We did not include the two species found on site in our assessment since they are not included/discussed/mentioned in the criteria.
- Deciding if a site is undisturbed requires peatland related knowledge, particularly ground layer bryophytes.
- Selecting appropriate aerial survey methods and collecting quality data for site assessment might require both clarification and professional training for surveyors.

Suggestions:

- **A peatland specific field guide on non-bryophytes for practitioners** would be immensely helpful. The criteria provided a guide on peatland bryophytes but there is no such list/reference for non-bryophyte species.
- Clarification is needed on whether professional judgment is acceptable or if a process for suggesting updates to the species lists will be put in place.
- Workshops on peatland ecology and application of the criteria.
- Field schools for practitioners on using the criteria in the field.
- NAIT Boreal Research Institute is going to organize a field school for practitioners in the fall of 2016 on peatland criteria.

CONCLUSIONS

The "Reclamation Criteria for Well Sites and Associated Facilities for Peatlands" is a much needed and timely update to the 2010 reclamation criteria. It is well laid out and has a very strong scientific basis for designing the criteria and for choosing the recommended methods for field assessment. In practice, we found that the criteria was easy to follow. Based on our discussion with professionals and practitioners, we believe that some clarification and slight modification will make the criteria even more practical to use, thus reducing confusion and increasing accuracy in peatland assessment. Additional training for practitioners will further assist in the rollout and application of the new Peatland Criteria across the province in the near future.

RECOMMENDATIONS

Based on our study, we would like to make the following recommendations as follow up action items:

- **Training for professionals**: Both classroom and field school training on peatland ecology and application of the criteria would be highly beneficial to professionals that will be using the criteria in the future.

- Further **clarification** on open-water, peatland type, and associated species list will greatly reduce potential mistakes and confusion by practitioners. Recommended **methods for field survey** could be reviewed and potentially updated as well. This will require direct dialogue with EAP and scientific communities.

- Develop a **field reference for non-bryophyte peatland specific list**.

- Our study focuses on well sites that are disturbed. We were not able to assess sites that are by definition "**undisturbed**". Examples are minimal disturbance OSE wells and winter access roads.

- We also did not assess the criteria on any **linear features**. The methodology to assess a linear feature in peatland is quite different from the grid layout on a well site. Further study is needed to assess how applicable and usable the criteria are for such features.

- **Aerial assessment** is allowed when sites are hard to access. But the criteria is vague on what's acceptable as aerial assessment and the quality of data acceptable. More studies using aerial technologies for field assessment are urgently needed.

- Our study site is in the NW Alberta and is limited to one site using a specific reclamation technique. **Additional reclaimed sites spanning the entire province with different reclamation practices** will further ground truth the methodology outlined in the criteria.

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